

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter discusses the theory of daylight and its importance towards human tasks such as reading and writing. Daylight theory components include a natural light source, climate condition, sun orientation and more. This chapter also discusses the daylighting performance and the effect on human biological conditions as well as students' performance. Understanding the effects of daylighting on students' performance will lead to an understanding of classroom layout designs, regulations, standards, and guidelines. The method to measure the daylight in the classrooms is also discussed in this chapter. The literature review includes a specific type of education in Malaysia that has been selected for the study. Schools that implement education is selected due to the different method, tasks and tools highlight specific *hafazan* learning task such as Arabic handwriting. The students' performance for *hafazan* learning measurement will be further discussed in this chapter.

#### 2.2 Daylight Theory

Sunlight, moonlight, and stars are some of the natural lighting examples that produce light that exists in nature. Also known as daylight, it is a source of light for full spectrum required for human vision adaptation (Rizal, et al., 2016). Daylight quantity, quality and distribution are the key factors that influences the daylighting environment in a space (Johnsen & Watkins, 1990; Gupta et al., 2015). Quantity and quality metrics for daylight are important in buildings' daylighting assessments (Janak, 1997) to identify its' effects on human health and visual comfort (Howlett, et al., 2007). These

factors that illuminates a space through window and openings are important in achieving visual comfort for the occupants (Sun et al., 2017). This shows that window design is crucial for daylight quantity in a space (Husin & Harith, 2012). Light quantity and quality can be explained as (Moeck, 1998):

i. Light quantity:

- a. Horizontal and vertical illuminance, daylight factors, average work plane illuminance, and related electric lighting energy use
- b. Sunlight protection, solar radiation
- c. Efficiency of a system, light transmission, light transmission as a function of light incidence angle or time
- d. Amount of light in certain areas of the space i.e., the rear ceiling or rear work plane
- e. Source luminance, luminance in die surround of visual displays

ii. Light quality:

- a. Daylight distribution, uniformity
- b. Glare, daylight glare index
- c. Luminance ratios at a visual display unit, reflected glare

Common research practices refer Daylight Factor (DF) for daylight quantity evaluation (Sun et al., 2017; Liu et al., 2019), although illuminance level is also used for evaluating daylight quantity (Hourani & Hammad, 2012). A good daylight quantity is based on

sufficient daylight on any working plane height, while a good daylight quality is based on the daylight uniformity ratio and glare avoidance (Wu & Ng, 2003; Antoniou & Meresi, 2003; 2005; Axarli & Meresi, 2008). Daylight quantity is not the only factor influencing daylight quality, where incorrect light density distribution, glare and low light colour also contributes to daylight quality (Pellegrino et al., 2015; Liu et al., 2019). The above floor corridor width is another factor that influences the daylight quantity that enters the classroom through the windows and openings (Bezjak, 2003). Previously, daylight studies majorly focus on daylight quantity, where now it is considered as the basis for evaluating daylight quality (Jovanovic et al., 2014).

In effort to avoid any dark areas in a day-lit classroom, Uniformity Ratio as a part of the design criteria should be considered (Loe et al., 1999). Chartered Institution of Building Services Engineers (CIBSE) refers the illuminance uniformity ratio in evaluating the daylight factor and distribution efficiency in a space, where the calculation is the ratio of the minimum illuminance to the average illuminance in the space (Loe et al., 1999; Mundo-Hernández et al., 2006). The value for uniformity ratio should be between 0.5 to 0.7 according to JKR standards (Mathalamuthu et al, 2018).

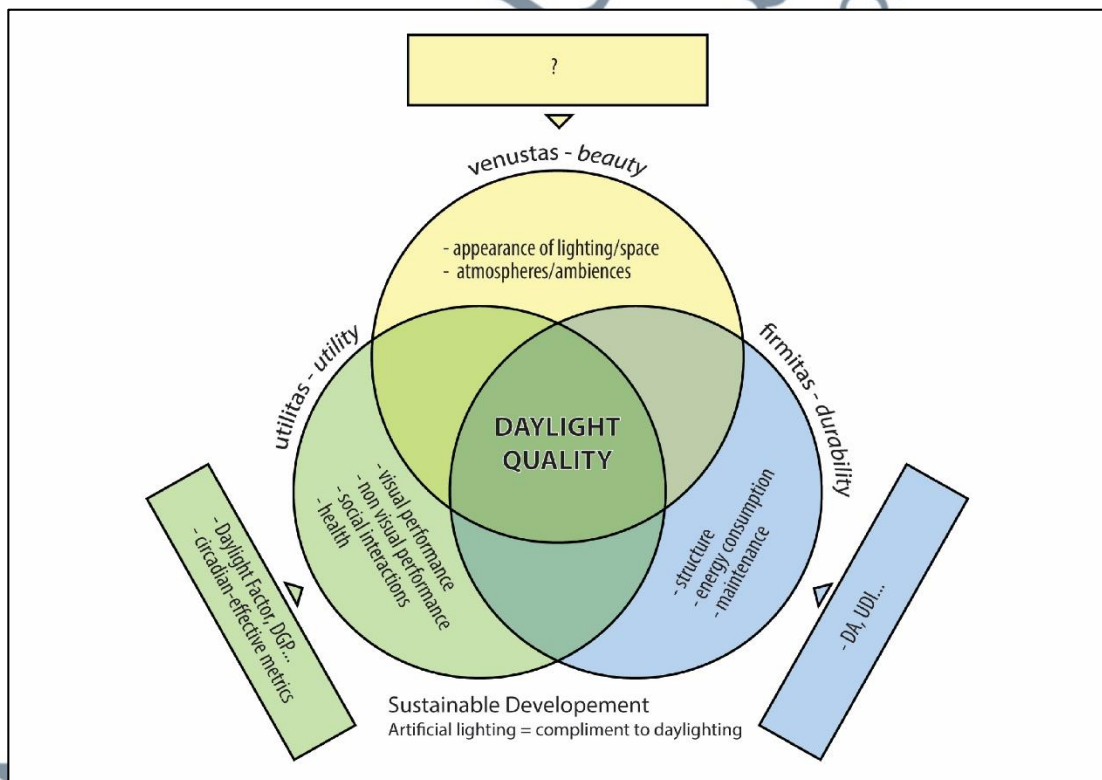
Daylight autonomy can be explained as the time percentage that illuminance levels are above a specified target within a space, where it determines the length of time for a person able to perform a task at an optimum visual (without glare) and physical comfort without requiring artificial lighting (Reinhart, et al., 2006; Jakubiec & Reinhart, 2011).

Visual discomfort due to glare is an issue that can be controlled through size and field view position of glare source such as windows. Glare Index based on these factors should be lower than the recommended Limiting Glare Index value (Loe et al., 1999).

Glare Index can be explained as the value that predicts the presence of glare from

daylight penetration into a space, where it is influenced by the size and relative position of fenestration, orientation to the sun, sky luminance, and interior luminance (Glare Index, n.d.).

Vitruvius stated that high-quality luminous ambiance satisfaction can be achieved by considering the three main components of architecture; *Venustas*-beauty, *Utilitas*-utility, and *Firmitas*-durability (Cauwerts & Bodart, 2013). Daylight quality does not only focus on visual needs and comfort alone, but also the satisfaction of social interactions, performance, health, and safety matters (Veitch & Gifford, 1996; Cauwerts & Piderit, 2018). The daylight quality theory by Vitruvius that has been adapted is as shown in figure 2.1.



**Figure 2.1:** Daylight quality design process in the sustainable development context, adapted from Vitruvius (Cauwerts & Bodart, 2013)

Phillips (1997) agreed that daylight is one of the important components to be considered in the development of architecture. Even though the daylight intensity and colour varies and offers a view to the outdoor environment, daylight is first and foremost a lighting source (Cauwerts & Bodart, 2013). Areas that receive daylight is comparable to the level of lighting measured at a particular point in a space on a flat surface illumination level in an open area, which measures the performance of the skylight of the room (Rizal, et al., 2016). This research looks into the *Utilitas*-utility component of the Daylight Quality, which focuses on the visual performances of students.

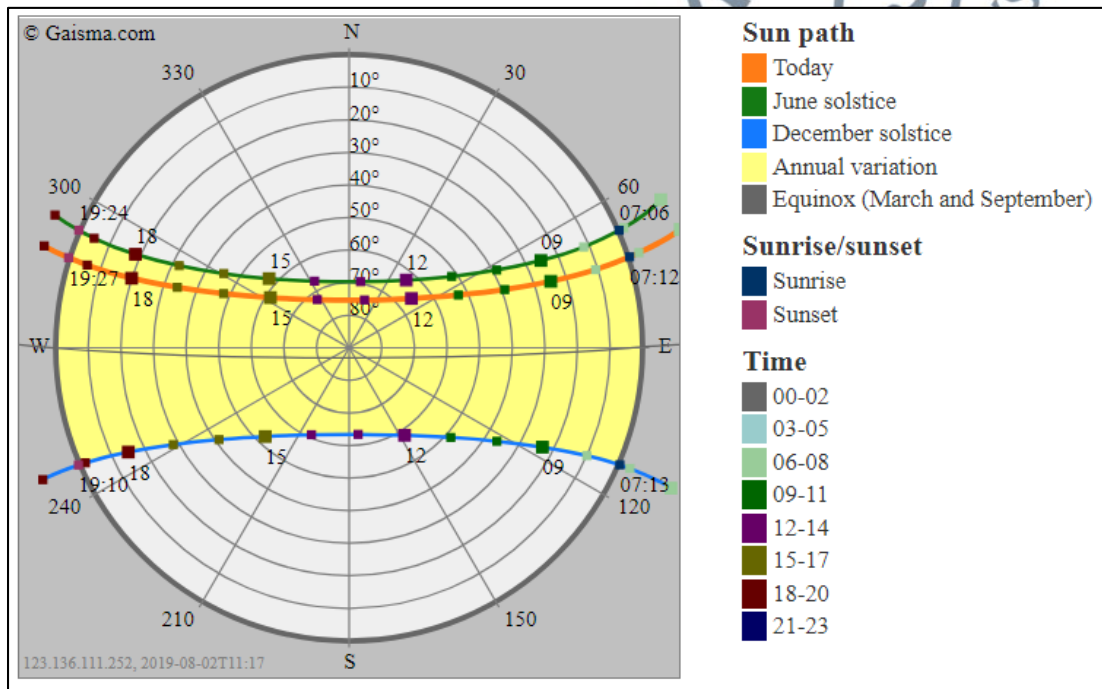
### 2.2.1 Sky Condition and Global Illuminance in Malaysia

Malaysia's climate condition is categorized as equatorial, since its location near to the equator of the earth (Saw, 2007). Malaysia coordinate is between 1° and 7° North latitude and 100° and 120° East longitudes, consist of Peninsular Malaysia and East Malaysia. The seasonal climate changes in Peninsular Malaysia is influenced by monsoon winds that occurs twice a year, which is the Northeast and Southwest monsoon (Nugroho, et al., 2007). Located in the Tropic of Cancer and Capricorn, Malaysia is a hot or warm and humid country (Roy, et al., 2005; Saw, 2007; Jamaludin, et al., 2014) that has climatic elements such as high temperature and uniform diurnal pattern for the whole year.

The sun orientation in Malaysia is generally in parallel with West and East, which the sunrise is from the East and the sunset is to the West. Sun-path diagram simulated in six different Malaysia state shows that the sun-path is generally the same for all location in Malaysia, where the orientation is East-West with the sun approximately 25° to the North on the summer solstice and 25° to the south on the winter solstice (Tang, 2012)

as shown in figure 2.2. The clear sky global solar irradiance includes beam, diffuse and reflected solar irradiance (Daut, et al., 2011).

There are a few references that mentioned Malaysia has overcast sky condition (Zain-Ahmed, et al., 2002) and intermediate sky condition (Lim, 2014; Yeop, 2014). Malaysia sky condition is 83 per cent intermediate with sun and clear sky according to International Commission on Illumination (CIE) standard overcast sky and clear sky (CIE, 1996; Yunus, et al., 2019).



**Figure 2.2:** Stereographic Sun Path for Malaysia (Gaisma, 2019)

Complete and clear sky ranging from 3.7 hours to 8.7 hours per day, with six hours of average sunshine received causes Malaysia to experiences high solar intensity and duration (Jamaludin, et al., 2014). This shows that daylighting in Malaysia is available throughout office hours (Roy, et al., 2005), where the minimum diffuse daylight in the space ranged between 10.00 am to 4.00 pm (Nedhal, et. al, 2016). Other researchers

also emphasized that daylighting can be obtained from 8.00 am until 6.00 pm (Tang & Chin, 2013). The first basic strategy to design a classroom is the orientation, where it can provide sufficient indirect daylight (EFM, 2010).

