CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the research method of the study including the research concept, framework, phases, and procedures. This chapter also discusses the research methods and processes for daylighting and students' performance evaluation in detail. Based on objective one of the research, this study evaluates and identifies the acceptable illuminance level in a classroom at a working plane of 300mm height from floor level. The results will be then used as a reference to achieve objectives two and three, which are to identify the optimum window sill height for a working plane of 300mm height. This chapter explores the Design Science Research (DSR) concept and the Theoretical Framework introduced in Chapter One. The tools used are field measurement, questionnaires, visual eye acuity tests, and computer simulations. Table 3.1 shows the corresponding method with the research objectives and research questions of this study.

Population sampling size for this experiment refers Between-Person Design (BPD) method, where different persons are situated in different setup, scenario or settings of the classrooms. The difference of the situation refers to the average illuminance level, window sill height and working plane height. 30 person or more is required in each session, where their age and education level are similar (Hygge & Löfberg, 1999; Creswell, 2012). However, since numbers of students that can fit in a classroom restricted by GRBP standards, each classroom or group only fit for 24 students, where the total students for the entire study is 192.

Table 3.1: Corresponding methods woth research objectives and questions

Research Objectives	Research Questions	Methodology
To identify the acceptable illuminance level for students' optimum Arabic handwriting performance for learning *hafazan* in Islamic religious school.	What is the acceptable illuminance level for students' Arabic handwriting performance?	Field measurement
		Arabic handwriting performance
	How do the students perceive the daylight conditions and their task performance in the current classrooms?	Questionnaire
		Arabic handwriting performance
	How does the performance of the illuminance level at working plane 300mm height affects students' Arabic handwriting performance?	Field measurement
		Arabic handwriting performance
To investigate the influence of window design on illuminance level measured at working plane of 300mm height in Islamic religious school.	What is the range of illuminance level measured at 300mm height working plane from floor level in the classroom with different window sill height?	Field measurement
	Why does the window sill height difference influence the illuminance level measured at 300mm height working plane in the classroom?	Computer simulation (IESVE)
To recommended window sill height for students' optimum Arabic handwriting performance for learning *hafazan* at the working plane of 300mm height.	What is the suitable window sill height from the floor level that achieves acceptable illuminance level at a 300mm working plane?	

3.2 Research Phases

The research consists of four phases with different method approach. The phases are as shown below:

Preliminary Phase – It is to collect the data and information on daylight and illuminance level theories for students' optimum learning task performance. Standards and guidelines are referred to identify the acceptable illuminance level and Window-to-Floor Ratio (WFR) for learning spaces. The efficiency of the standards and guidelines

implemented for learning spaces are studied through a literature review. The students' performance measured based on the illuminance level is also included in the literature review.

Phase One – It is to achieve objective one of research, which is to identify the acceptable illuminance level for students' optimum Arabic handwriting performance for learning *hafazan* in Islamic religious school. This phase involved experimental studies established at selected classrooms that follow Malaysian standard layout design. The data collected are conducted in the selected secondary schools that implemented *hafazan* as one of the education syllabuses.

The first part of the phase is field measurement, where the layout and physical components such as Window-to-Floor Ratio (WFR) and window sill height of the classrooms are measured. Classrooms with different window sill height are also selected, which are at 300mm and 900mm. This part also measures the illuminance level of the selected classrooms at 300mm and 900mm working plane height from floor level.

The method used for part two of the phase is surveying. The survey is divided into two sections, which are questionnaires and visual acuity eye test. The questionnaire consists of questions that identify the students' perception of the visual comfort of the classroom. The data collected will be analysed with the Statistical Package for the Social Sciences (SPSS) statistics software. Balsam Alabdulkader – Leat (BAL) eye chart used for the visual eye acuity test is to evaluate the students' Arabic handwriting performance in the classroom.

Phase Two – The data collected in phase one will be used as a reference for the second phase, which is computer simulation using Integrated Environmental Solutions Virtual Environment (IESVE). The simulation evaluates different window sill height from floor level. The result of the simulation identifies the windows sill height that allows acceptable illuminance levels for students based on the results of the previous survey in the first phase. This phase is to achieve the research objective two. The objective is to investigate the influence of window design on illuminance level measured at working plane of 300mm height in Islamic religious school. The recommendation is the final phase of the research.

Phase Three – the Third Phase is to achieve objective three of the research, which is to recommended window sill height for students' optimum Arabic handwriting performance for learning *hafazan* at the working plane of 300mm height. The recommendation is based on the simulation result in Phase Two, where the variable considered is based on the results from Phase One. The recommendation contributes to the improvement of daylighting strategies in Islamic religious schools in Malaysia.

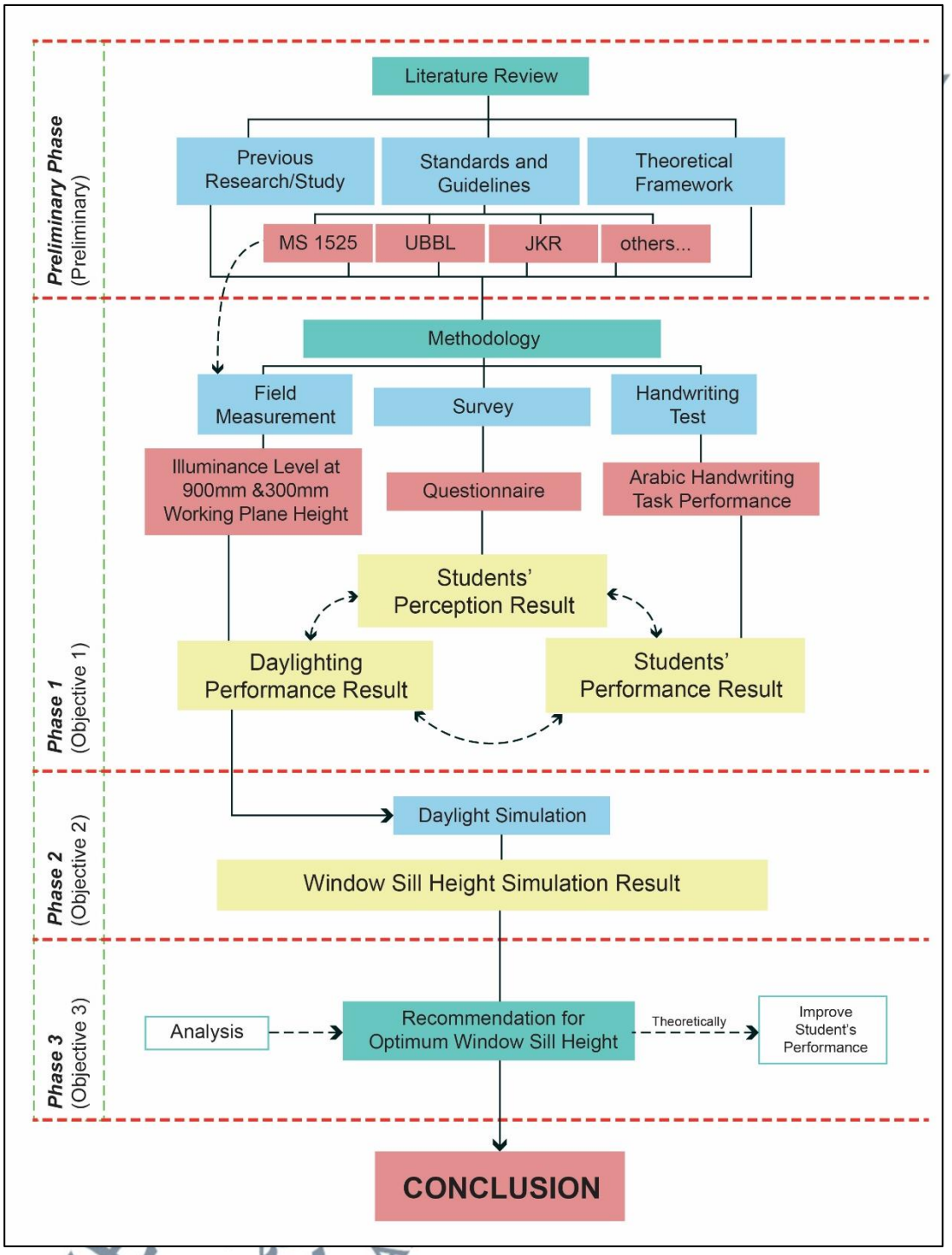


Figure 3.1: Research Flow

3.3 Research Procedure

There are three research procedures required for the study. The three research procedures are as shown below:

i. **Field Measurement** – It is for the field measurement and survey conducted in phase one. The selected classrooms are based on the layout design and the Window-to-Floor Ratio (WFR). The WFR will be set as recommended by the Malaysian standards and guidelines of 20 per cent to achieve acceptable illuminance level in the classroom. The floor area of the classroom's layout design will follow the recommendation by JKR and GRBP with a ratio of 2.5 m2 per student. The illuminance level is measured with students occupying the learning space, where the students selected are secondary school students with ages ranged between 13 to 17 years old. Each classroom consists of students in three rows. The illuminance level is measured using a lux meter or data logger placed on tables and *rehal* with a working plane height of 900mm and 300mm respectively in different and separated experiments.

ii. **Survey** - Afterwards, the students are given a set of surveys each. The survey consists of two-part, which are questionnaires on daylight perception and task performance perception. The students are given a brief of the experiment by the researchers. The students are required to answer the questionnaire within the located time.

iii. **Handwriting Test** – The BAL eye chart were included with the questionnaire. The students are not time restricted to rewrite the BAL eye chart provided within the survey. The Arabic handwriting speed is recorded by the students based on the provided stopwatch at the front of the classrooms. The students' Arabic handwriting speed will be recorded to evaluate the students' Arabic handwriting performance. The students'

Arabic handwriting performance is evaluated by the students' average words per minute (wpm).

iv. **Simulation** – The third procedure is for the simulation. Using the IESVE, the results will provide the optimum window sill height for the working plane at 300mm height in the learning space.