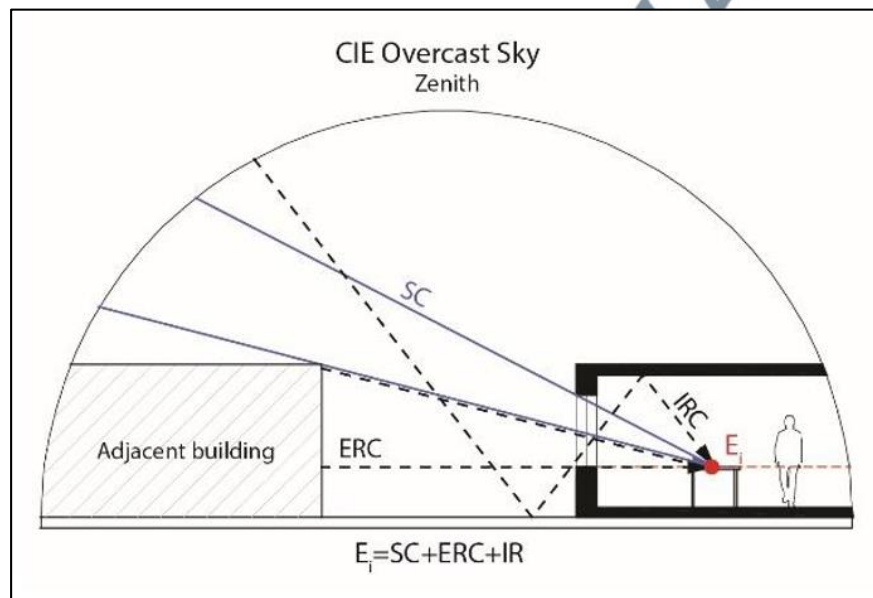
Tropics climate in Malaysia shows an abundance of daylight due to the high intensity of sun exposure, where the global illuminance in the clear sky can be estimated at 120,000 lx (Roshan, 2014). The highest hourly illumination recorded in March exceeds 80,000 lx, where the lowest illumination recorded is in December, with mean 60,000 lx (Zein-Ahmed, et al., 2002). The average outdoor illuminance level in Malaysia recently recorded is 19,000 lx (Al-Obaidi, et al., 2015). This research refers to the intermediate sky condition for the experiments. The average outdoor illuminance will be referred to at 80,000 lx for this study.

#### 2.2.2 Daylight Factor and Illuminance Level

The original daylight evaluation and window design systems were based on the assumption of the uniform sky and unity luminance over the whole sky vault. Photometry and theory such as Bouguer (1729) and Lambert (1760) on Sky Factor and Daylight Factor criteria developed and elaborated various calculation methods and design tools such as nomograms and protractors (Darula & Kittler, 2004a). Kittler (1967) added and proposed a more complex formula for Clear sky standard, as per requested by daylight experts in the tropical countries. Tregenza (1983) introduced the concept of daylight coefficients, where the mathematical functions that relate the luminance distribution of the sky to the illuminance at a measured point of any space.

Illuminance level for Daylight Factor can be calculated with the three sum component measurement;  $\text{Illuminance} = \text{SC} + \text{ERC} + \text{IRC}$ , where the sky component (SC) is direct

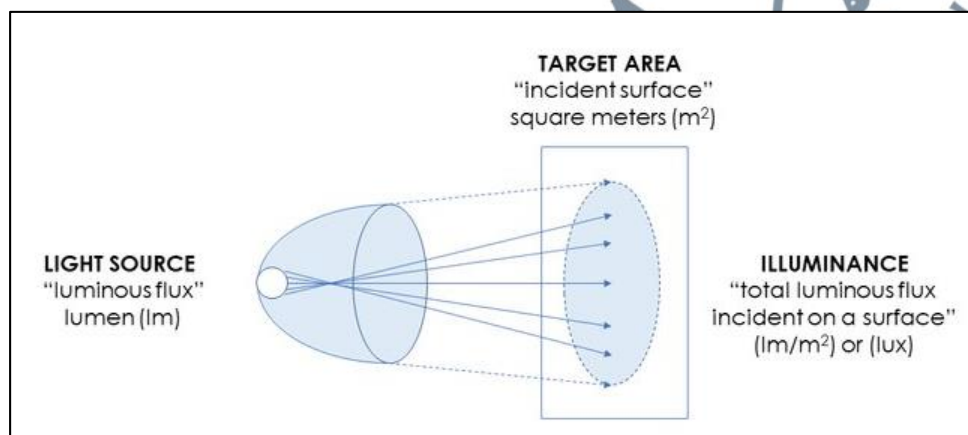
light from a patch of sky visible at the measured point, externally reflected component (ERC) is light reflected from an exterior surface and then reaching the measured point and internally reflected component (IRC) is light entering through the window and reaches the measured point after reflection from internal surfaces (Rizal, et al., 2016), as shown in figure 2.3.



**Figure 2.3:** illuminance level as a sum of three components (Szokolay, 2004)

Research by Darula & Kittler (2004b) shows that the general formula calculation of absolute zenith luminance is reliable to identify the dynamic daylight situations for all-sky conditions. Daylight Factor (DF) is a daylight calculation of the ratio between outdoor light level and indoor light level, which develops the DF measurement in guidelines and standards varies based on various factors such as climate condition, sky condition and many more. The formula to calculate the DF of space is  $DF = (E_i/E_o \times 100\%)$ . According to Malaysia Standard 1525:2014 (MS1525), any space requires 1 per cent to 3.5 per cent of DF. However, Gene-Harn, et al. (2017) research supports an argument that mentioned about the inaccuracy of daylight performance measurement based on DF.

In recent years, the researchers have used illuminance levels as an indicator of daylighting in a space. Luminous emittance, luminous exitance or illuminance is the total amount of luminous flux incident or emission on a surface per unit area, where the area is the working plane for main tasks of the space (Starling & Woodall, 1956; Long, 1994). According to the photometric study, it measures the amount of incident light that illuminates the surface, which correlate with human brightness perception of the surface (Ohno, 2005). Figure 2.4 shows the theory of illuminance.



**Figure 2.4:** Illuminance in photometry and photography

Previously illuminance level is described as brightness, where brightness usually describes the physiological sensations and perception of humans towards the intensity of the illuminance level of daylight. The International System of Units (SI) derived units for illuminance level is lux (lx), or equivalent to lumens per square meter.

### 2.2.3 Daylighting Measurement

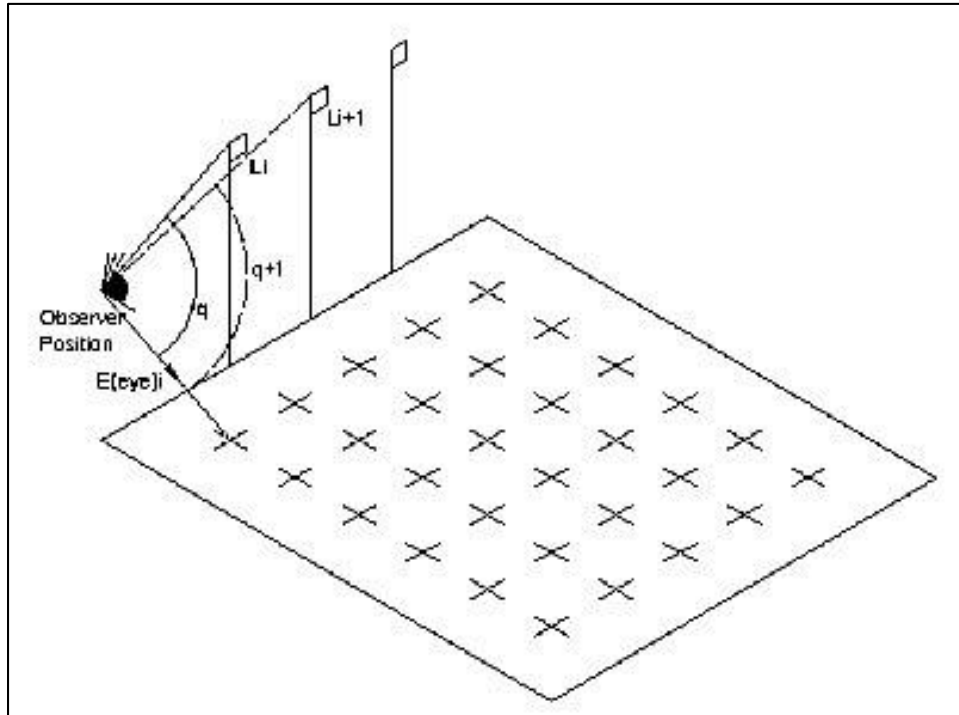
Daylight measuring methods for open planning spaces such as Hegbie method, Moon and Spencer method (Hopkinson, et al., 1954), daylight factor of Waldram and Fenestra method of Randall and Martin lack the essential variables in their method including reflected illumination of interior materials and colours, as described by

Biesele, et al. (1953). Biesele instead proposed a method that is sufficient enough to identify the illumination level just by considering the average, maximum and minimum illumination level of any space such as classrooms and offices (Wu & Ng, 2003). The illuminance level measuring tools such as light meter or lux meter is used to identify lux value at a working plane height for any tasks. The lux meter is equipped with silicon light detector, amplifier circuit and display monitor. The silicon is layered with various coloured filters to simulate the human's eye responses. The lux meters that are going to be used for measuring illuminance level of any spaces requires calibration against a reference, where this procedure is to ensure the accuracy of the lux meter readings (LightLab, n.d.). The accuracy of the lux meter is highly dependable for measuring the illuminance level for human sleep and circadian rhythms studies (Figueiro, et al., 2012).

The lux meter can be calibrated with a luminance meter calibration tool such as Bentham's LuxCal250, which refers to national metrology institute standards such as Physikalisch Technische Bundesanstalt (PTB) in Germany (Bentham, n.d.). This calibration method is also known as detector-based luminous intensity calibrations, which reduces the uncertainties and errors of the lux meter (Sametoglu, 2008; Fiorentin & Scroccaro, 2010). Various light and illuminance researches commonly refers to detector-based calibration methods that uses either incandescent (standard lamp) or LED-based light source. However, a calibration method that uses incandescent light source proven to be more reliable compared to LED-based light source due to its accurate absolute illuminance responsivity (Hovila, 2005), which explained the reasons why incandescent light source being exclusively used for lux meter calibrations (Ohno, 1998). Other calibration methods commonly used in illuminance level studies are Auto Calibration, Root-Mean Square Error (RMSE), Scatter Plots, Time Plots, Work Plane

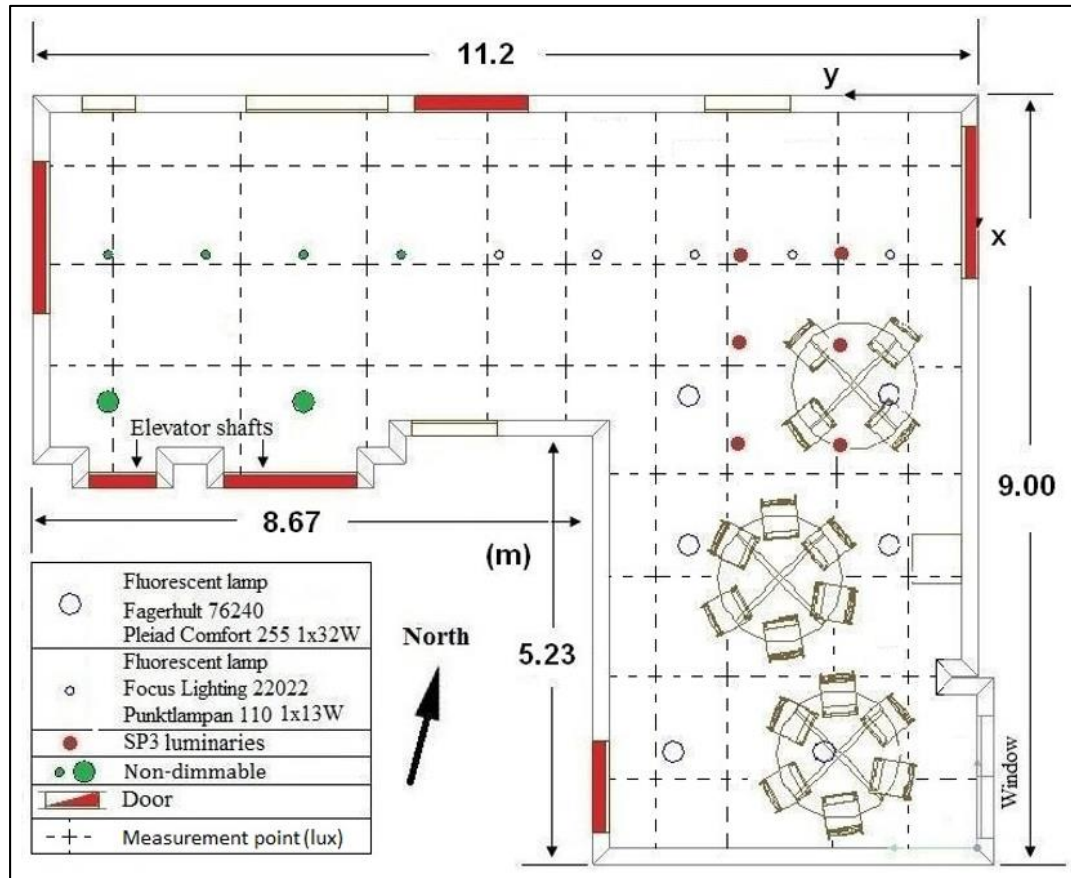
Illuminance, Sunlight Penetration and Coordinated Graphics (Mistrick, et al., 2015). A research that adapts detector-based calibration method uses a calibrated lux meter or a constant illuminance level source such as incandescent lamp for true illuminance level reference, where each lux meter for calibration are tested with the setup to study and analyse the range of error and accuracy (Gutierrez-Martinez, 2017). The detector –based calibration method by Gutierrez-Martinez analyses the absolute error of the devices, where the illuminance level is recorded at different true lux values. Gutierrez-Martinez added that medium value for absolute error is approximately 12 per cent, where lower values indicate a more accurate illuminance level reading.