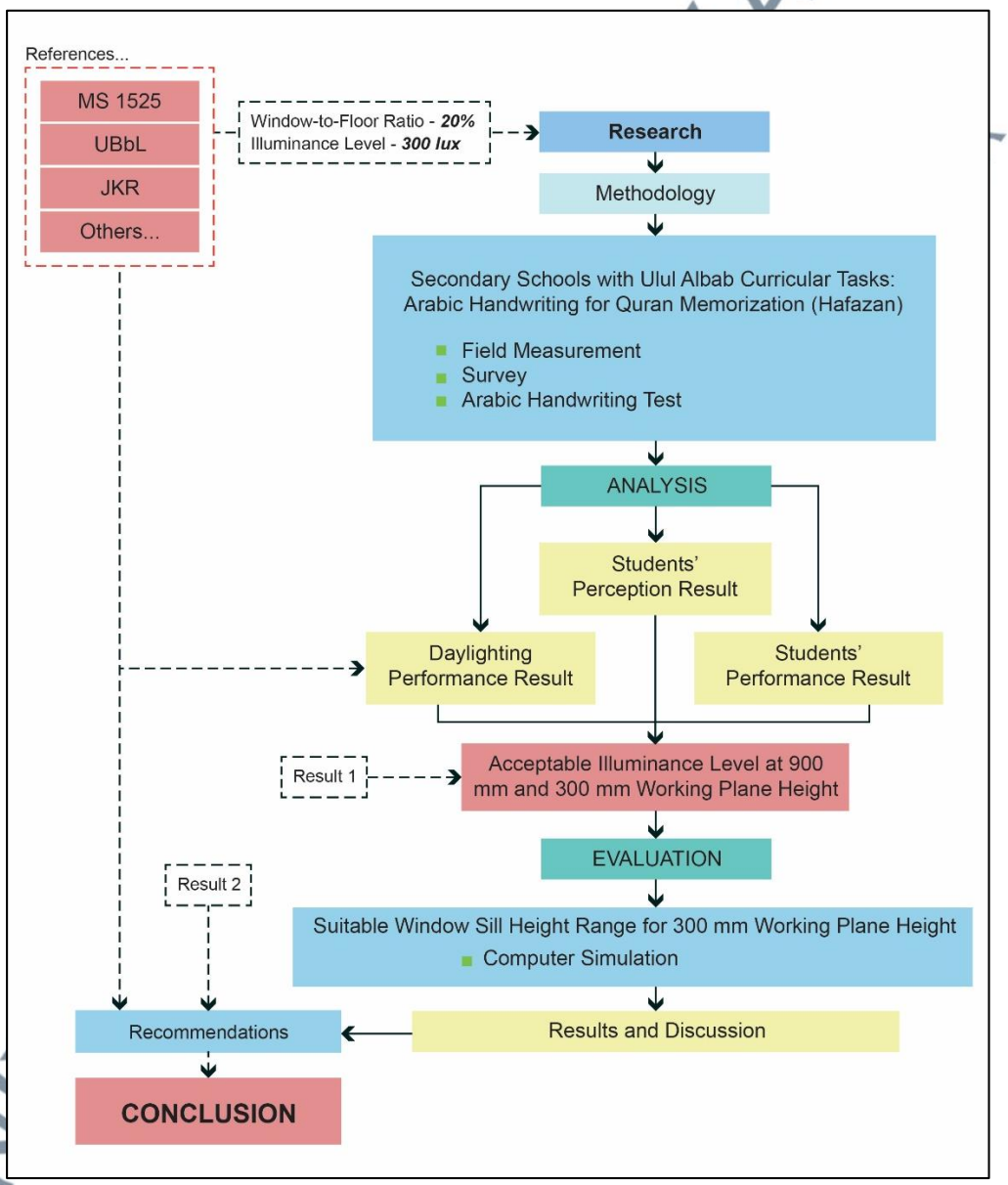


Figure 3.2: Methodology Flow

Figure 3.2 shows the methodology flow for the study. There are three experiments in the research that will contribute to the progress of the findings and results. The research

consists of three different experiments with different variables tested for each. The experiments are conducted to identify and clarify certain results and findings, which will be discussed further.

3.3.1 Experiment Field Measurement

The selected classroom is according to Malaysian standards and guidelines. Malaysian Standards and Cost Subcommittees have updated the Guidelines and Regulations for Building Planning (GRBP) in 2015, where the requirement is that each student needs 2.5 m2 of space in each classroom for boarding schools. The maximum number of students per classroom is 30, with the minimum floor area for the classroom is 75 m2. According to MS1525 and UBBL, the Window-to-Floor Ratio (WFR) for learning spaces is 20 per cent of the total area.

The first step in this experiment field measurement is to gather and measure related building and classrooms data such as length, width and height, colour of the walls, ceiling and floor (Megri 2014). The selected classroom for the research must follow these standards and guidelines. The classroom is located on the second level to avoid daylight obstruction from outside at the ground level.

The experiment of the research will be conducted between February to April and August to October. The most optimum selection is in March and September, where Malaysia is a tropical climate country with overcast sky conditions and the highest hourly illumination of exceeding 80,000 lx in March. The lowest illumination is in December with mean 60,000 lx (Zain-Ahmed, et al., 2002). The experiments are conducted in different months of the year. Experiment One has been conducted on 19 March 2017 for sessions one and two. The third session for the experiment is conducted on 23

September 2017. Experiment Two has been established from 15 to 16 September 2018. The final experiment is conducted from 20 to 21 April 2019.

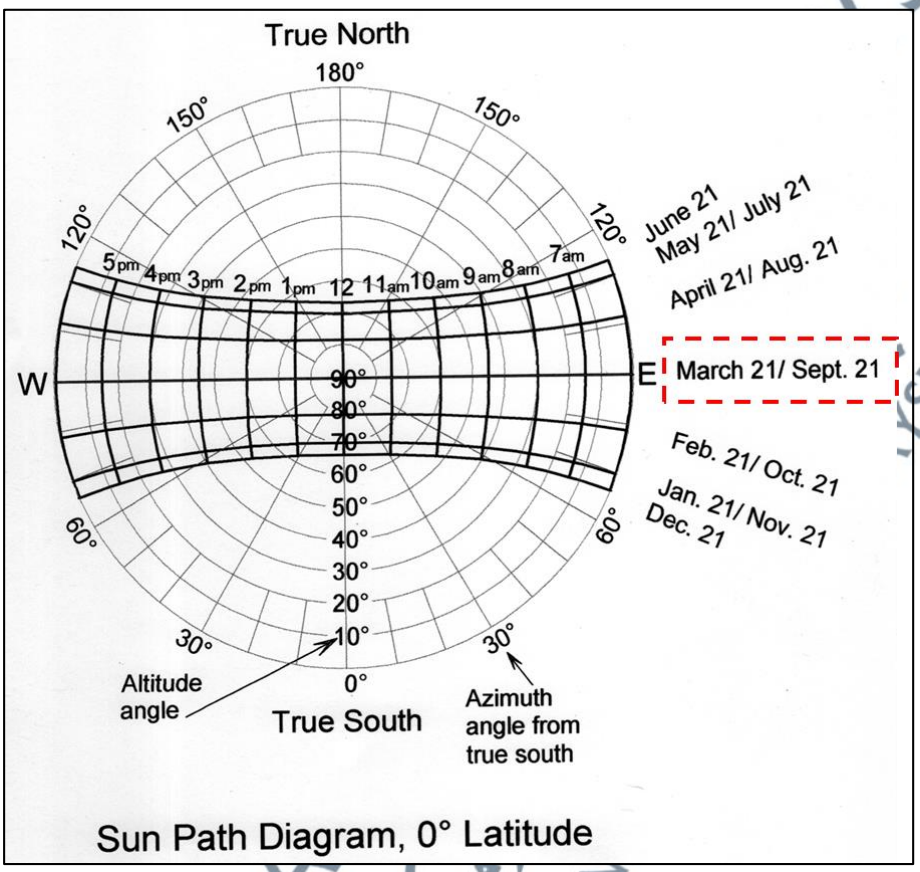


Figure 3.3: Stereographic Sun Path; Altitude Angle (www.harvestingrainwater.com)

Direct sunlight influence occupants due to low sun altitude in the space should be avoided. The suitable time range to avoid direct sunlight penetration, when minimum diffuse daylight is available in the space according to Nedhal et al. (2016) is between 10.00 am to 4.00 pm. Concerning the human circadian study by Adhikari (2014), it shows the human has the highest alertness around 10.00 am as well.

Therefore, the time selected to conduct the experiments for illuminance level is between 10.00 am to 11.00 am due to the high alertness of the respondents and minimum diffuse daylight availability during that time. Calibrated Amprobe LED Light Meter as shown in figure 3.4 are used in this research.

Figure 3.4: Amprobe LED Light Meter

The lux meter selected for the data collection has been calibrated with detector-based method in order to identify the range of absolute error and accuracy for each session. Figure 3.5 shows the lux meter calibration setup, where incandescent lightbulbs with 0.3 watts (50 lx), 0.6 watts (100 lx), 0.9 watts (150 lx), 1.2 watts (200 lx), 3 watts (500 lx) and 5.5 watts (900 lx) were used. The conversion formula for watts to lux referred was that the illuminance Ev in lux (lx) is equal to the power P in watts (W), times the luminous efficacy η in lumens per watt (lm/W) divided by the surface area A in square meters (m^2). The regression analysis using Statistical Package for Social Sciences (SPSS) for the lux meter calibration shows a high total variation of 99% explaining the correlation between the lux meter and illuminance level.

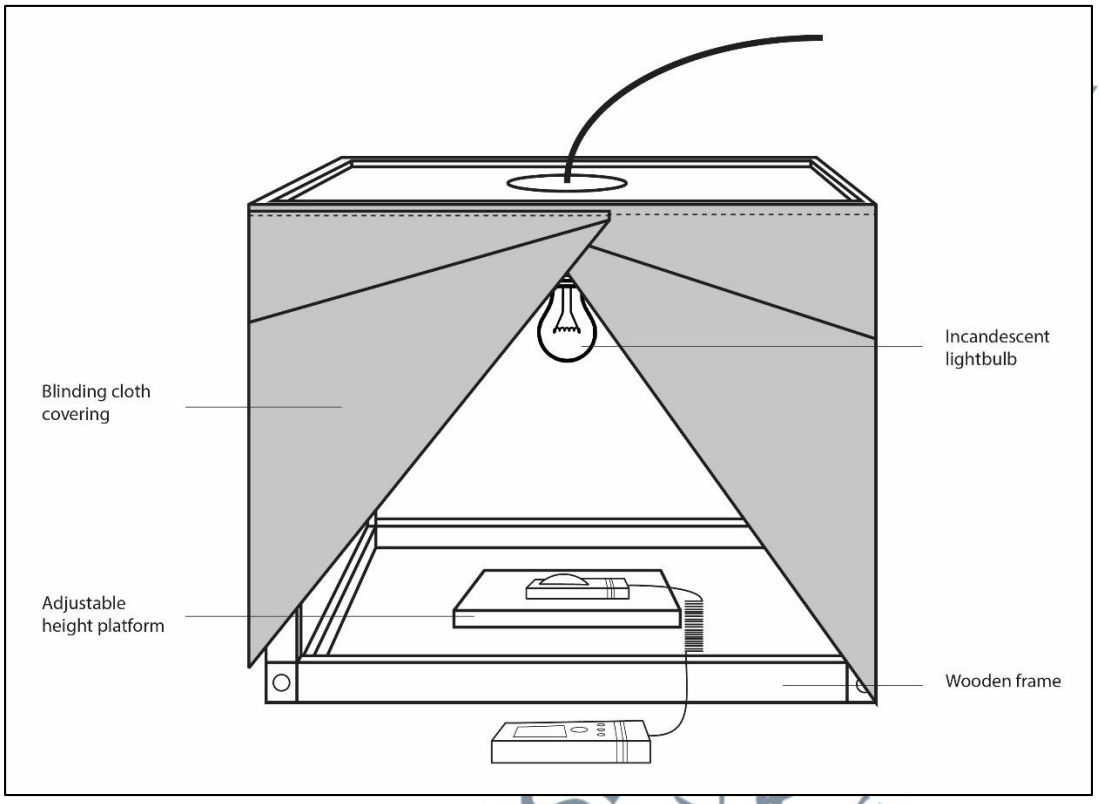


Figure 3.5: Amprobe LED Light Meter detector-based calibration

School and Classroom Selection

The selected classrooms in Kolej Genius Insan (previously known as Permata) located in Universiti Sains Islam Malaysia (USIM), Nilai as shown in figure 3.6. The school was selected reasons:

i. Secondary school with male and female students aged 13 to 17-year-old

ii. Classrooms design according to Malaysian standards and guidelines

iii. Implements *Ulul albab* education as teaching criteria in the curriculum

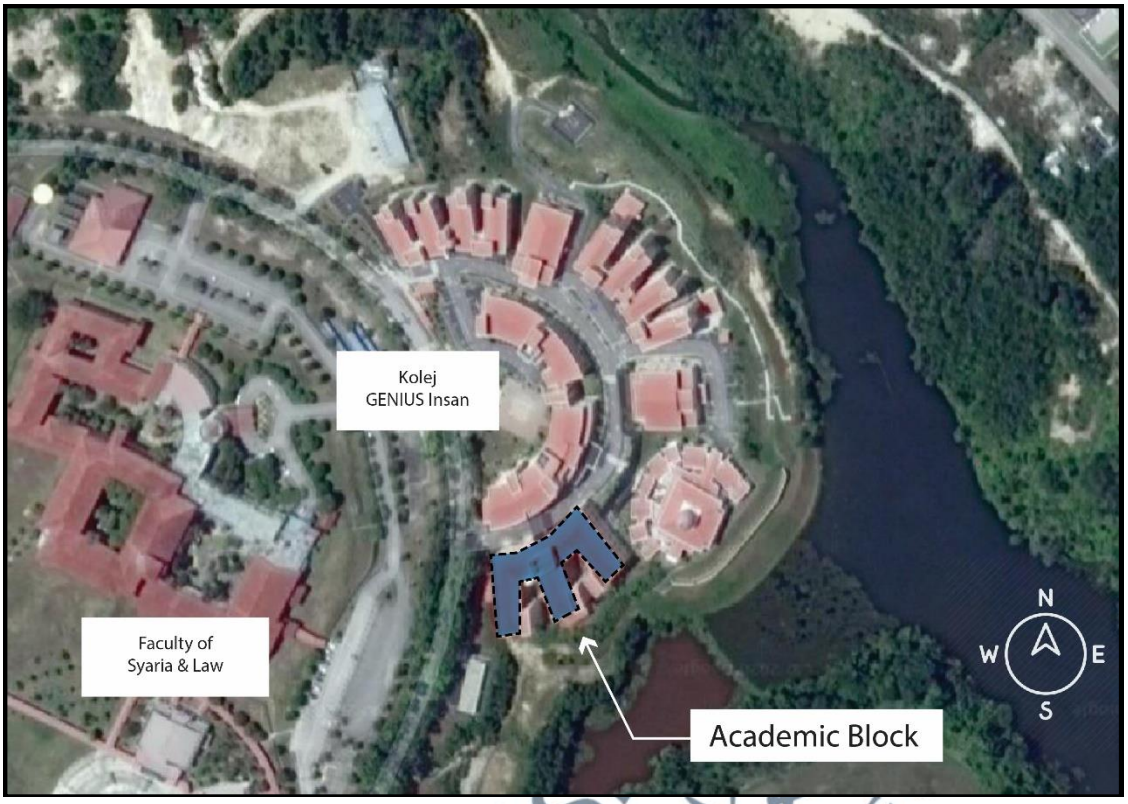


Figure 3.6: Kolej Genius Insan Site Plan

This secondary boarding school is operational since 2014 with more than 300 students currently enrolled. The school complex consists of a few buildings such as the administrative block, academic block, hostels, and mosque. The selected classrooms are located in the academic block on the second floor of the building. Figure 3.7 shows the second level layout plan of the building.

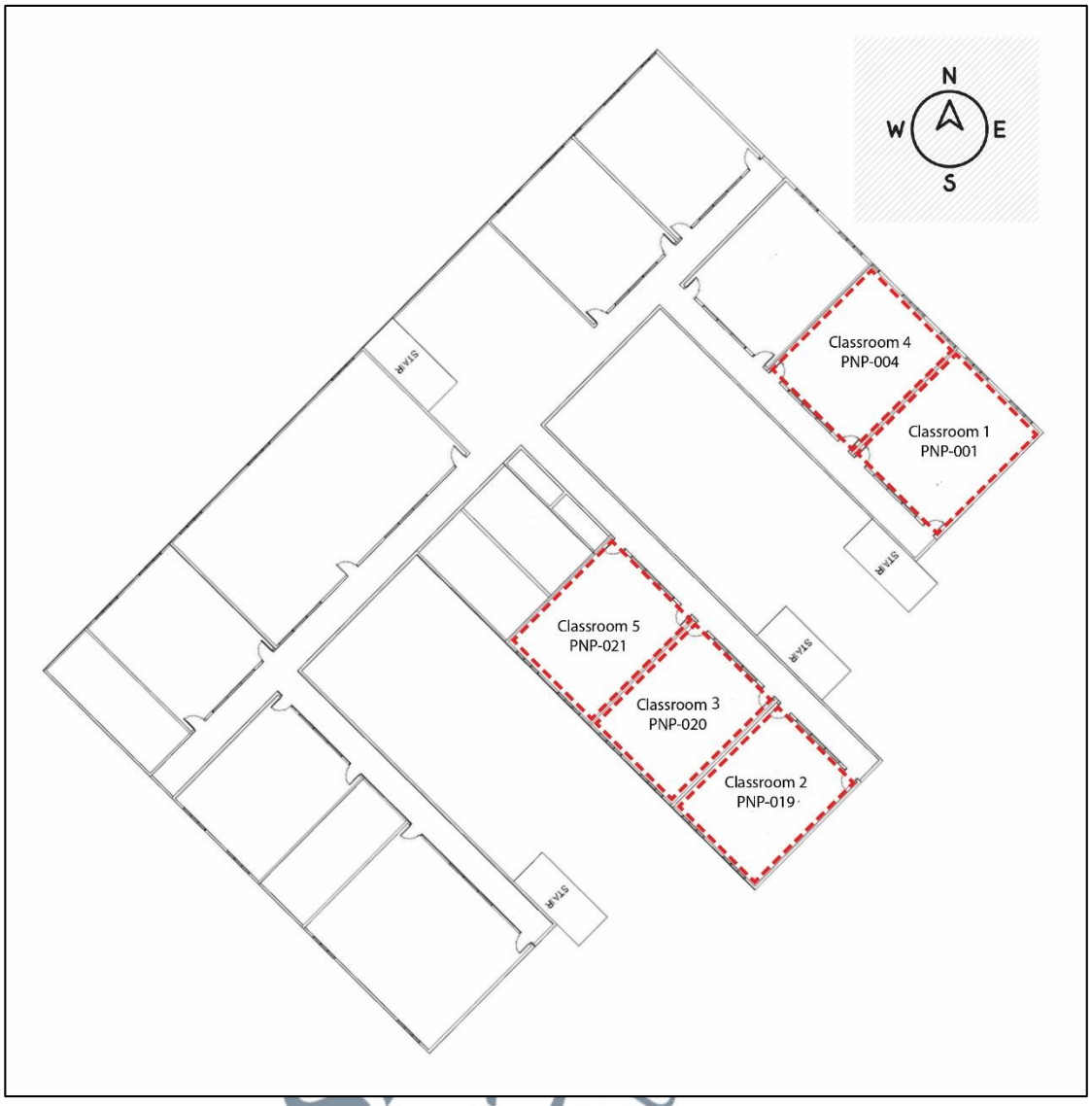


Figure 3.7: Kolej Genius Insan Second Level Floor Plan and Selected Classrooms

The classrooms selected uses similar surface finishes as public schools in Malaysia, where the surface reflectance for cement rendered ceiling is 0.7 (70%), darker cement rendered floor is 0.3 (30%) and white painted wall is 0.5 (50%), with window glazing at 0.81 (81%). Figure 3.8 shows the section of the academic block second floor, where the adjacent mosque is 7.3m apart from the selected classrooms.