International Commission on Illumination (CIE) developed an evaluation method for glare based on outdoor sports lighting and area lighting applications in 1994. The measurement method requires for the observers to look at each point on a horizontal illuminance grid (ground plane) to evaluate the glare rate outdoor, as shown in figure 2.5. However, it is restricted for horizontal grids of points below eye level and applicable for outdoor area and sports lighting applications (CIE112, 1994). Although this method uses a similar illuminance grid at the working plane lower than the eye level, it is not suitable for this research due to its application for glare evaluation in the outdoor environment.



**Figure 2.5:** Layout of grid points to measure illuminance outdoor.

In order to measure the average illuminance level of a space, the lux meters are arranged in grid for luminance spot measurement method. The luminance spot measurement on the grid of the space layout is suitable to measure the illuminance level of the classroom at the task level (Theodorson, 2009; Zomorodian, et al., 2016). The depth and width of the classroom influence the grid of the luminance spot measurement setup (Al-Sallal, 2010). Figure 2.6 shows an example of the illuminance measurement network grid for irregularly shaped space (Lingfors & Volotinen, 2013).



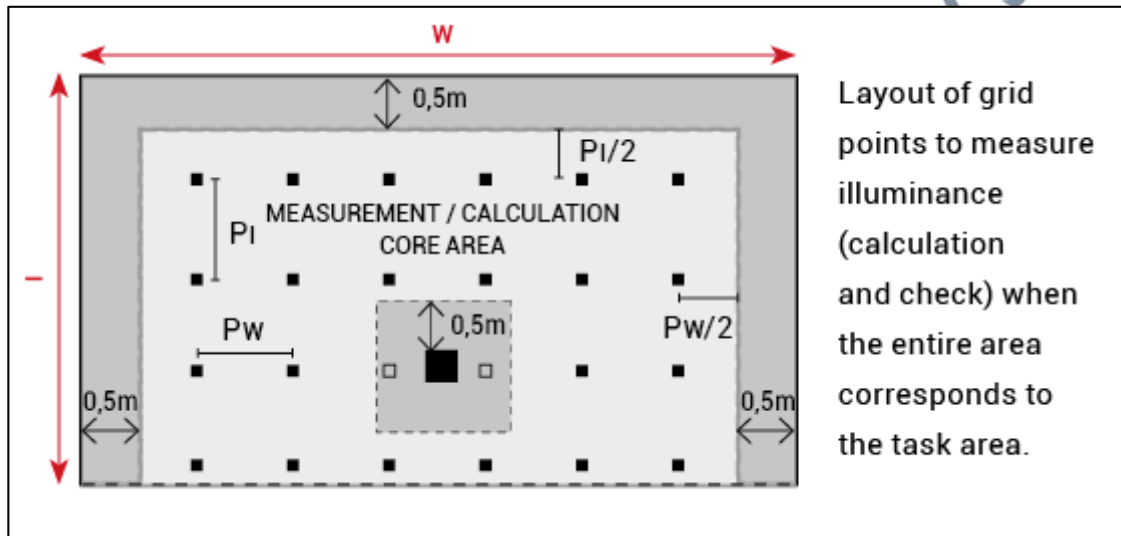
**Figure 2.6:** Illuminance measurement network grid (Lingfors & Volotinen, 2013)

The existing standardized sky types enabled simulation programs to evaluate more realistic daylight simulation, where turbidity or pollution situations and local sunshine duration considered to determine the sky patterns (Darula & Kittler, 2002). Different task areas influence the minimum number of measuring points and the dimensions of the illuminance grid cells (EN12461, 2011).

Measuring points along the other side of the grid are calculated similarly. The ratio of one side to another side should be close to value 1 as possible. A band of at least 0.5m wide from the walls must not be included in the illuminance grids unless the visual task required is not at lower distance or height (Esse-ci, 2019) as shown in figure 2.7.

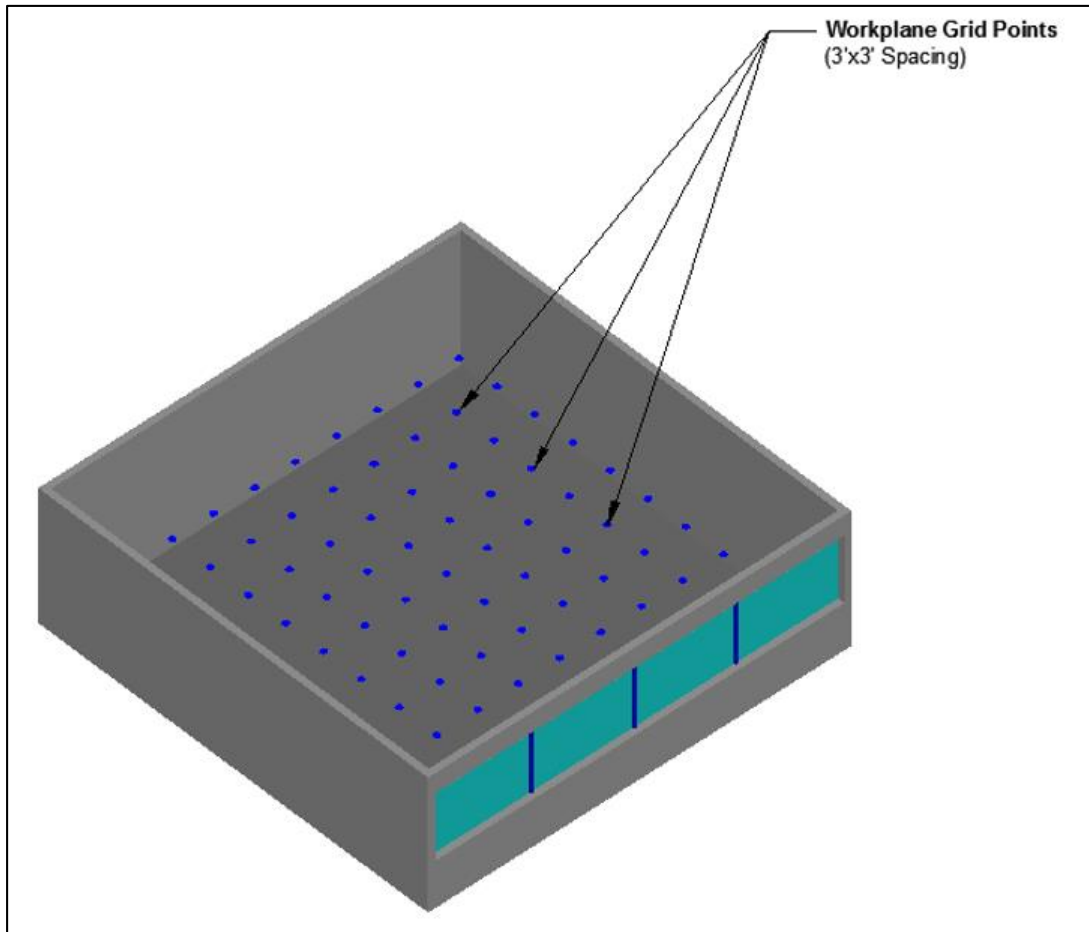
Similarly, it is not necessary to position the equipment 2 meters near the windows due

to its excessive amount of daylight (Mathalamuthu & Ibrahim, 2014). This might due to the angle of the daylight entering the space from the windows.



**Figure 2.7:** Layout of grid points to measure illuminance indoor (Esse-ci, 2019).

Illuminance level measurement in a 3ft x 3ft (900mm x 900mm) or 1m x 1m illuminance grid points at 2.5 feet (750mm) working plane height of the classroom that identifies the uniformity of the daylight distribution is a suitable method for intermediate sky conditions in Malaysia (Subramaniam, 2013; Mathalamuthu & Ibrahim, 2014) as shown in figure 2.8.

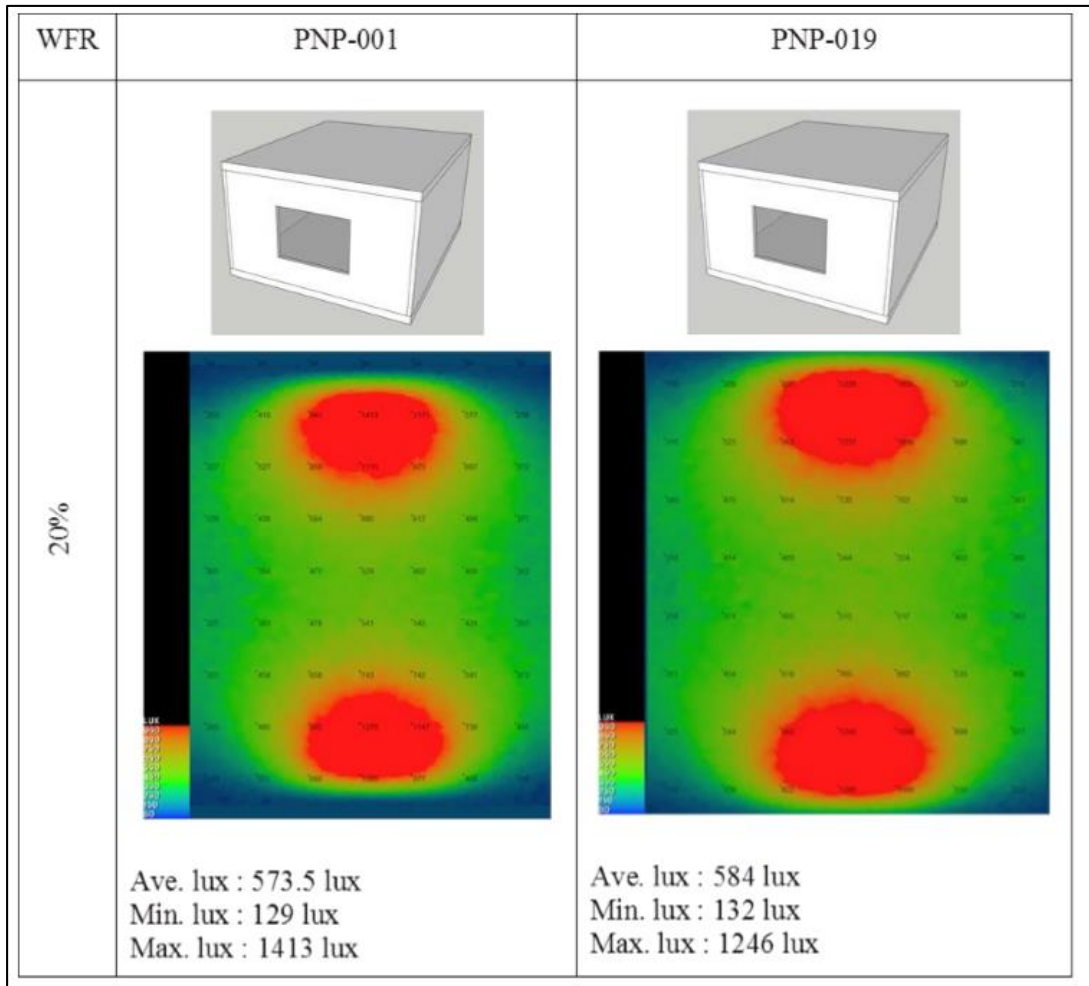


**Figure 2.8:** Grid for measuring work plane illuminance (Subramaniam, 2013)

Simulations using a scaled model still produce reliable daylighting results due to the characteristics of the daylight distribution do not varies, even as compared to a computer-generated simulation (Lim, 2014), where another study shows a consistent result between computer-generated simulation and conventional design wisdom (Reinhart, 2005). A research-based on students' preference shows that physical modelling was more manageable and simulation was more flexible (Wu, et al., 2000). Due to the flexibility use of simulation software, this research focuses on the use of computer-generated simulation. One of the simulation software that evaluates daylighting is DAYSIM, which includes parameter such as climate, daylight factor, daylight autonomy and daylight illuminance (Jovanović, et al., 2014b; Mistrick, et al., 2015). An interview with Ove Haldin by Karppi (2013) shows that lighting design

calculations can be evaluated using DIALx, free software for daylighting, with MagiCAD for composing the lighting design. The software provides a report consisting of a short introduction of the luminaires used, values of illuminances on each wall and the portions of direct and indirect illuminances, and also produces ray-traces, rendered images, of the simulated lighting (Karppi, 2013).