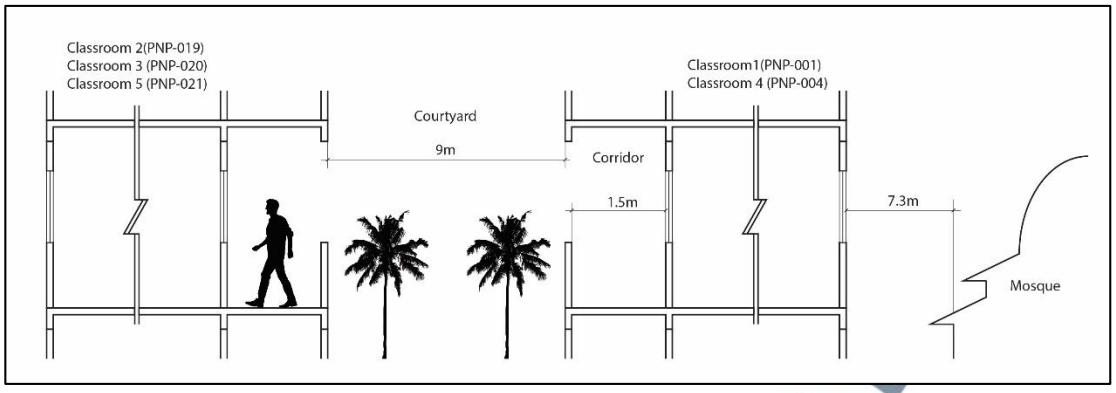


Figure 3.8: Kolej Genius Insan Second Level Section

Classroom Layout Measurement

Measuring the dimensions of the classrooms, laser distance meter measurement equipment was used. Figure 3.9 shows the laser distance meter Fluke 414D used in the experimental study. Additionally, Kennedy 50m/165ft. tape measurement is used to measure the dimensions of the windows and openings including the window sill height as shown in figure 3.9. The dimensions are sketched on white paper and then transferred into a digital format using AutoCAD 2013. The AutoCAD drawings will be further use for the next procedure of the research.

Figure 3.9: Laser Distance Meter Fluke 414D (left) and Kennedy 50 m/165 ft tape measurement (right)

The classrooms that are selected to conduct Experiment One and Two are located on the second floor of the academic block in Kolej Genius Insan. The selected classroom layout is similar in design and floor area of approximately 60 m^2 with 20 per cent WFR.

Experiment Three classrooms layout is designed specifically for *hafazan* education known as *Tasmi'* located in the school's mosque with a 300mm height window sill. There are a few other similar and constants variable on the classrooms selected such as:

i. Classrooms are on the second-floor level, to avoid external obstruction,

ii. Classrooms are used for *Ulul albab* and conventional education,

iii. Front of the classroom is designated for educational components such as whiteboard and teacher's desk,

iv. Back of the classrooms is designated for storage and compartment components such as bookshelves,

v. No external shadings and tinted glass window,

vi. Equipped with internal roller blinds, which will not be used,

vii. The total students in each classroom depends on the floor area, where each student is designated for 2.5m^2 floor area,

viii. The WFR of the classrooms are at 20 per cent,

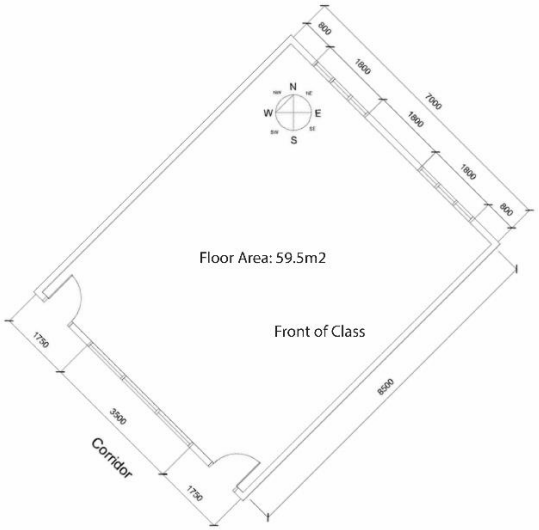
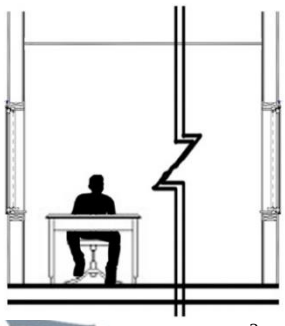
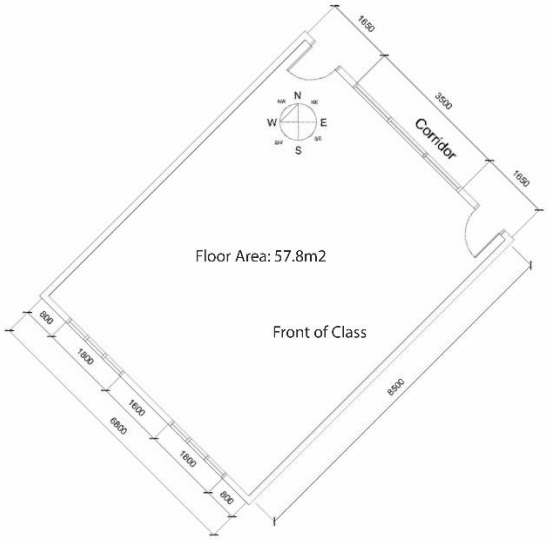
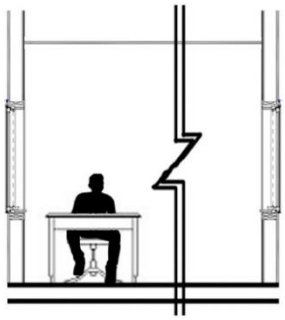
ix. The surface reflectance ceiling (70%), floor (30%) and wall (50%) are the same for every classroom,

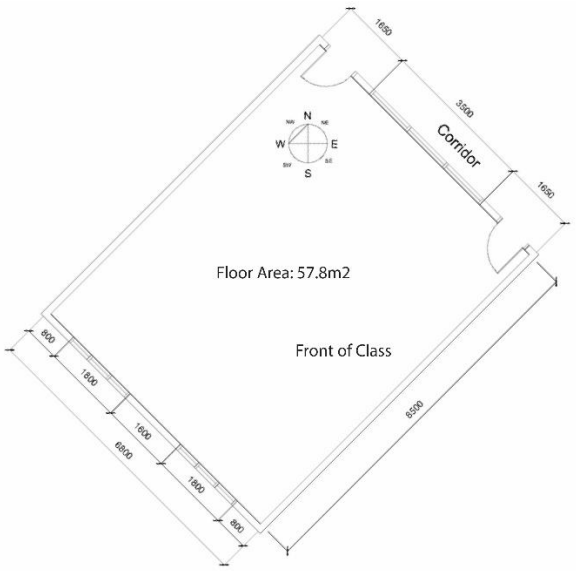
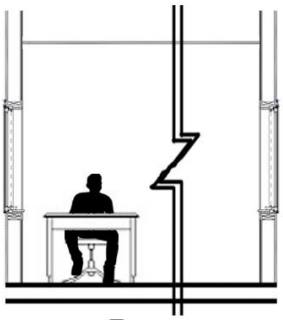
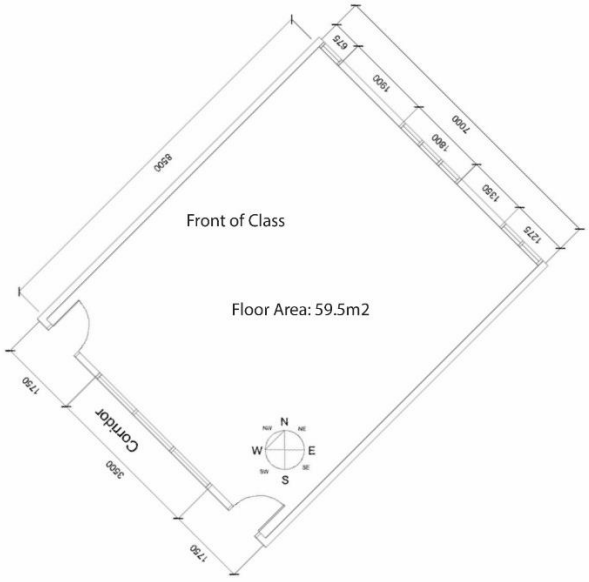
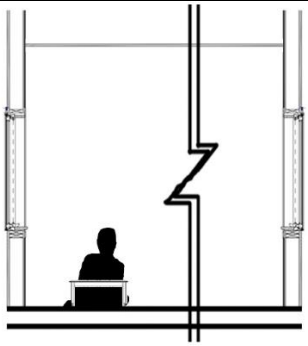
x. The window glazing transmittance (81%) are the same for every classroom,

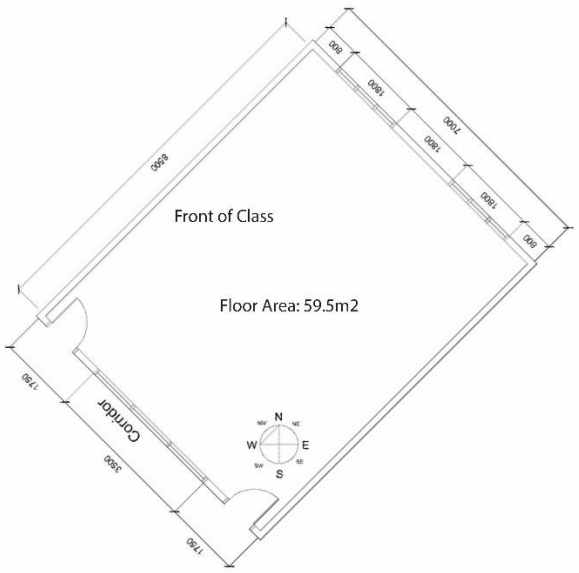
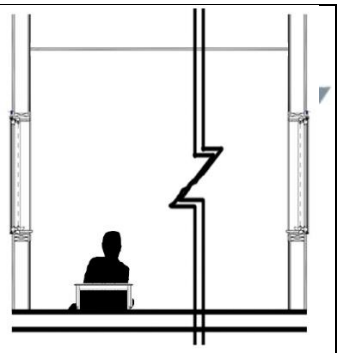
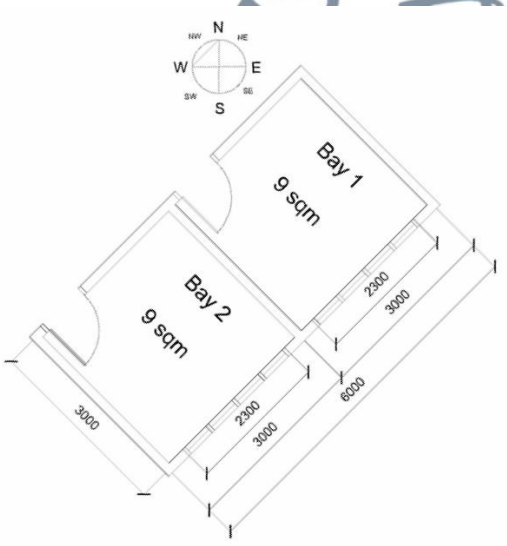
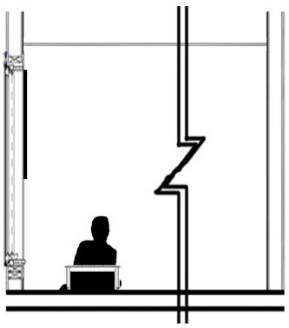
xi. Classrooms window sill height is 900mm and 300mm from floor level,

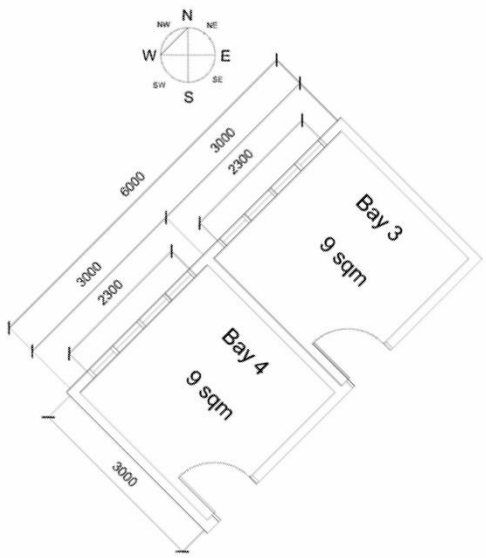
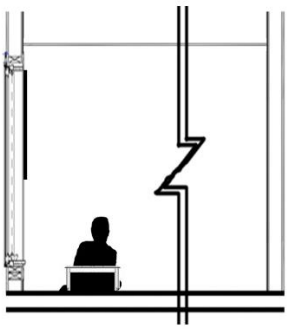
xii. The classroom height is 4 meters without ceiling installed.