A digital lux meter is commonly used to measure the surface reflectance (illuminance value) in space as a reference for the computer-generated simulations (Mousavi, 2017). Integrated Environment Solution - Virtual Environment (IESVE) is commonly used to identify the illuminance level based on windows and openings, where one of the independent variables is the dimension of the window that influence the illuminance level received in a room (Mirrahimi, et al., 2012; Amaral, et al., 2015). A daylighting study by Abdelhakeem, et al. (2015) and Mathalamuthu, et al. (2018) uses both IESVE simulation and field measurement for illuminance level. The IESVE illuminance level results based on different sizes of windows, or a window-to-floor ratio (WFR) and illuminance grid can be as accurately simulated (Syaheeza, et al., 2018), as shown in figure 2.9.



**Figure 2.9:** IES illuminance level simulation result (Syaheeza, et al., 2018)

IES lighting analysis also included with Radiance, a ray-tracing software to estimate daylight accurately (Mirrahimi, et al., 2012; Amaral, et al., 2015), similarly with DIALx. The Radiance-IES is also used to validate the daylighting results through the analysis of measured data taken from a building under any identified sky condition, such as the tropical sky in Malaysia (Mousavi, 2017). A study using IES Radiance shows that the daylight factor simulated in the software is between 0 per cent to not more than 10 per cent difference with experimental measurement. This shows the reliability and validity for daylight analysis using IES software (Nikpour, et al., 2013a).

Comparison studies show that IES is among the most less reliable, less accurate and more uncertain in evaluating the energy consumption of buildings (Hopfe et al., 2007;

Reeves, et al., 2012). However, this research only looks at the daylight evaluation function of the software. Other researcher sets the floor reflection at 0.2 (20%), walls reflection at 0.5 (50%) and ceiling reflection at 0.8 (80%). The transmittance sets at 0.7 (70%), similarly with the default settings in IESVE 2019 (Naeem & Wilson, 2007). The model for the simulation is on a dark ground without any contextual obstructions. The suitable room surface reflectance and light transmittance values for the simulation in this study referred at (Altan, et al., 2015):

- i. Floor; 0.3 (30%)
- ii. Walls; 0.5 (50%)
- iii. Ceiling; 0.7 (70%)
- iv. Light transmittance; 0.81 (81%)

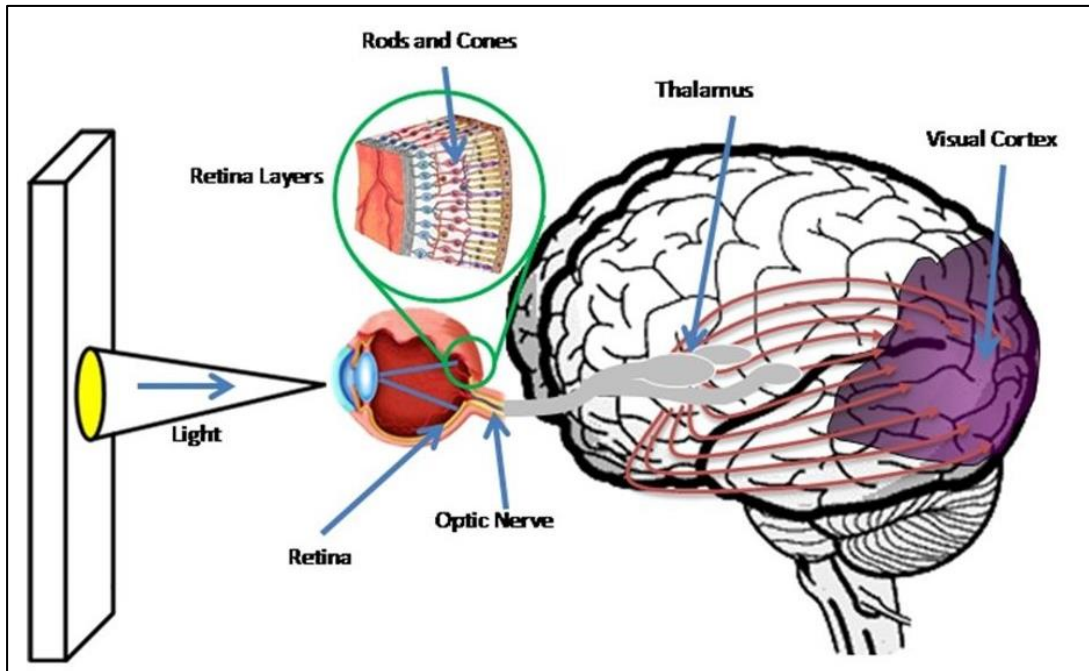
### **2.3 Daylight Effects**

Daylight studies related to its effects on a living organism, in general, are known as photobiology. The most relatable effects of light on a living organism such as a human is towards the functionality of the eye. Light provides the required intensity of illuminance level for any task to be performed efficiently such as reading and writing. Daylight also influences human sleeping patterns and schedules due to its effect on the human circadian rhythm and biological clock. This are also no exceptions to the students' biological conditions. Various studies have been done that shows efficient daylight in a classroom can affect the student's health and performance (Edwards & Torcellini, 2002; Heshong, et al., 2002; Zomorodian, et al, 2016).

### 2.3.1 Daylight Affects the Human Conditions

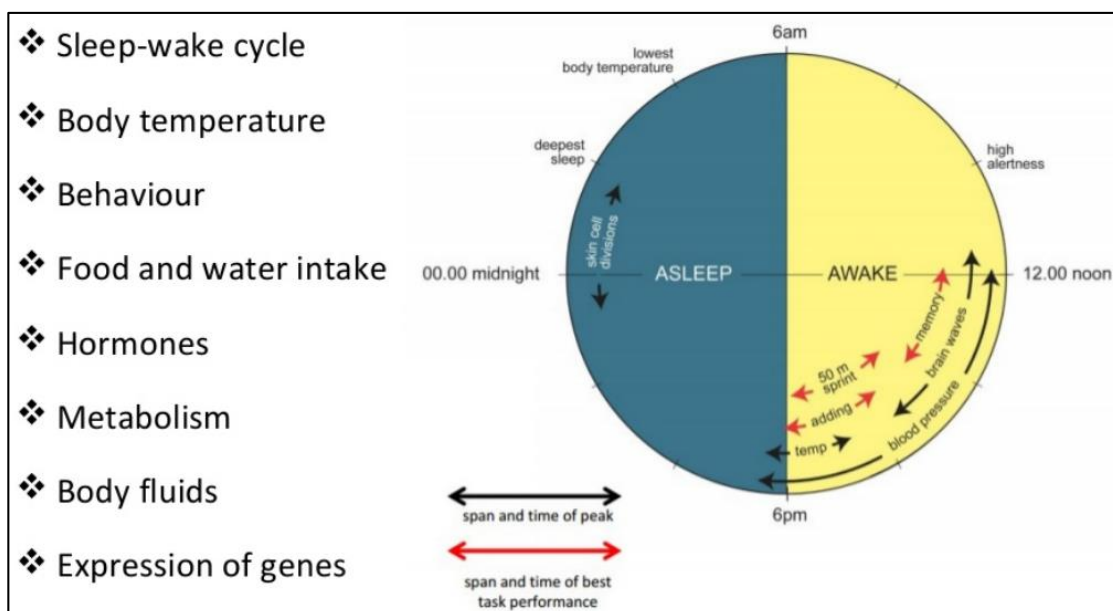
Islam, Judaism, and Christianity as major monotheistic religions describe light as an important element (Antonakaki, 2007; Gilavand, et al., 2016), wherein Islam, the whole chapter of *surah* An-Nur is dedicated to light. Verse 35 of the *surah*, Allah's guidance is seen as a light in a lamp during a dark night (Antonakaki, 2007). The importance of daylight to the living organism such as human are studied in a scientific field known as photobiology. This shows that there is a common acknowledgement of light importance in both the science and religious field.

Ibn Al-Haytm was the earliest Islamic scholar that studies the effect of light on the human eye. Ibn Al-Haytm has contradicted the theory of extra-mission by Plato, Aristotle, and Euclid. This contradiction was founded by him when he observes the pain sensation felt by human eyes that are exposed to intense light. This causes the eye's structure to change and causes visual discomfort. The study was on the relationship between human eye anatomy and physiology with light theory (Gorini, 2003).



**Figure 2.10:** Human Visual Path (Maghami, et al., 2012)

The human eye functions normally when there is light. Through the optic nerves system, the retinal image is changed into visual stimulus information and transmitted. The images transmitted depend on the amount of light received by the cornea. The limitation of the eye to receive and accept a certain amount of light intensity influences the human circadian system and rhythm (Boyce, 2003). There are two light exposure effects in human circadian such as acute suppression of melatonin and its ability to shift to the circadian phase (Blume, et al., 2019). The circadian system of a human body requires a reset period within the 24-hour circle to be synchronized with external environmental time (Duffy & Czeisler, 2009). The synchronization shows that time cue in the human circadian system is majorly influenced by light (Skene, et al., 1999).



**Figure 2.11: Human Circadian System (Adhikari, 2014)**

The brightness of the light received by the human body influences the circadian rhythm, which influences the sleep-wake cycle, behaviour, hormones, and metabolism. Exposure of bright light sometimes is effectively used for a certain type of patient for treatment (Wever, 1989). Students that sleep less during the night often sleep during the evening, which causes sleepiness, having attention deficiency, poor performance, emotionally upsets and experience more injuries while in the classroom (Giannotti, et al., 2002). Natural daylight source and artificial lighting have three same effects known as ‘Triple Effect’, which are visual functions, creating biological effects and emotional perceptions. The effects are explained as below (Zumtobel, 2018):

- i. Visual functions
  - a. Illumination of task area in conformity with relevant standards
  - b. Glare-free and convenient
- ii. Creating biological effects

- a. Supporting people's circadian rhythm
- b. Stimulating or relaxing
- iii. Emotional perception
  - a. Lighting enhancing architecture
  - b. Creating scenes and effects

Referring to the 'Triple Effect' above, this research studies the first effects, which are visual functions. Veitch & Newsham (1998) describes lighting quality exists in a space with appropriate environment luminous required for the person using the space for specific task or activity. The lighting quality requirement is identified in six groups:

- i. visual performance,
- ii. post-visual performance such as eating, reading, walking and all activities,
- iii. communication and social interaction,
- iv. mood state such as happiness, performance,
- v. aesthetic judgments and
- vi. safety and health.

This research also adapts the first two lighting quality requirements above, which are visual performance and post-visual performance for students. Occupant's satisfaction to perform a specific task is highly influenced by the indoor lighting in general (Husini,

2016). Jago & Tanner (1999) described that the visual environment such as daylight intensity affects the students' perceived visual stimuli, which affects the students' mental attitude and performance (Samani & Samani, 2012; Higgins, et al., 2005). Students at adolescent age that have poor sleep quality due to their circadian rhythm being disrupted recorded low grades and association with depression (Short, et al., 2013). Eye strain experienced by occupants can be reduced by providing an efficient light spectrum through proper design and integration of daylight in the space (Heerwagen et al., 1998).

### 2.3.2 Daylighting and Student's Performance

Efficient daylight provided in the classroom not only beneficial to the economy due to its energy-saving outcome, but also enhances the classroom atmosphere that beneficial to the students both in health and learning outcomes (Sojoudi, 2014). The studies on efficient illuminance level through daylighting in learning spaces show a significant effect towards the students' performance and behaviour (Samani & Samani, 2012; Mirrahimi, et al., 2013; Yacan, 2014; Vi Le, et al., 2016; Al-Ashwal & Hassan, 2018). The effect includes improvements in the students' behaviour, and increasing test score results shown through the statistical analysis (Heschong, et al., 2002). The evaluation of visual discomfort in learning spaces requires lighting aspects considerations such as light inefficiency for the task performance, shadows, uniformity distribution of light, veiling reflections, artificial lighting flicker, and glare (Boyce, et al., 2003). High intensity of the uncontrolled light source and bright coloured surfaces causes direct glare, whereas high light reflectiveness of walls, ceilings and floors surface causes reflected glare (Zumtobel, 2018). Reflected glare caused by the intensity of the interior finishes colours influences the visual comfort based on the task provided

(EFM, 2010). Insufficient lighting negatively influences human physiology, students' learning capabilities and abilities (Edwards & Torcellini, 2002). A study shows that 88 per cent of existing classrooms evaluated received illuminance level higher than recommended by guidelines and standards. Another 84 per cent of the classroom evaluated exceeded the illuminance level recommended that causes the visual comfort decrease (Winterbottom & Wilkins, 2009).

The students' subjective moods, attention span, cognitive performance and alertness in classroom increases with adequate natural light (Shishegar & Boubekri, 2016), which also can be improved by implementing strategies that optimize the students' sleep quality while maintaining adaptive circadian body clock (Short, et al., 2013). The visual environment quality of a classroom can be optimized with low glare and ample daylight source supported by high-quality artificial lighting (Barret, et al., 2015). Other studies also show that optimum daylight in classrooms improves the students' eyesight, increased growth, improved immune system and less dental decay or cavities (Nicklas & Bailey, 1997). The healthy environment increases the health of the students that there were 1/3 fewer absences due to illness, which is 3.5 fewer days absent per year (Olson & Kellum, 2003). A research shows that students feel sleepier and unable to concentrate in classroom due to inadequate illuminance level, where the students understand that adequate lighting improves their academic performance (Samani & Samani, 2012).