Table 3.2: Classrooms for Experiments

Classroom Figure			Explanation
Experiment 1	Classroom 1		 Area: 59.5m^2 Orientation: southeast Glazing: northeast/ southwest Student pax: 24 student Window Sill: 900mm Working Plane: 900mm Window Head: 2.1m WFR: 20% Reflectance Floor: 0.3 (30%) Walls: 0.5 (50%) Ceiling: 0.7 (70%) Transmittance: 0.81(81%)
	Classroom 2		 Area: 57.8m^2 Orientation: southeast Glazing: northeast/ southwest Student pax: 24 student Window Sill: 900mm Working Plane: 900mm Window Head: 2.1m WFR: 20% Reflectance Floor: 0.3 (30%) Walls: 0.5 (50%) Ceiling: 0.7 (70%) Transmittance: 0.81(81%)

Experiment 2	Classroom 3		 Area: 57.8m^2 Orientation: southeast Glazing: northeast/ southwest Student pax: 24 student Window Sill: 900mm Working Plane: 900mm Window Head: 2.1m WFR: 20% Reflectance Floor: 0.3 (30%) Walls: 0.5 (50%) Ceiling: 0.7 (70%) Transmittance: 0.81(81%)
	Classroom 4		 Area: 59.5m^2 Orientation: northwest Glazing: northeast/ southwest Student pax: 24 student Window Sill: 900mm Working Plane: 300mm Window Head: 2.1m WFR: 20% Reflectance Floor: 0.3 (30%) Walls: 0.5 (50%) Ceiling: 0.7 (70%) Transmittance: 0.81(81%)

Experiment 3	Classroom 5		 Area: 59.5m^2 Orientation: northwest Glazing: northeast/ southwest Student pax: 24 student Window Sill: 900mm Working Plane: 300mm Window Head: 2.1m WFR: 20% Reflectance Floor: 0.3 (30%) Walls: 0.5 (50%) Ceiling: 0.7 (70%) Transmittance: 0.81(81%)
	*Tasmi'*Classroom 1		 Area: 18m^2 Orientation: northeast Glazing: southeast Student pax: 6 student Window Sill: 300mm Working Plane: 300mm Window Head: 2.1m WFR: 20% Reflectance Floor: 0.3 (30%) Walls: 0.5 (50%) Ceiling: 0.7 (70%) Transmittance: 0.81(81%)

	*Tasmi'*Classroom 2		 Area: 18m^2 Orientation: northeast Glazing: northwest Student pax: 6 student Window Sill: 300mm Working Plane: 300mm Window Head: 2.1m WFR: 20% Reflectance Floor: 0.3 (30%) Walls: 0.5 (50%) Ceiling: 0.7 (70%) Transmittance: 0.81(81%)

Classroom 1 – The first classroom selected is PNP-A2-001. It is located 7.3 meters away from the school's mosque.

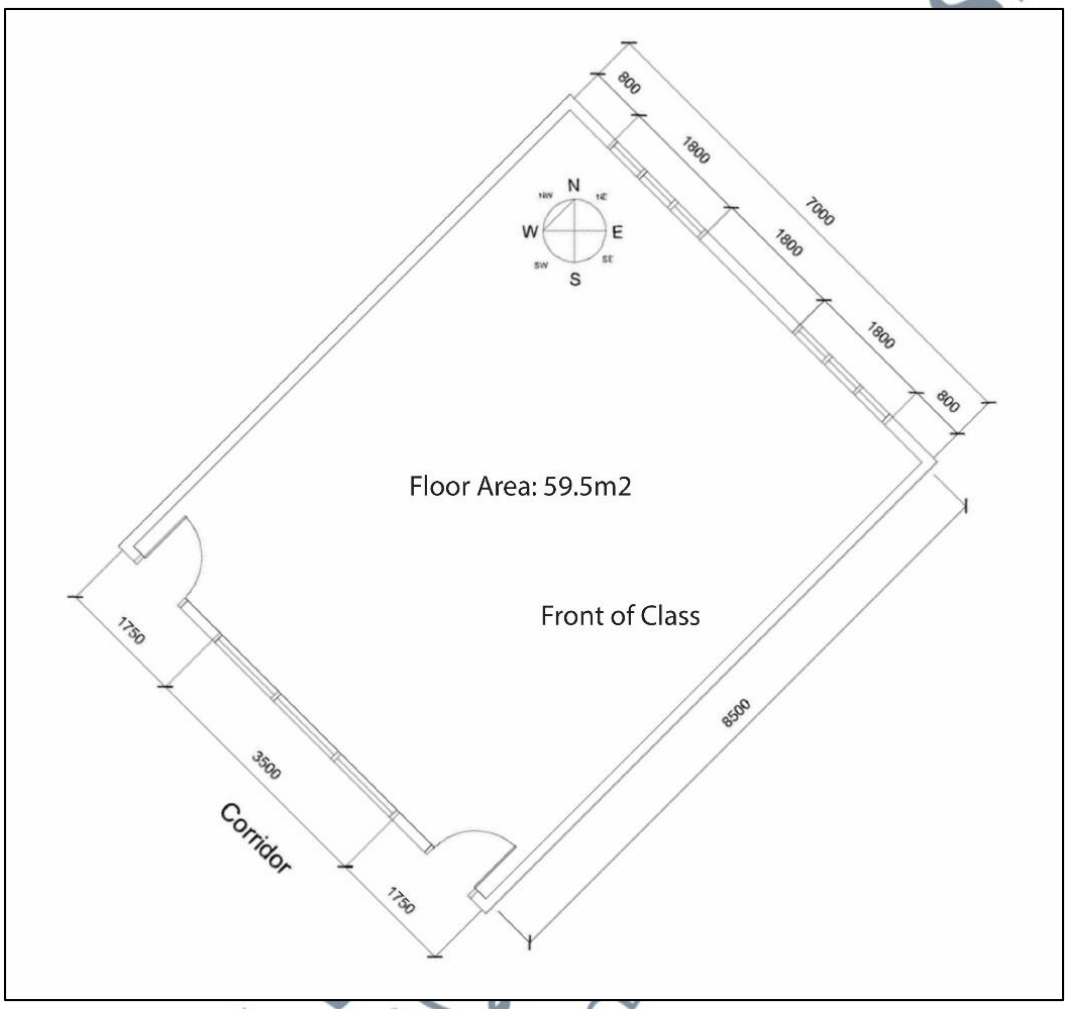


Figure 3.10: Plan 1; Classroom 1

Figure 3.10 shows the floor plan of the classroom with floor area 59.5m^2. Classroom 1 layout consists of windows on both sides of the classroom with two doors on the right side as shown in figure 3.10. The orientation of the classroom is southeast, where the windows are facing northeast and southwest. The corridor is on the southwest of the classroom.

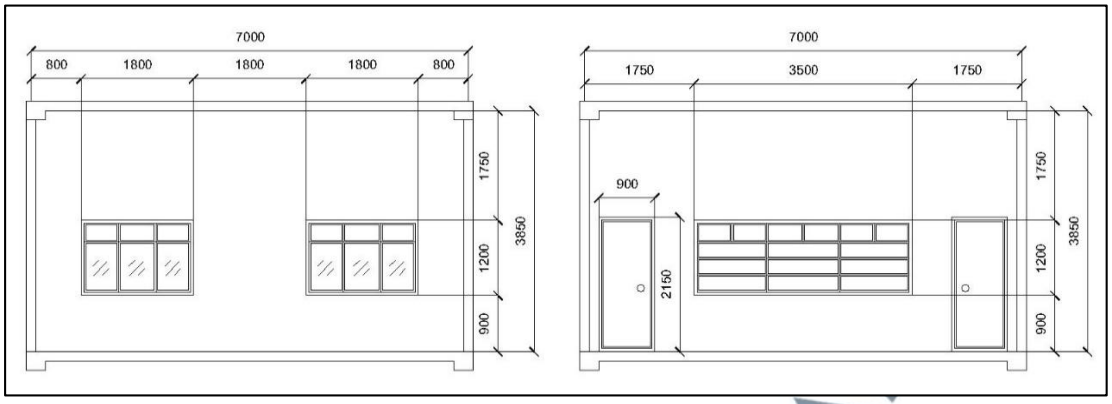


Figure 3.11: Classroom 1 Left and Right Elevation

Figure 3.11 shows both the right and left elevation of the classroom. The front and back of the classroom are solid walls. The total windows and openings Window-to-Floor Ratio (WFR) on the both side of the classroom 20 per cent following the recommended Malaysian Public Works Department (JKR) standard. The window sill height for windows on both sides is 900mm from floor level, where the window head height is 2.1m from floor level with depth ratio of 4 times more than the head height. The height of the classroom is 4 meters from floor finishes without a ceiling installed.

Classroom 2 – Classroom 2 is PNP-A2-019. It is also the opposite wing to Classroom 1. The floor plan and floor of the classroom are similar to Classroom 1.