Sustainable design elements and strategies in green schools need to include in the daylighting considerations (Vi Le, et al., 2016). Green schools that implements and operates the sustainable strategies such as efficient daylighting improves the student's performance (Nicklas & Bailey, 1996; Issa, et al., 2011; Sanoff & Walden, 2012; Ibrahim & Ahmad, 2013) as well as the students' health (Demir & Konan, 2013), where

the teachers also experienced the same benefits (Radwan & Issa, 2017). However, high intensity of daylight reduces the students' performance due to glare that reduces the students' eye acuity (Plympton, et al., 2000; EFM, 2010; Arabi, et al., 2018). Waldram (1913) mentioned in his paper that glare and eyesore are visual discomforts that can distract the student's attention in class that can affect the student's health and performance. Quoting Figuero and Rea (2010), reported that eye fatigue ness caused by visual discomfort is one of the reasons for the loss of concentration (Ibrahim & Ahmad, 2013). Inappropriate visual comfort for the required learning tasks causes the reduction of students' performance (Gilavand, et al., 2016). Therefore, adequate daylight should be provided in a classroom that requires these natural sources in specific learning tasks such as reading and writing.

Daylighting design of a building can improve productivity in space (Rizal, et al., 2016). The students can read 26 per cent faster in a better daylight quality than students in a lower quality of daylight in the classrooms (Heschong Mahone Group, 1999). Similarly, research by Hathaway, et al. (1992) shows that the students learned faster and achieved higher test scores. The students' writing performance also decreases when the illuminance level in the classrooms are too high (Syaheeza, et al., 2019). A study on Optimum Task Performance Zone (OTPZ) and Non-Optimum Task Performance Zone (NOTPZ) shows that the students perform better-writing tasks at a lower illuminance level in the classroom (Arabi, et al., 2018). Due to its importance to students' performance, daylighting design strategies should be prioritized in the classroom design (Erwine & Heschong, 2002). All of this research shows a strong relationship between the students' learning performance with the daylighting quality in the learning space.

Bülow-Hübe's (1995) questionnaire that consists of components such as light level, coloration, distribution, directivity, glare, and contrast was adapted in the lighting questionnaire. The questionnaire adopted was a 6-scale descriptive scale that consists of perception on the brightness of the room and the amount of glare produced from the window (Cauwerts, 2013). In one of the previous researcher's questionnaire, a few references to the occupants are direct responses based on the visual environment of the classroom such as (Hirning, et al., 2016) and as per stated in the followings:

- i. Details on location, time and reference of the questionnaire (assessor),
- ii. Questions on general lighting,
- iii. Indication of the location of a disturbing or distracting light source (glare indication diagram),
- iv. Types of glare identified by occupants,
- v. Basic questions on demographic and task performance and
- vi. Comments on discomfort glare.

Variables such as sky condition, viewing direction and location of the participant are recorded by the assessors. The location of participants recorded reduces the discrepancies of data collected, where the location can be next to a wall, in mid-plan or deep plan (Hirning, et al., 2016). A survey on visual comfort consisting of 40 examinees (students), where there are 55 per cent male respondents and 45 per cent female respondents to reduce the discrepancy of data collected between both gender (Jovanović, et al., 2014). In general, the selected students' age should be 11 years old or

older to overcome the limitations of student's reading skills (Vi Le, et al., 2016). Sleepiness Scale (KSS), Office Lighting Survey (OLS) and Short-form 36 Items (SF-36) are the three validated questionnaires used in research to evaluate the level of self-reported sleepiness, measure occupant's light perception and measure self-reported general health respectively (Duijnhoven, et al., 2016).

Another variable indicated in a questionnaire of research evaluates the occupants' perceptions of the importance and size of the office windows (Doulos, et al., 2007). Descriptive rating scales have been developed and used in research that evaluates the participants' brightness perception in real-world conditions and controlled conditions (Cauwerts & Bodart, 2013). A study in an office building uses a questionnaire that evaluates the daylight environment of the working space (Bian & Luo, 2017), where another research included the demographic and the respondents' perceptions of the rooms and quality of the visual environment in the questionnaire survey for office spaces (Erell, et al., 2014).

### 2.3.3 Handwriting Performance

Handwriting speed has been associated with the assessment of performance, where the time is taken to finish a writing task of a specific text or the amount of text produced within a limited and short time (Ferrier, et al., 2013). A method conducted on students aged 9 and 16 requires them to perform five tasks, which are copying with 'best' and 'fast' instructions, alphabet writing, 10 min free writing and non-language based task that involves drawing specific instruction (Barnett, et al., 2009). Designing valid and reliable methods to assess a complex multifactorial skill such as writing speed is challenged with ethical, practical and scientifically implications. The assessment is

regularly carried out in secondary schools, high schools, colleges, and universities to identify literacy skills. Three principle methods are (Ferrier, et al., 2013):

- i. Copying
- ii. writing to dictation
- iii. expository or narrative writing or 'free writing'.

Wallen, et al. (1997) Handwriting Speed Test (HST) and Ziviani & Elkins (1984) Handwriting Performance Test (HPT) both requires the students to write a certain sentences and word within a short time ranged from 2 to 3 minutes (Ziviani & Watson-Will, 2010; Ferrier, et al., 2013). A group of students aged 14 to 17 years old wrote two argumentative or free writing tasks with a 75-minute time limit to finish each writing task consisting of 600 to 800 words. The students' writing task performance was evaluated with an analytical assessment protocol (De Smet, et al., 2014). Test of Legible Handwriting (TOLH) introduced by Larsen & Hammill (1989) records the time speed for the writing task to measure the holistic legibility of students' handwriting at age 7 to 18 years old. The word per minute (wpm) was recorded and evaluated for the students' writing performance (Rogers & Case-Smith, 2002). Measurement of Handwriting consist of three measures, such as (Medwell, et al., 2009):

- i. Handwriting (SAT) - handwriting style and neatness are assessed as part of the national test.
- ii. Handwriting speed - copying test that evaluates the students' handwriting speed, scores in letters per minute (LPM)

- iii. Alphabet task - measured using a form of the alphabet writing task involving writing as many letters in lower-case as much possible in one minute, scores in alphabet letters per minute (ALPM).

Another reliable method to evaluate students' handwriting performance is the Handwriting Proficiency Screening Questionnaire (HSPQ), which consists of a 10-item questionnaire that identifies respondents' handwriting difficulties (Roseblum, et al., 2003). Children's Questionnaire for Handwriting Proficiency (CHaP) is specifically developed to evaluate children's' handwriting proficiency, with similar items referred from HSPQ (Engel-Yeger, et al., 2009). The items for both HSPQ and CHaP are handwriting deficiencies indicators based on Likert scale type for three domains (Roseblum & Livneh-Zirinski, 2008; Engel-Yeger, et al., 2009):

- i. legibility
- ii. performance time
- iii. physical and emotional well-being

Detailed Assessment Speed Handwriting (DASH) is another method that evaluates the handwriting products and speed performance to complete various writing tasks introduced in the United Kingdom as the only standardized speed test. The test includes tasks to evaluate the best copy, the fast copy, alphabet writing and freewriting (Prunty, et al., 2013; Webb, n.d.). Barnett et al., (2011) and Prunty et al. (2016a) also adapt DASH to evaluate the handwriting performance of people with Development Coordination Disorder (DCD), which evaluates the respondents' Copy Best, Copy Fast,

Alphabet Writing, Free Writing, and Graphic Speed. The explanation for each evaluation are as shown below (Barnett, et al., 2011; Prunty, et al., 2016b):

- i. Copy Best – number of words written based on provided sentences is recorded and divided by two for 'word per minute' score.
- ii. Copy Fast – similarly with above, but the students are required to write the sentences as fast as possible.
- iii. Alphabet Writing – students are required to write the alphabet numbers based on memories as repetitive as possible for 1 minute in lower case. Correctly sequenced lower case letters are recorded.
- iv. Free Writing – Students are required to write on a topic for 10 minutes. The total number of legible words written is recorded and divided by ten for 'word per minute' score.

Hebrew Handwriting Evaluation (HHE) by Erez & Parush (1999) is a standardized Hebrew alphabet handwriting (Rosenblum, et al., 2003; Preminger, et al., 2004), along with DASH are some of the most comprehensive handwriting evaluation reviewed in this research. Although, some of the other handwriting evaluation only focuses on English and Hebrew Alphabet, instead of Arabic Alphabet as required for this research. Handwriting performance for Arabic and Hebrew alphabets are much lower compared with English or Latin alphabets (Ziviani & Watson-Will, 2010). However, one of the DASH evaluation, which is Copy Best, can be adapted for the research to identify the students' handwriting performance.

Most of the evaluation for handwriting performance uses word per minute (wpm) as measuring the performance. Although this research refers to wpm, the speed per letter performance are divided with different average letter per word such as 1.5, 3 and 5 based on the respondents' background and demography (MacArthur & Graham, 1987; Vacc, 1987; Graham, et al., 1998; Connelly, et al., 2005). The most common wpm calculation used is dividing the written letters by the minutes taken to finish the writing task and divide by average letter per word of five, the results show the average word per minute rate for the respondent as shown below (Ziviani & Watson-Will, 2010). Incorrect words or letters do not penalize or deduct the score of the evaluation (Keerthi & DeCoste, 2005). The average words per minute (wpm) for students aged 13 to 14 years old is between 14.3 wpm to 15.6 wpm (Ziviani & Watson-Will, 2010). These are the reference that will be used for this research.

There is a various method of measurement for different aspects of visual acuity throughout the history such as Snellen, Green's Chart, Landolt C, ETDRS Chart and many more (Colenbrander, 2001). Dutch ophthalmologist Herman Snellen introduced the Snellen eye chart to measure visual acuity in 1862, where there should be good natural light on the chart (Sue, 2007). Snellen eye and Early Treatment Diabetic Retinopathy Study (ETDRS) chart are used to measure respondents' visual acuity through the standard procedure (Falkenstein, et al., 2007; 2008). Respondents' function of refractive error after surgery can be determined using Snellen acuity results (Tucker & Charman, 1975). Although the Snellen eye chart has poor reliability and reproducibility, it is still universally accepted as a tool to test visual acuity. Pelli-Robson letter chart is one of the means that functions as a measuring tool for eye acuity test for patients or respondents (Williamson, et al., 1992).

The available Logarithm of the Minimum Angle of Resolution (logMAR) eye charts that negates the disadvantages of the Snellen eye chart has not yet been universally used during that time (Hussain, et al., 2006). LogMAR eye chart also known as Bailey-Lovey and EDTRS. LogMAR chart used by Anter (2013) with visually similar letters such as D, C, and O or R and K in ten lines of random letters with the same numbers of characters, where the font size ranges from 4 to 36 point, Calibri bold font with double spacing for each letter was adapted (Husini, et al., 2017) as shown in figure 2.12. However, these eye charts that measures the reading task eye acuity are not similar with required sentences such as “the quick brown fox jumps over the lazy dog” theme to measure writing task performance and wpm (Prunty, et al., 2013).



**Figure 2.12:** Modified LogMAR Eye Chart (Husini, et al., 2017)

Rosenbaum's card, a handheld card in the form of a mobile eye chart is widely used to measure near visual acuity (Horton & Jones, 1997). Minnesota Near Reading Test (MNREAD) acuity charts in the Greek language (MNREAD-GR) were established based on the extensive and comprehensive sentences or paragraphs structuring, experts' evaluation and testing results, validation for repeatability and linear mixed-model

analysis (Mataftsi, et al., 2013). MNREAD chart is a continuous-text reading-acuity chart that measures (Mansfield, et al., 1994):

- i. Reading acuity – smallest print that can be read without any significant errors.
- ii. Critical print size – smallest print that can be read with maximum speed.
- iii. Maximum reading speed – reading speed when reading tasks is not limited by the print size.

Jaeger chart is a card that printed paragraphs of text, which the texts font size increases in a range of 0.37mm to 2.5mm that tests near vision acuity (Blesi, et al., 2011). The original Jaeger chart was in 1867, 5 years after the Snellen eye chart introduced, consist of seven scaled size paragraphs (Khurana, 2008). The acuity is measured based on the smallest paragraphs that can be read while holding the card at a comfortable distance (Pal, et al., 2006). Even though the paragraphs or sentences of the Jaeger chart are similar to the required for measuring writing task performance and wpm, the alphabets used are English, instead of Arabic as required for the research.