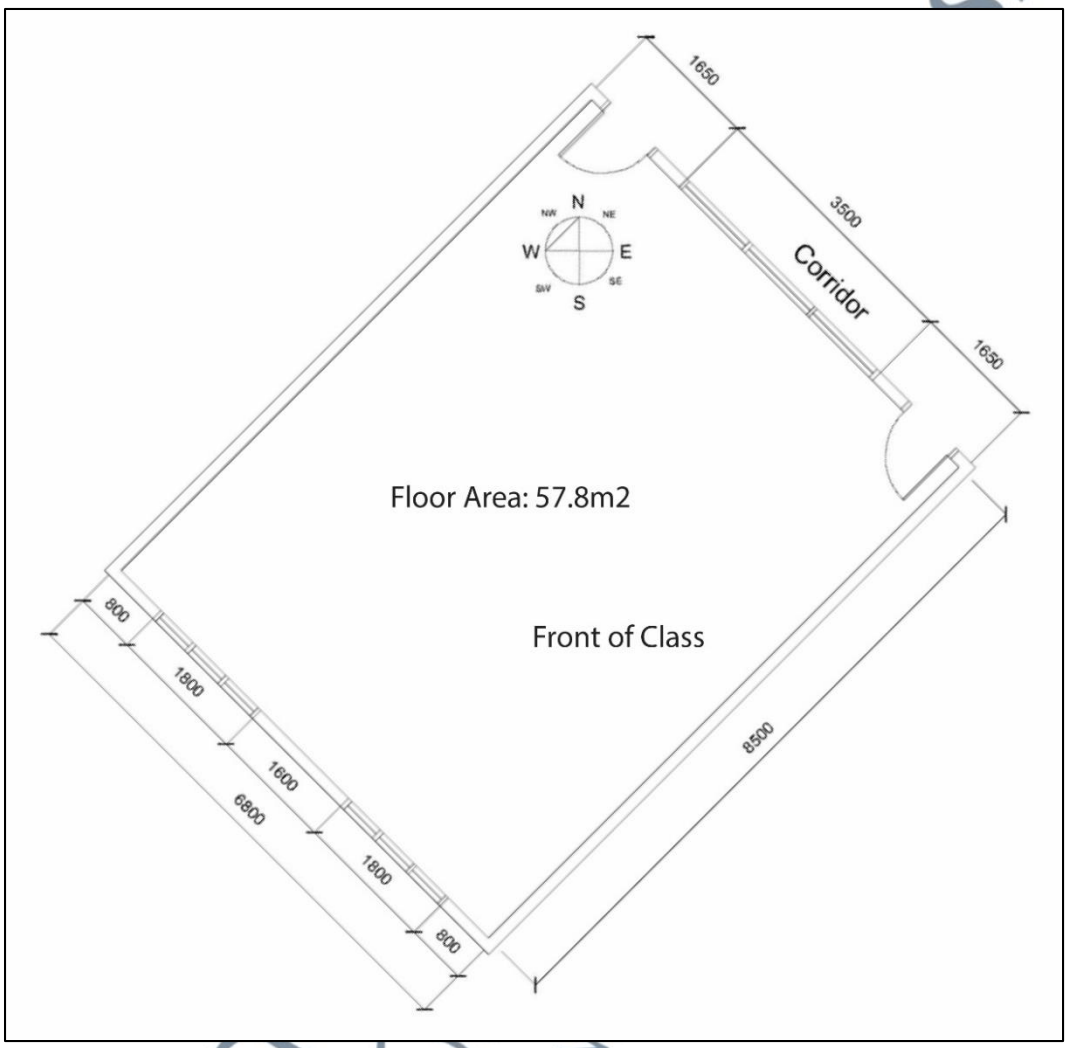


Figure 3.12: Classroom 2 Floor Plan

The layout of Classroom 2 as shown in Figure 3.12 have a different location of doors and windows compared to Classroom 1. Two exit doors located on the left side of the classroom, where windows are on both sides of the classroom facing northeast and southwest. The floor area of the classroom is 57.8 m2 with the orientation facing southeast, where the corridor is on the northeast of the classroom.

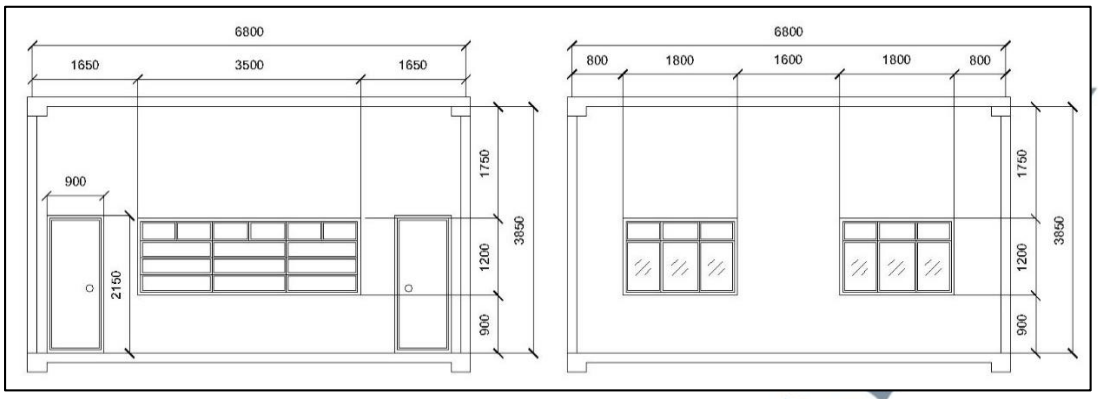


Figure 3.13: Classroom 2 Left and Right Elevation

Figure 3.13 shows both the right and left elevation of Classroom 2. The classroom's windows and openings Window to Floor Ratio (WFR) is 20 per cent as recommended by JKR standards. All the window sill height of the classroom is 900mm from floor level. The depth ratio is four times the window head height of 2.1m. The height of the classroom is 4 meters without a ceiling.

Classroom 3 – Classroom 3 selected for the experiment is PNP-A2-021. It is located on the academic block.

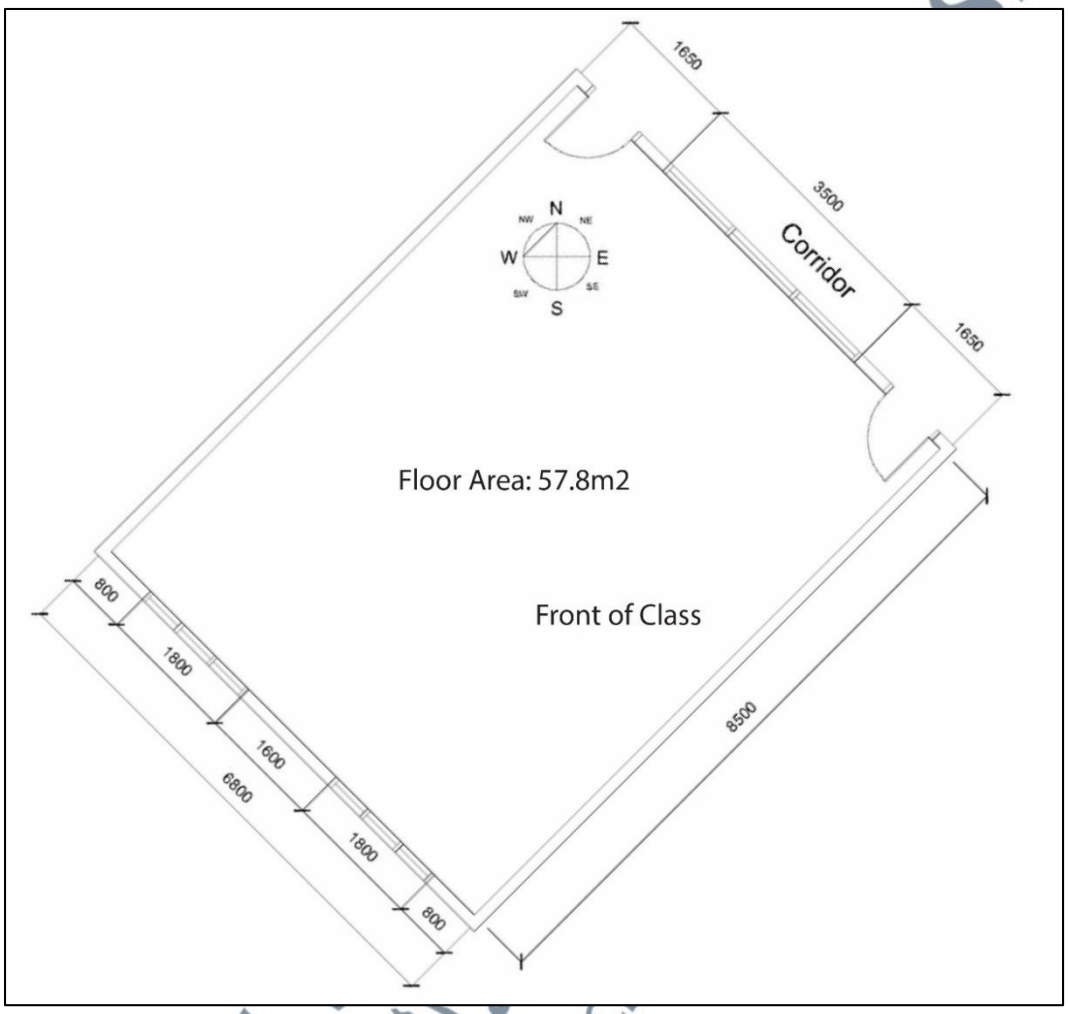


Figure 3.14: Classroom 3 Floor Plan

The layout of Classroom 3 is shown in figure 3.14. Classroom 3 has a similar location of doors and windows with Classroom 2. The floor area and orientation of the classroom, glazing and corridor are also similar to Classroom 2.