Colenbrander eye chart is a tool used to measure the eye acuity performance of respondents, based on the specific target group (Colenbrander, 2009; Buari, et al., 2013; 2015; Radner, 2017). Colenbrander chart is a logarithmically scaled chart that has the Snellen notion. The chart consists of sentences with 44 characters that built up 9 to 11 words. The reading parameters in a standardized logarithmic reading chart identifies the visual performance of a patient through reading acuity, the reading acuity score, maximum and mean reading speed, and many more (Radner, 2016). Similarly, a standardized and validated Arabic eye chart has been established by Alabdulkader &

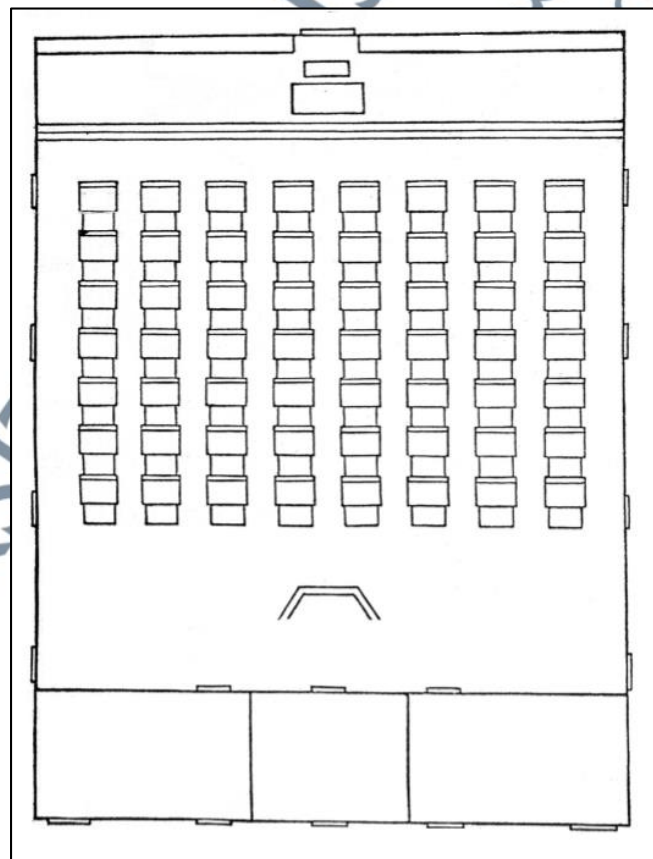
Leat (2017) through extensive progress research based on MNREAD, Jaeger and Colenbrander chart.

Through validated sentences of the Arabic paragraphs, reading acuity (RA) and reading speed in standard-length words per minute (SLWPM) were measured and compared for the Balsam Alabdulkader-Leat (BAL) eye chart, where the results of normal visual acuity (0.00 logMAR [log minimum angle of resolution]) were calibrated with linear regression analysis (Alabdulkader & Leat, 2017). Initially, the layout of the Arabic sentences adapts that of the Colenbrander chart with a similar grade level of difficulty (Alabdulkader & Leat, 2016). The BAL eye chart will be modified to fit the required chart to measure the students' Arabic handwriting performance based on Arabic word per minute (wpm) written by the students.

#### **2.4 Educational and Learning Space**

Based on the first recorded literacy from ancient Egypt civilization, it shows that education was held in old scribe schools within shines and temples (Tanic, et al., 2016). The evolution of learning space design in the 19th century was influenced by construction technology, government policies, educational systems and many others (Sanoff & Walden, 2012). The earliest recorded school design in the United State was a single room building where the students are in one house and learn in a typical educational system known as 'School House' design (Robson, 1874). However, Barnard & Mann in 1842 loathed the 'School House' design due to its closely universal, bad location, exposed to noise pollution, dust and highway traffic, un-aesthetic and repulsive external and internal experience (McClintock & McClintock, 1968; Weisser, 2006). Horace Mann has introduced an early model for the standard adequate classroom as shown in figure 2.13, where there are standard rows of desks, windows on two sides

of the room included with other facilities, utilities, and amenities known as Common School movement in the 1840s (Baker, 2012; Sanoff & Walden, 2012). The classroom started to integrate with other larger institutional bodies with larger accommodations such as a church's hall and community hall due to the increment of students. Once the educational system changed to specific and different education, modern schools design with a few classrooms in a single building were introduced (Wu & Ng, 2003; Sanoff & Walden, 2012). The development of school design in history stretched extensively within a careful research, standardization and calculated design process (Baker, 2012), thus created and introduced various school design movement such as 'Open-Air Design', 'School House' design and 'Common School' or 'School Architecture' design (Wu & Ng, 2003; Weisser, 2006).



**Figure 2.13:** Horace Mann, One-Room Schoolhouse, 1838, Plan (Weisser, 2006)

School building can be explained as 'Exclusive' and 'Selective', where 'Selective' school building uses ambient energy or a design based on daylighting and 'Exclusive' refers to the exclusion of environmental effects to the indoor environment of the classroom such as smaller window design and the use of air-conditioning systems (Wu & Ng, 2003). 'Exclusive' school buildings were a trend in the early 1970s during the energy crisis period, where designers started to design buildings without windows to save energy (Baker & Bernstein, 2012). 'Exclusive' school buildings proven to be an unhealthy environment that can cause a psychological effect on the students (Karmel, 1965). 50 per cent of the students in 'Exclusive' school building prefers more windows in the classrooms compared to 94 per cent of the students in 'Selective' school building (Tikkanen, 1970). The students' behaviour also differs between both school building, where 'Exclusive' school buildings students are timid and complain more frequently (Demos, et al., 1967). The psychological study identified that due to the amount of daylight received, the view content and visual and also thermal comfort factor, the students prefer to sit nearer to the windows. This shows that a design that has minimum windows and openings for daylight can cause a gloomy atmosphere for the students (Barrett & Zhang, 2009).

#### 2.4.1 Daylighting Design for Classrooms

Socioeconomic Factor relates to the fundamental of policies, economics, and systems or ideologies of education, where Built Environment looks into the physical conditions, environment of the school, and building design features and components that effects temperature, acoustics and lighting such as windows and openings, layout design and others (Earthman, 2002). The 'intangible element' in a classroom design is the non-physical variable such as energy use, rules and regulations, the sound within

the room and daylight factor, where 'physical element' is the arrangement of desks, windows and openings, walls and other physical elements (Hannah, 2013). Indoor lighting, in general, gives an impact to the occupants' desire and satisfaction to do specific work tasks (Husini, 2016). This research refers to 'physical element', such as the height of the table working plane and the classroom window sill height. 'Intangible element' such as rules and regulations, acceptable illuminance level, students' perception and learning task for *hafazan* are also considered.

Since the 1830s, architects and educators alike consistently struggling to elevate public education through school building modernization, such as improving the irregularly cut windows and openings of 'School House' building that limits the indoor light and air (Weisser, 2006). Scholars agreed that after the 1900s, the space requirement for schools evolved from big halls into smaller rooms, which started a new movement in Europe called 'open-air design' (Wu & Ng, 2003; Baker, 2012). Introduced as Waldeschule (forest school), in Charlottenburg, Germany near Berlin in 1904, it focuses on the improvement of the classroom's natural ventilation and daylighting by having with less solid walls and full-height openings without glass (Châtelet, 2008). Although the movement was focusing on daylighting, issues such as visual discomfort caused by too much daylight received in the classrooms were unavoidable. It also can occur when the design of the window and location of an artificial lighting source are inappropriate (Boyce, et al., 2003; Zumbel, 2018). Thus, according to Waldram in 1913, there was a design concept that disagreed with the use of large windows in the classroom due to issues such as (Wu & Ng, 2003):

- i. Method to reduce excessive glare,

- ii. Advancement of cooling technology, usage of air conditioning system has made the engineers introduce a smaller window to save the energy use of the classroom,
- iii. A large window that allows large views to outside distract the student's intention, as suggested by educational theorist,
- iv. The method used to measure daylighting accurately,
- v. Undefined minimum natural illumination level in classrooms, and
- vi. Recommendation for reflectance level of walls and ceilings.

During this period, the school design started to focus on the 'physical element' such as windows and openings that provides efficient daylighting (Husini, et al., 2017). A renovated preschool classroom in Copenhagen that installed a skylight improved the efficiency of daylight. Classrooms in Denmark that use skylight also proven to have a uniformly distributed illuminance level (Christoffersen, et al., 2016). Similarly, roof windows or skylights in classrooms distribute a more uniform illuminance level (Bruin-Hordijk, 2005). However, students in Sweden that use classrooms with skylight or roof window experienced eye fatigue more frequently compared to side-view windows at eye-level height in sitting position. Thus, a skylight may not provide efficient daylight and optimal visual comfort in the classroom (Tikkanen, 1979). This shows that the climate condition, sky condition, and geographical condition influences the efficiency of windows and openings design for efficient daylighting in a classroom.

The same sizes of windows with different height of its location in the wall influences the distribution of daylight to the deepest part of the classroom, such as using a large or

high positioned windows and clerestory windows (Barret & Zhang, 2009). The higher position of windows and openings in a classroom seems to be efficient to distribute daylight (Barret & Zhang, 2009; Christoffersen, et al., 2016). Excluding the factor of glare, window design for classrooms should be low sill, wide and high position on the wall to maximize daylight intake (EFM, 2010). Suggested that glare in a classroom can be reduced by providing two different directions of daylighting equipped with adjustable shading devices or bilateral fenestration (Barret & Zhang, 2009; EFM, 2010). Results from research by Fadzil & Sheau-Jiunn (2004) show that the optimum bay of windows with the least sunlight penetration was oriented at 0°, where 30°, 180° and 330° were the other few options (Nedhal, et al., 2011).

Design configuration and layout of the classroom influences the daylight performance of the classroom significantly, where the low ceiling and deep plan causes daylight disparity from the difference of daylight intensity between the area nearer to the windows and farther from the windows (Barret & Zhang, 2009). The intensity of the illuminance level can be influenced by other factors such as (EFM, 2010):

- i. Natural illumination - design and dimensions of windows and openings
- ii. Condition of the classroom (sizes, finishes, materials, etc.) – the condition of the interior environment
- iii. Building typology – single-story, low rise or high rise building
- iv. Climatic conditions and context
- v. Height of ceiling – single or double volume, etc.

Another study on illuminance level and visual performance of the student in the Middle East clarified that shows there are three issues regarding daylighting in classrooms which are (Al-Sallal, 2010):

- i. the contrast of luminance between task surfaces,
- ii. brightness from too much light source from the window and
- iii. the daylight distribution is not uniform.

Adequate distance between blackboards to the low row seat should be considered due to the surface of the blackboards influences the illuminance level of the classroom. Although colours and materials of the classroom's finishes influence the illuminance level, it is the least considered component (EFM, 2010). Therefore, colours and materials of the interior finishes are not considered in this research.

#### 2.4.2 Regulations, Standards and Guidelines for Daylighting Design

The classroom design at some point started to be redesigned into a smaller room in a single building with smaller numbers of students in each classroom. This created a concern for daylighting in a classroom among designers and architects (Robson, 1874). The refinement of school design rules by architects such as Hamlin in the 1910s and 1920s was an effort for a more efficient use of light and space. The standards were created based on the assumption of desks and chairs sat in stationary rows (Weisser, 2006; Baker, 2012):

- i. The light came from the left side, and slightly in front; to prevent shadow on desk

- ii. Windows run the full length of only a single side of the room
- iii. Windows are 40-50 per cent of the area of the exterior wall, equivalent to 25 per cent of the floor area
- iv. Width of the room does not exceed two times the overall height of the windows
- v. The window sill is three to three-and-a-half feet above the floor; to avoid glare
- vi. Window ended six inches below the ceiling

Based on the daylight thumb rule (DTR), there are a few components that need to be considered when designing a space, which are (Ibrahim & Hayman, 2005):

- vii. Window width and room depth at one fifth and one quarter ratio
- viii. Windows height at two and one-sixth of window width
- ix. Window head height (or ceiling height) to room depth ratio, where maximum room depth is four to five times the height of the window
- x. Window to floor (WFR) or window to window wall (WWR) area ratio, where the window area is approximately one tenth of the square of the room depth

The head height of windows on both side is commonly considered in daylighting study (Reinhart & Weissman, 2012). Window head height is the distance from the floor to the top of the window glazing (ASHRAE, 2013; Ghafari, et al, 2018). Various DTR

recommends that the depth of the space should be 1.5 to 2.5 times more than the window head height (O’Conner et al., 1997; Cofaigh et al., 1999; Reinhart, 2005; Bian & Ma, 2017). Hence, the most commonly referred daylight penetration depth and window head height ratio for daylighting studies is 1.5 to 2.5. (Reinhart & LoVerso, 2010). A research shows that increasing the window head height and reducing the window sill height resulted in lower daylight uniformity and intensity (Ahmad & Razon, 2015).

Suggested by Hamlin in 1910, the window sill height should not be higher than three and a half feet, approximately one meter, from the floor level due to any light from below window sill height is redundant (Baker, 2012). The working plane height recommended to measure the illuminance level in a space is at 800mm to 900mm height (GBI, 2009), which is the height of a typical table and window sill. Guidelines in Virginia recommends that the height of the window sill in a classroom should be 762mm height to define the task and illumination level (VDE, 2013). Commonly a study on daylighting evaluates the illuminance level in a space at 2.5 feet (750mm) working plane height (Subramaniam, 2013; Mousavi, et al., 2016). The minimum height of window sill for windows with openings or operable windows at 6 feet above the ground level of the exterior wall is 24 inches (600 mm) from the interior floor level (IRC, 2016). Thus, this research evaluates the illuminance level at various working plane height in various window sill height classrooms.

Window to wall ratio (WWR) commonly related to thermal comfort, where it limits the glazing area but still provides adequate view to the outdoor. The range identified for efficient WWR was between 20 per cent to 30 per cent, although other researches limits the range between 15 per cent to 25 per cent. Window to floor ratio (WFR) in the other hand is the most referred rule in identifying the minimum glazing area for habitable

rooms (Ibrahim & Hayman, 2005). Described in a research that WFR has been referred in school design for efficient daylighting since 1910s by Waldram and Price, where WFR implemented was 1/5 or 20 per cent for rooms with openings only on one side of the room (Wu & Ng, 2003). Therefore, this study also uses WFR to identify the window design for efficient daylighting in Islamic religious schools.

Reform efforts by Perkins in 1925 and a few others established one of the earliest detailed guidelines for lighting, air quality, sanitation, fire safety, and square footage per pupil (Weisser, 2006). WFR is related to windows configurations of any space which influences the daylight performance of that space (Zomorodian, et al., 2016). Efficient daylighting involves the height ratio to floor area depth of the classroom, which influences the WFR, including the method to evaluate the daylight factor and illuminance level in a classroom (EFM, 2010).

Section 39(3) of the Uniform Building by Law (UBBL) stated that any space or room that serves as education and learning should have windows and openings at least minimum 20 per cent of the floor area functions as natural lighting and natural ventilation, with openable windows not less than 10 per cent from the floor area for an uninterrupted natural airflow (UBBL, 2013). A daylighting study on a public school with 20 per cent WFR in Ipoh, Malaysia shows that without outside obstruction and human error for daylight to enter the classroom, the average illuminance level is within acceptable range as recommended in standards and guidelines (Mathalamuthu & Ibrahim, 2014). Although, a research in the same location shows that only 25 per cent of public schools received acceptable illuminance level in the classrooms (Mathalamuthu, et al., 2018). A research also shows that the rule of thumb for WFR based on standards and guidelines can be reformulated or modified to suit the design

beyond the usual standards and guidelines (Ibrahim, et al., 2019). WFR of a classroom in Malaysia ranged from 15 per cent to 20 per cent is adequate for acceptable illuminance level, especially in a small classroom with windows facing north (Mirrahimi & Ibrahim, 2013; Husini, et al., 2017). However, classrooms with depth too large unable to receive uniformly distributed daylight even though the WFR exceeds the recommended 20 per cent (Al-Sallal, 2010). Therefore, the classrooms selected for this research should be a public school standard design that has WFR between 15 per cent to 20 per cent as suggested.

General teaching space for reading and writing task requires certain illuminance level with high illuminance uniformity ratio, where the range recommended is 0.3 to 0.4 for side-lit classrooms. However, a classroom integrated with artificial lighting requires not less than 0.8 illuminance uniformity ratio and Limiting Glare Index of 19 (Loe et al., 1999). Acceptable illuminance level recommended in standards and guidelines is based on the comfortability of visuals during any specific tasks that require a certain amount of light such as writing and reading for students' learning development (MS1525, 2014). Standards and guidelines such as the Illuminating Society of North America (IESNA) handbook have been referred by architects and designers alike to identify the maximum and minimum foot-candle (fc) levels in specific areas of space appropriate for a certain task. The handbook also specifies the ranges of illuminance levels for various specific tasks required in various specific spaces. Learning spaces requires an average of 300 lx to 500 lx illuminance level (DiLaura, 2011). The Indoor Lighting Standard, SFS-EN 12464-1:2011 also recommends the illuminance level for the classroom should be 300 lx. The recommended average illuminance level usually referred to for minimizing energy consumption (DiLaura, 2011; UBBL, 2013).

A similar range of average illuminance is recommended for learning spaces, where the common reading tasks include reading pencil writing, printed material, poor and good duplicated materials. A bright interior surface such as walls, ceilings, and floors enhance the visual of the space (Zumtobel, 2018), which influences the reading task performed as well. Table 2.1 shows the recommended illuminance level for specific learning spaces. European standards mentioned that the classrooms' ceilings and walls should have illuminance levels ranged between 30 lx to 50 lx and 50 lx to 75 lx respectively. The illuminance level for walls should be at least 175 lx to achieve light for an emotional perception according to EN12464.

**Table 2.1:** Illuminance Level Based on Space Type (Zumtobel, 2018)

Space Type / Task	Lighting Level Range (lx)
Classroom, tutorial rooms	300
Classrooms, evening classes	500
Lecture halls	500
Art rooms	500
Art rooms in art schools	750
Black, green wallboards	500
Whiteboards	500
Technical drawing rooms	750
Laboratories	500
Library; bookshelves	200
Library; reading areas	500

The Philippines in the Southeast Asia region recommends a lower average illuminance level for learning spaces at 215 lx to 430 lx (EFM, 2010), maybe due to its geographical location. The manual also explains that specific tasks require a more detailed level of illuminance, where each manual's recommendation differs, such as the minimum illumination level is 10 fc (108 lx) instead of 30 fc (323 lx) in certain situations and regarding the tasks. The recommended average illuminance level for the general

background of learning spaces in Malaysia is 300 lx to 500 lx (OSHA, 1996; MS1525, 2014). Illuminance level recommended in the Public Works Department (JKR) Technical Guide refers to Malaysia Standard 1525 (MS1525) of 300 lx to 500 lx for learning spaces.

**Table 2.2:** Standards and Guidelines Recommended Lx Level (Syaheeza, et al., 2018)

Standards and Guidelines	Malaysia			Others		
	OSHA	MS1525	JKR	ZUMTOBEL	EFM	IESNA
General Teaching Space	300	300	300	300	215	300
		500	500		430	500
Library		300	300			300
		500				

Table 2.2 shows the recommended average illuminance level for general teaching space in Malaysia and other standards and guidelines (Syaheeza, et al., 2018). The common average illuminance level recommended is between 300 lx to 500 lx, with exception Education Facilities Manual (EFM), which recommends a lower illuminance level range between 215 lx to 430 lx. Similarly stated a lower than recommended illuminance level of 300 lx is required in classrooms for better students' performance (Husini, et al., 2017; Arabi, et al., 2018). Researchers and architects also refer to the recommended daylight factor (DF) of 1.5 per cent for various tasks (Lim, 2014), where the general range for acceptable Daylight Factor is 1 per cent to 3.5 per cent (MS1525, 2014). However, this research will measure the average illuminance level of the learning spaces at the working plane height.

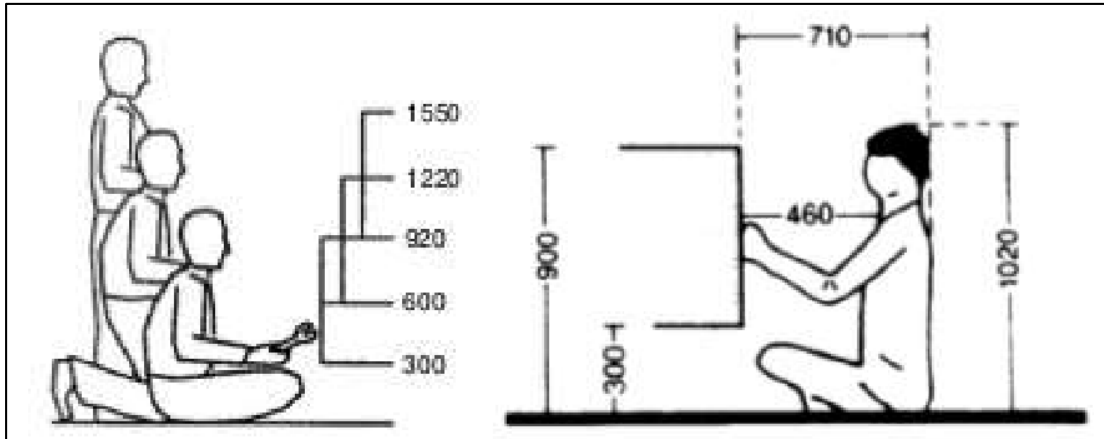
## 2.5 Islamic Religious Schools and Education

Islamic education *hafazan* requires only a small space such as a platform to sit, a small table for the Quran and certain madrasah uses ancient Egyptian stylus as a

pointer. Michael Stanton stated that a similar small table is used in Madrasah Nizahamiyah during the Seljuq dynasty, where the scholars recite and the students sit and listen to the Quran recitation in the learning space (Fuady, 2015). Fuady continues with a citation from Nekosteen (1996) stating that even though Islamic education is the core importance in the knowledge field during the 10th century of the Seljuq dynasty, political turmoil has made the education institution such as madrasah to be separated from the core Islamic institution such as the mosque. Madrasah is directly translated from the Arabic word which means any type of educational institution (Asimov, 1999).

### 2.5.1 Islamic Religious Schools in Malaysia

A traditional Islamic school in Malaysia is known as *pondok*, which adapts the *Ulul albab* education such as *hafazan* education. Students in traditional *pondok* learn *hafazan* differently, where the teacher is at the centre of students' semi-circular seating arrangement as the focal point. This arrangement allows equal opportunity for the students in the classroom to interact with the teachers (Marx, et al., 1999). However, Malaysia in the early 20th-century approach towards madrasah teaching system, thus method of *hafazan* through a circle (*Halaqah*) or semi-circular seating arrangement with the teacher at the centre instructing through reading and listening (*Talaqqi*) were no longer practiced (Sulong, 2015). The height of a traditional *rehal* is between 220mm to 280mm, which is approximately close to the required clearance for maintenance or work height of 300mm for squatting (Neufert, et al., 2012) and similarly for a crossed-leg position (Adler, 2007) as shown in figure 2.14. The clearance height of 300mm indicated is based on human anthropometrics, ergonomics, and comfortability.



**Figure 2.14:** Clearance Height for Crossed-leg Maintenance (left) and Squatting (right). (Adler, 2007; Neufert, et al., 2012)

Tunku Abdul Rahman Putra Al-Haj as the prime minister during the launching of the national mosque in 1966 established a *Tahfiz* Institution based on the idea concept coined by Sheikh al-Azhar Sheikh Mahmud Syaltut. *Tahfiz* school can be defined as a regular standardized government curriculum school with the insertion of Islamic subjects and moral pedagogy, which these Islamic values and codes of conduct are being inserted systematically between all the classes, tasks and activities in the school. (Hassan, et al., 2015). Similarly, in Indonesia, a *Tahfiz pesantren* is a school associated with Islamic education, which teaches the Quran and the exploration of science knowledge (Mubarok, et al., 2018). A *Tahfiz* school in Malaysia implemented the *hafazan* learning throughout the day, where the teachers recorded the students' performance in three separate *hafazan* class session per day (Abdullah & Maksom, 2016). Most Islamic religious schools in Malaysia requires the students to do *hafazan* between one hour to four and a half hours every day, where the students have to memorize the whole Quran between two to five years (Bakar & Yusoff, 2016; Hadi & Latif, 2016; Mohamad, 2016). A research in various Islamic religious schools shows

that the daily learning schedules for students was adequate and sufficient for *hafazan* education and learning (Abdullah et al., 2005).

There are two types of Islamic religious secondary school in Malaysia, which are Islamic National Secondary Schools and Islamic Government-aided Secondary Schools. Establishment of Sekolah Menengah Kebangsaan (Agama) (SMKA) or Islamic National Secondary Schools started in 1977 during the acquisition of 11 Religious and State Religious Schools by the Ministry of Education, now with 55 SMKAs in Malaysia. The idea to establish SMKA was inspired by the late Haji Nik Mohammed Mohyideen bin Haji Wan Musa, Director of the Ministry of Religious Affairs at that time (MoEM, 2019). Sekolah Agama Rakyat (SAR) or Islamic Government-aided Secondary Schools in Malaysia is managed based on the concepts translated by respective governing states due to its position under the state power and legislation. However, the federal government continues to play minor roles in safeguarding SAR's efforts in establishing religious schools (Siren, et al., 2018). Various public and boarding schools in Malaysia had also integrated *Ulul Albab* education in students' daily learning schedule (Ghani, 2016).

A General Circular from the Ministry of Education Malaysia (MoEM) stated that secondary public schools will implement *Ulul albab* pedagogy such as Quran *hafazan* (MoEM, 2016). The deputy prime minister during that time also stated that Islamic religious education should be implemented in all public schools. The focus on *Tahfiz Ulul albab* Module increased in recent years, with an increment of parents enrolling their children in schools that implements the module (Utusan Online, 2019). An interview with Dr. Mohd Kamal from Jabatan Agama Islam Selangor (JAIS) stated that his increased demand is due to the belief and confidence of the community towards this

institution, especially its contribution not only from academic perspectives but also from the aspect of spirituality and personality (Siren, et al., 2018). The demand for Islamic religious schools in Malaysia increased from 1999 to 2011 as much as from 58 institutions to 278 institutions (Bani, at al., 2014). In the year between 2011 to 2017, new religious schools increased more than 900 in Malaysia (The Strait Times, 2017).