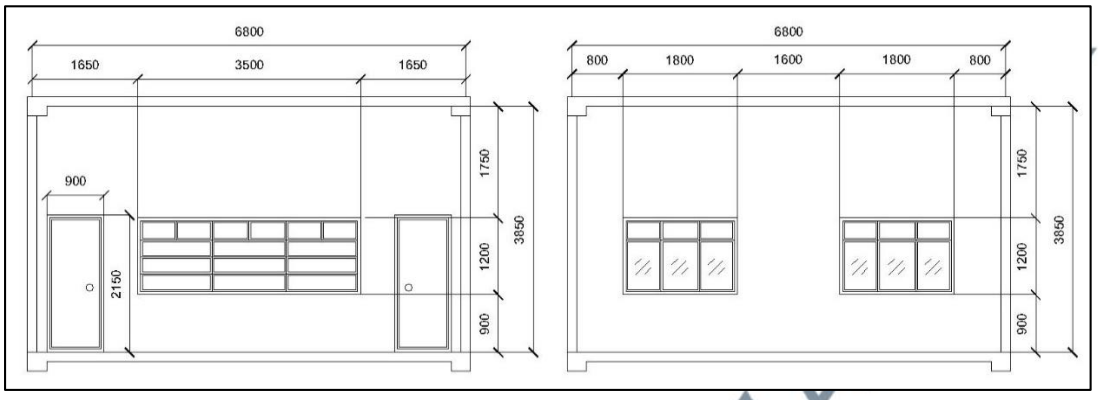


Figure 3.15: Classroom 3 Left and Right Elevation

Figure 3.15 shows both the right and left elevation of the selected classroom. The windows and openings of the class are 20 per cent of rooms Window to Floor Ratio (WFR) as recommended by guidelines and standards. The window sill height of the classroom on both sides is 900mm from floor level. The depth ratio is similar with previous classrooms, which is 4 times longer than 2.1m of window head height. The height of the classroom is 4 meters without a suspended ceiling installed.

Classroom 4 – Classroom PNP-A2-004 located on the second-floor level is selected for Classroom 4.

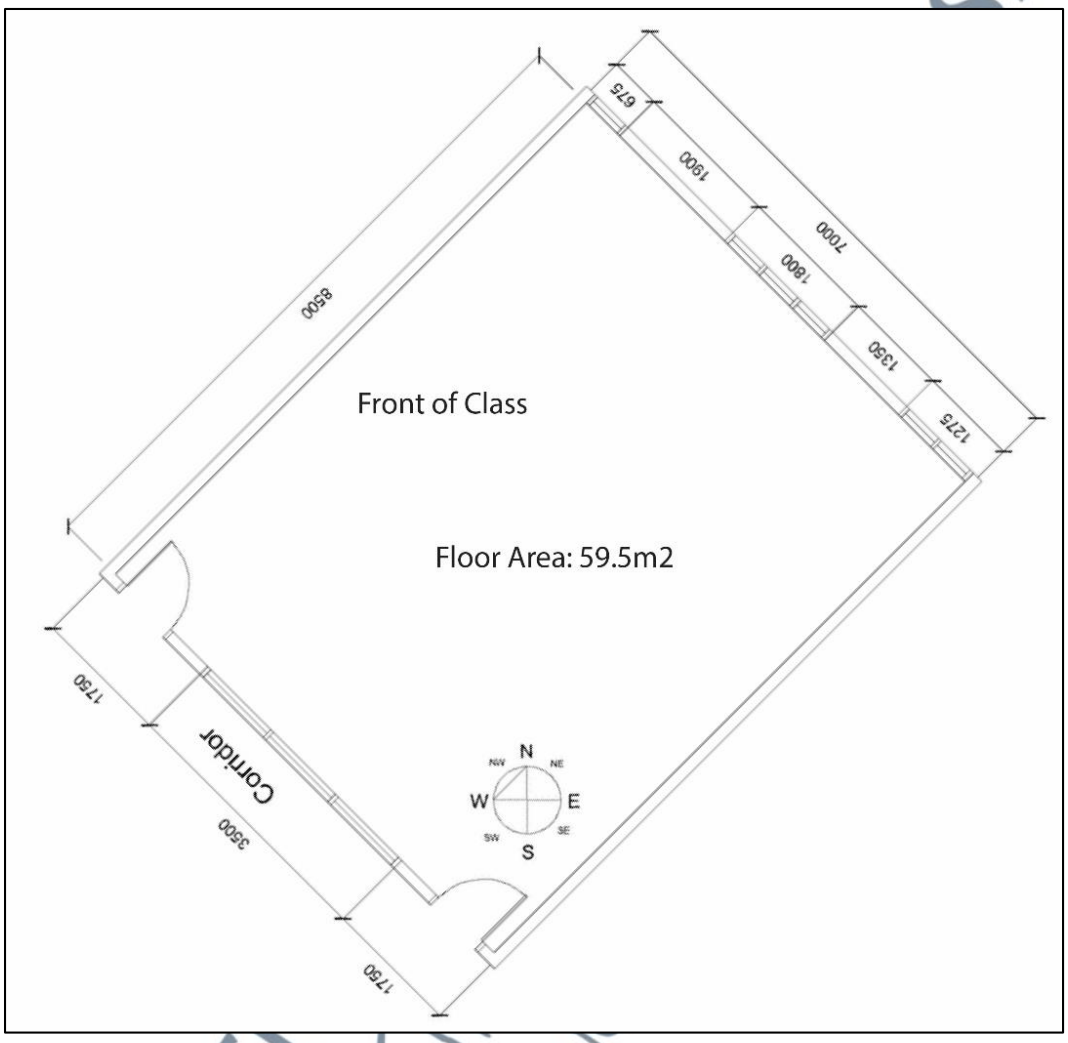


Figure 3.16: Classroom 4 Floor Plan

Figure 3.16 shows the floor plan and area of 59.5m^2 for Classroom 4. Both sides of the walls consist of windows and openings, where two exit doors are located on the left side of the classroom. The classroom is facing northwest, where the glazing is facing northeast and southwest. Corridor is on the southwest of the classroom.

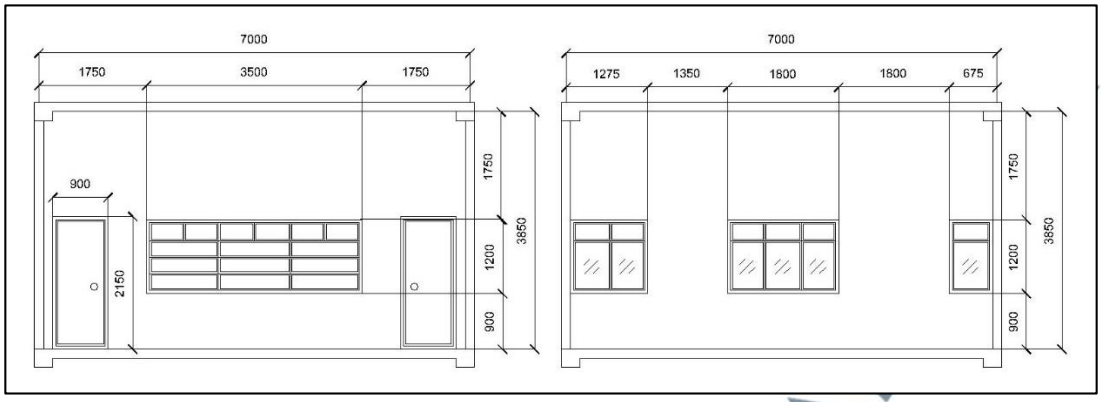


Figure 3.17: Classroom 4 Left and Right Elevation

The left and right elevation of Classroom 4 is as shown in figure 3.17. Although the window design is different compared to other selected classrooms, the WFR of the classroom still approximately follows the recommended 20 per cent. The height of the window sill is still constant at 900mm from floor level. The classroom has the same value of 2.1m window head height and depth ratio of 4 as the previous classrooms. Similarly, the classroom height is 4 meters without any ceiling finishes.

Classroom 5 – The fifth classroom that has been selected for the experiment is PNP-A2-006.

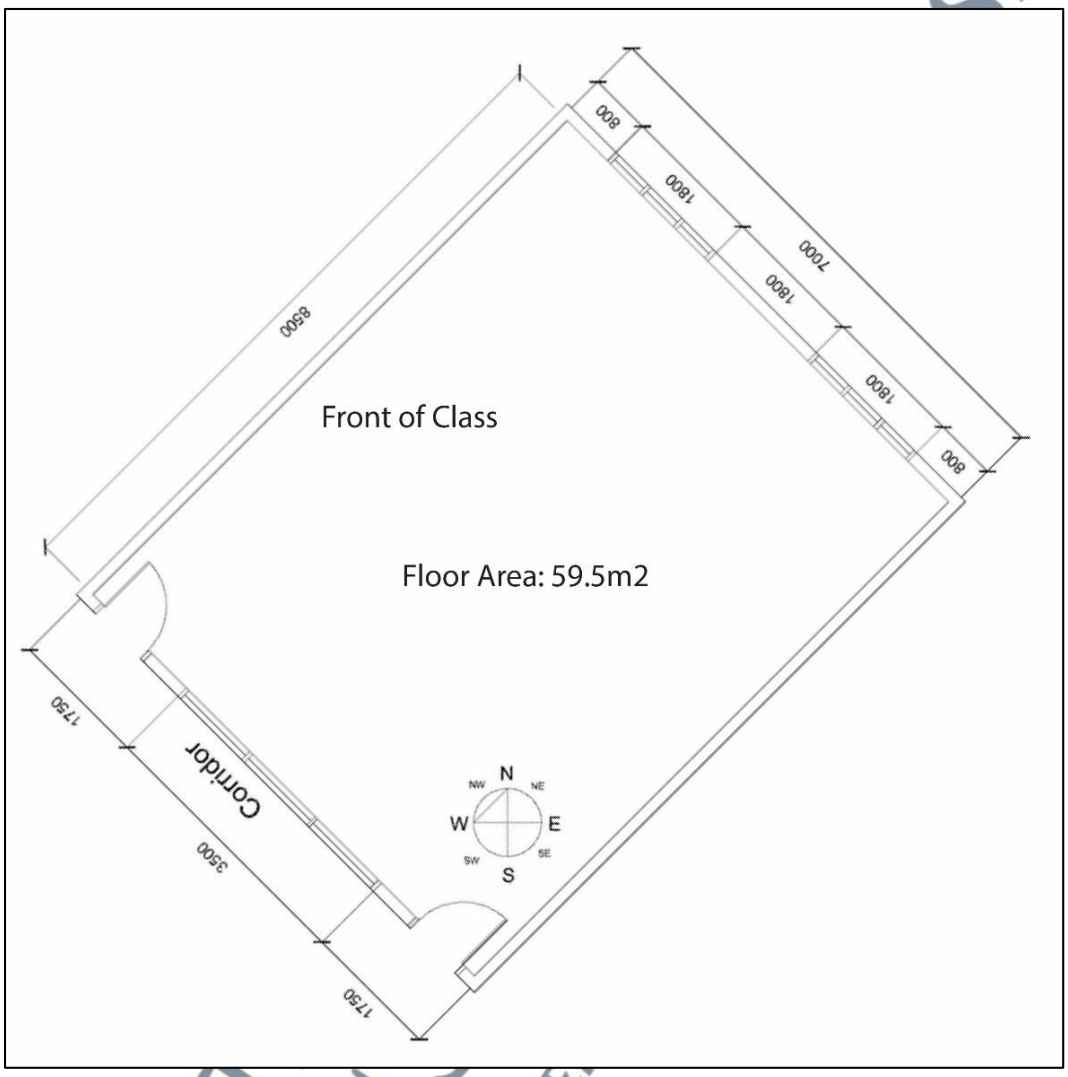


Figure 3.18: Classroom 5 Floor Plan

Similarly, the classroom is located at the academic block on the second-floor level. The layout for the classroom is shown in figure 3.18. The right and left side of the classroom has windows and openings that follow the required 20 per cent as recommended by standards and guidelines. The classroom is facing northwest, where the glazing of the classroom is facing northeast and southwest. The corridor is on southwest of the classroom.