### 2.5.2 Method of Quran Memorization (*Hafazan*)

There are two types of memory retention, which are long and short term memory retention. *Hafazan* is memorization as defined by the psychologist. The Quran *hafazan* process such as recitation of the verses involves long memory retention brain activities (Fadhilah & Ashaari, 2015). Methods used for *hafazan* are *Sama'i* (listen), *Jama'* (recite together), *Wahdah* (read one by one) and *Kitabah* (write). *Wahdah* is the most preferred method by students due to it eases the *hafazan* process. *Wahdah* and *Sama'i* is a commonly used method for *hafazan* learning in Malaysia (Ikhwanuddin & Hashim, 2014). Two of the method, *Sama'i*, and *Jama'* were a common *hafazan* method during the Seljuq dynasty (Fuady, 2015), a similar method used by Gabriel (Jibril) to teach Prophet Muhammad the revelation (Sulaiman, 2004). Teaching *hafazan* based on Prophet Muhammad's oral and writing is the basic Quran learning method (Jamaluddin, et al., 2018). Madrasah usually adapts *Tasmi'* method, where the teacher evaluates the students' recitation, writings or both individually (Abdullah, et al., 2003).

Some other methods for *hafazan* are *Tahriri* (write), *Syafawi* (recite) and *Tasmi'* (check the memorization). The study on these methods shows that each method of learning style highly influences the students' learning performance for *hafazan* (Abdullah, et al., 2003). *Syafawi* method is widely and commonly adapted in *hafazan* learning process,

where *Tahriri* is seldom used (Hashim, 2015). Early Islamic scholars learned *hafazan* by writing the verses, memorize and rewrite the verses again, similarly like *Tahriri* method. They then had a teacher to check the writings, not the recitation (Abdullah, et al., 2003), similarly like *Tasmi'* method. This method is also agreed upon by various *Tahfiz* institution in Malaysia. However, *Tahfiz* students disagree with this type of method, thus prefers a method where the students learn to recite the verses fluently and correctly first before attempting to memorize it (Abdullah, et al., 2005), similarly with *Muraja'ah* method.

*Muraja'ah* is a more systematic method used, where the students are scheduled to read certain sentences of a verse repeatedly throughout the entire day, improving the students' long-term memory retention (Al-Hafiz, et al., 2016). In Pakistan, *Panipati* method also similarly focuses on a recitation of the verses throughout the day, where later the teacher checks the students' performance (Ariffin, et al., 2014; Dzulkifli & Solihu, 2018). Other than the *Panipati* method, some other most common methods used in *Tahfiz* schools in Malaysia are the *Deobandy* method, a method originated from Saudi Arabia and one method from Indonesia (Dzulkifli & Solihu, 2018). Othman method is another method that refers to several techniques such as Ten Time *Khatm*, *Chi* (new memorization), *Zor Pismis*, *Kolay Pismis*, *Tekrar*, *Tekrar Hepsi Seyfa*, and Has. Students are required to complete Ten Time *Khatm* as a prerequisite requirement before advancing to the next technique (Ariffin, et al., 2014; 2015). This supports a finding by Ikhwanuddin & Hashim (2014) that the most widely preferred *hafazan* method is reading. However, there is also a study that shows rewriting the Quran verses in Arabic strengthen the students' memory retention (Abdullah & Maksom, 2016), where method

such as *Tasmi'* and rewriting the verses shows a significant efficiency in students' *hafazan* performance (Abdullah et al., 2016).

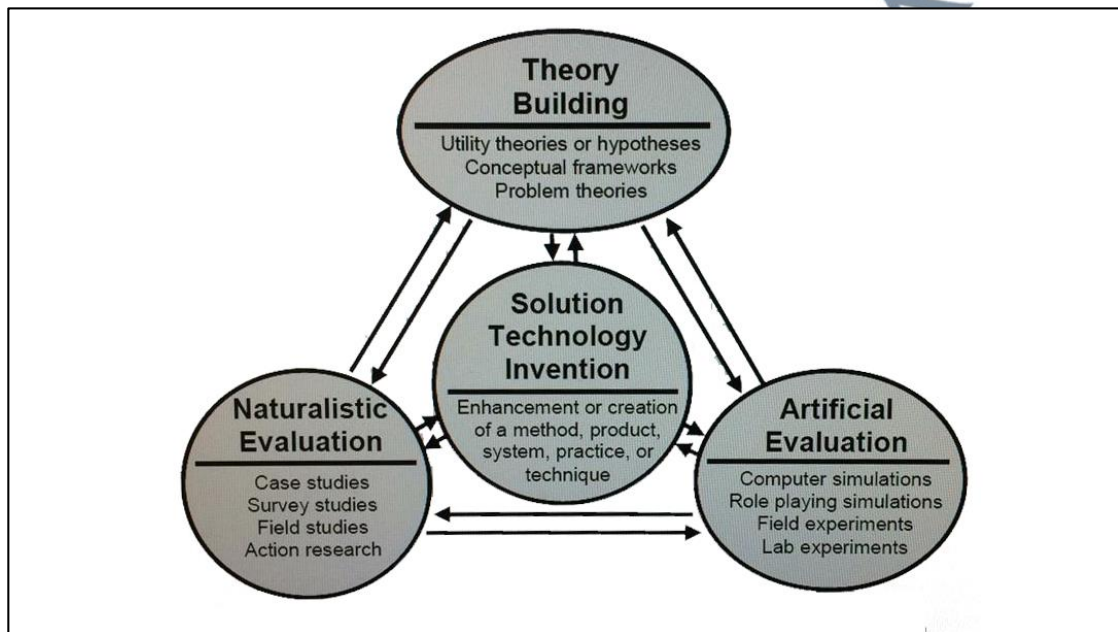
## 2.6 Design Science Research

Design Science Research (DSR), or constructive research (Dresch, et al., 2015a; 2015b) disciplines seen by Van Aken (2005) as a quest to gather understanding on human performance such as students' performance and improving it. Although this is comparable to explanatory science, DSR is more pragmatic in its process similar to exploratory science research. Venable (2006a) mentioned that the first component Theory Building refers to utility theories or hypotheses that are a precursor to the Solution Technology Invention, where the theories is a possible approach to reduce the problem or issue of the study. Solution Technology Invention is seen as the core idea of the solution provided, where it can be a new solution or a fragment of improvement within an existing solution. The solution provided requires evaluation through three main areas (Venable, 2006a):

- i. Effectiveness and efficiency in solving the problem
- ii. Comparison with other existing solution
- iii. Undesirable impacts from the solution

Artificial Evaluation is one of the components required to evaluate the Solution Technology Invention through virtual or non-real time evaluations such as computer simulations, lab tests, and field experiments. The other component is Naturalistic Evaluation, which evaluates and explores the Solution Technology Invention through real-time and environment evaluations such as case studies, surveys, ethnography and

action research (Venable, 2006b). Research methods based on design science paradigms such as design science research can increase the relevance of a study (Dresch, et al., 2015b).



**Figure 2.15:** Design Science Research Framework adapted from Venable and Travis, 1999 after Nunamaker, 1991 (Venable, 2006a)

Hevner, et al., (2004) also mentioned that DSR's main purpose is to achieve knowledge and understanding about an issue by designed artefact application, which can be seen as the window sill height for Arabic handwriting tasks in this research. Thus, this research mixed method is adapted from Design Science Research, which leans more towards a quantitative evaluation of the technology invention or design for suitable window sill height and technology evaluation through field studies or measurements, experiments, and the computer-generated simulations.

There are three basic design mixed methods, which are (Creswell, 2013):

- i. Convergent Design – convergence of both qualitative and quantitative results

- ii. Explanatory Design – qualitative data explains the quantitative results
- iii. Exploratory Design – quantitative results generalize the qualitative findings

This study refers to Exploratory Design, where the acceptable illuminance level and window sill height as the quantitative result generalizes the students' visual and Arabic handwriting performance as the qualitative findings. There is a few mixed method approach for data collection such as (Creswell, 2016; Creswell & Creswell, 2017):

- i. Questionnaire survey - Samples as representative of the study population, where statistical analysis to be performed. Larger number of studies uses samples between 300 and 500 individuals
- ii. Qualitative interviews: Consist of 12 to 15 interviews until saturation point reached, where new themes or categories no longer appear
- iii. Focus group: At least two groups with six to 12 participants per group until saturation point reached, where no new interesting information emerges

This study adapts the questionnaire survey as data collection method, where the samples are to represent Islamic religious school students in Malaysia. Based on Between-Person Design (BPD) method, the population sampling size in different situations or scenario should be random sampling, where 30 or more respondents are randomly selected. This means that different individuals selected are exposed to different settings of the space such as a classroom, since that individuals are genuinely different. However, the randomly selected should be in similar group of age, sex, education,

health, type of work or any other criteria (Hygge & Löfberg, 1999; Creswell, 2012). This study refers to population sampling for each session of 24 students due to the retraction of classroom floor area based on GBRP standards, where the total sampling size is 192 students.

## 2.7 Summary

All the literature reviewed shows that the student's performance and acceptable illuminance level in a classroom are highly related. Not only has that it increased performance, but the health of the students as well, although this will not be considered in this research. This research only focuses on the daylight effect on the students' performance. Various daylight and students' performance measuring procedure has been reviewed in this chapter. The daylight measurement will be adapted from the illuminance grid spot-measurement procedure, where the students' performance will be evaluated using a daylighting and perception questionnaire, with Detailed Assessment Speed Handwriting (DASH) Copy Best evaluation. The Copy Best evaluation is based on Balsam Alabdulkader-Leat (BAL) eye chart that will be modified to follow Jaeger chart and Colenbrander chart format.

This chapter also reviews the traditional *hafazan* learning method including classroom layout and students' arrangement, sitting position, working plane height of the traditional *rehal* and the most used method for learning *hafazan*. The review shows that traditionally students learning *hafazan* sits on the floor with a small table or *rehal* with a working clearance of 300mm height. The most common method used to learn *hafazan* identified is through reading and writing. Thus, this research uses a small table or *rehal* to identify the students' Arabic handwriting performance for *hafazan* based on provided

Arabic language eye chart. Figure 2.16 shows the relationship between the components of the literature review.

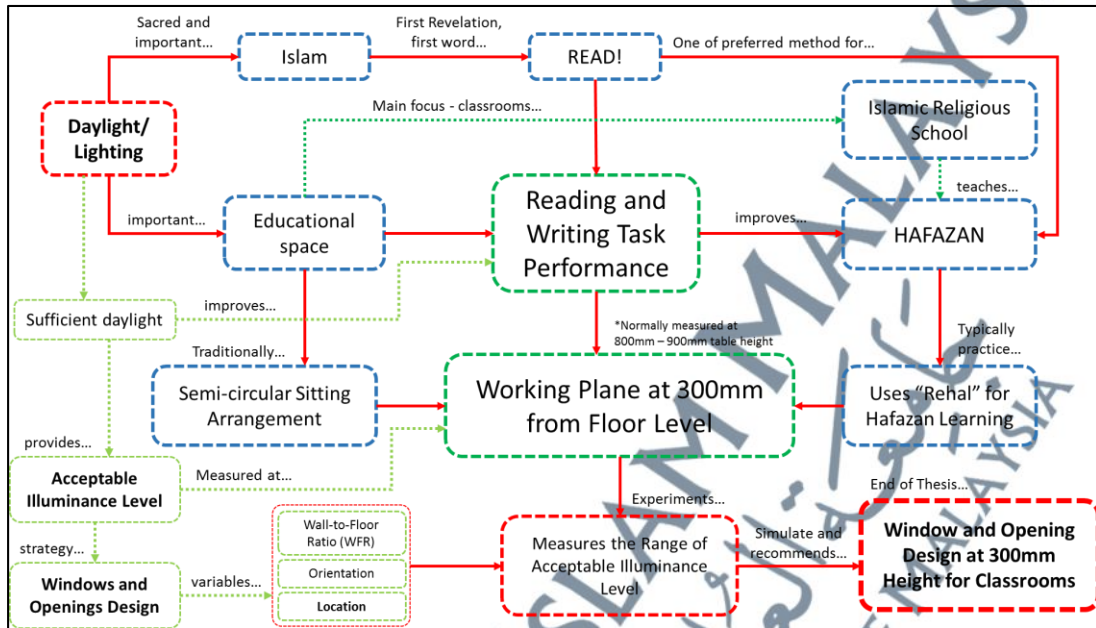


Figure 2.16: Thesis Scope Relationship Figure

Some many standards and guidelines have been introduced and established in the world, such as OSHA, MS1525, JKR, Zumtobel, EFM and IESNA. This chapter also discussed the historical aspect of both general schools and Islamic religious schools, including Malaysia. The layout of the schools including the daylighting consideration based on the window and opening design development for classrooms were also included. The typical height design for the windows sill is between 750mm to 900mm. Based on various research, the most suitable Window-to-Floor Ratio for learning spaces is between 15 per cent to 20 per cent, which will be kept constant for this research. The identified acceptable illuminance level for learning spaces is between 300 lx to 500 lx. However, this variable shall not be kept constant to identify the acceptable illuminance level for students' Arabic handwriting performance. The next chapter will discuss the research methodology, where the procedure of the experiments based on the literature review will be established.