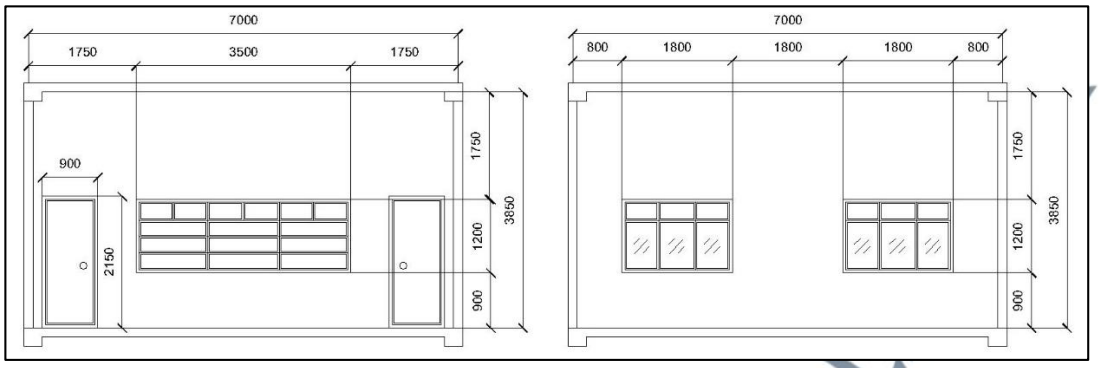


Figure 3.19: Classroom 5 Left and Right Elevation

Figure 3.19 shows the left and right elevation if Classroom 5. The WFR of this classroom constantly 20 per cent, similar to all previously selected classrooms. Both sides of the classrooms consist of a casement window at 900mm sill height and 2.1m window head height, with depth ratio of 4 times more than the window head height 4-meter height of the classroom is without any ceiling.

Classroom *Tasmi'* 1 – The first *Tasmi'* classroom selected have parameter differences with the previous experiments. The layout of the classrooms is 70 per cent smaller compared to Experiments 1 and 2, where the classroom is used specifically for *hafazan* education. The classrooms are located in the school's mosque, detached from the main praying hall. There are four classrooms located on the front and back of the mosque. Each classroom has two bays with a floor area of $9m^2$ each as shown in figure 3.20. Since the classroom layout is significantly smaller, each bay can only accommodate three students based on the recommended ratio.

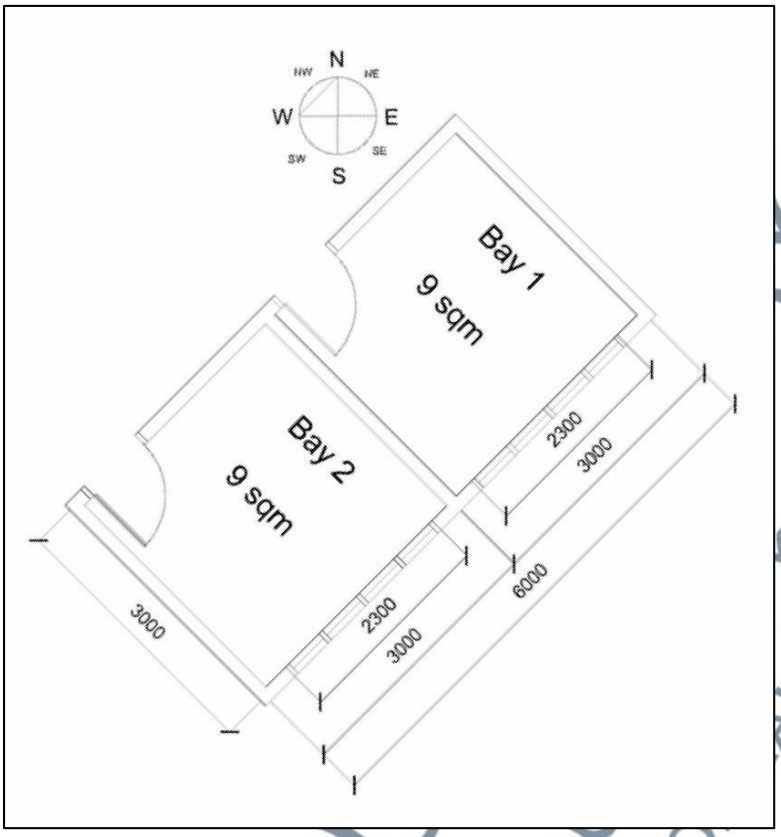


Figure 3.20: Classroom *Tasmi'* 1 Floor Plan

Each bay is separated from the drywall and has one exit door each on the left side of the classroom. The window of the classroom is located on the right side of the classroom with no external and internal shading device. The glass is also not film tinted as previous experiments. The classroom is facing towards the northeast, where the glazing is only on the southeast of the classroom.

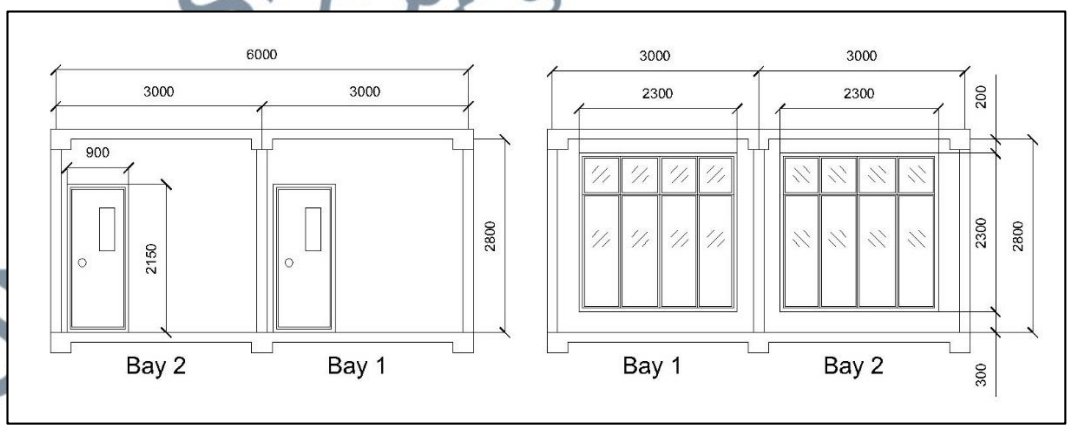


Figure 3.21: Classroom *Tasmi'* 1 Left and Right Elevation

The right elevation of the classroom consists of a tall casement window as shown in figure 3.21. The classroom height is 2.8m^2 from the floor finish. The window sill height is low at 300mm from floor level. This window sill height is a similar working plane height of a *rehal* with window head height at 2.6m. The depth ratio is 1.15 times the window head height. The WFR of the classroom is too high at approximately 59 per cent. Thus, an adjustment will be done to control the WFR value as recommended in the standards and guidelines.

Classroom *Tasmi'* 2 – The second *Tasmi'* classroom has the same parameter with the previous *Tasmi'* classroom. The classroom selected is also used specifically for *hafazan* education. Mirrored to Classroom *Tasmi'* 1, the classroom is located on the opposite side of the mosque. Figure 3.22 shows that three students can be seated in the classroom based on the recommended ratio.

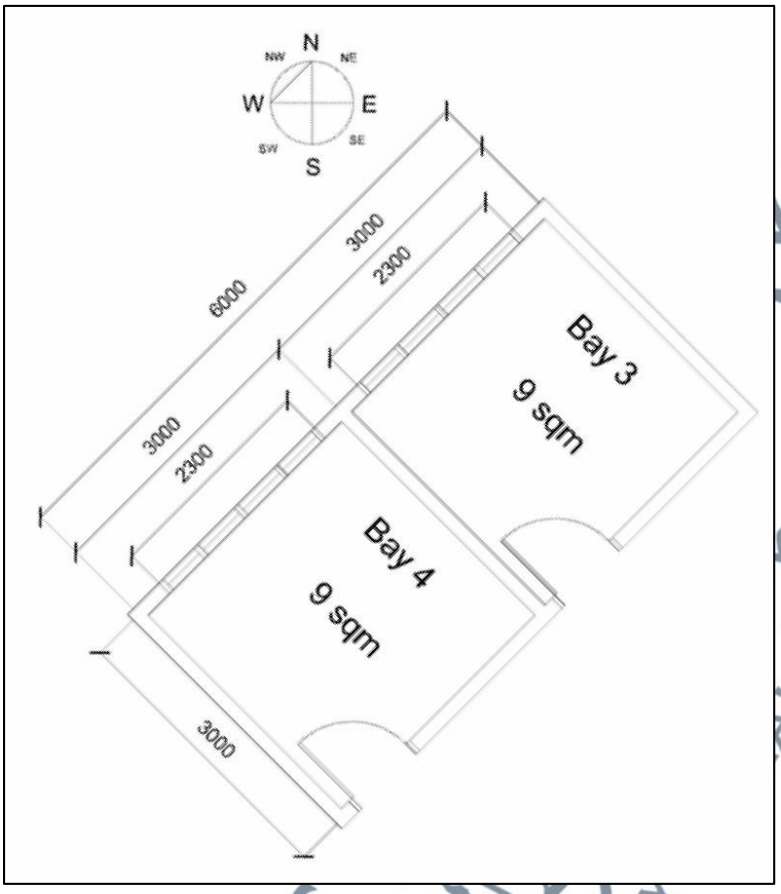


Figure 3.22: Classroom *Tasmi'* 2 Floor Plan

Similarly, each bay is separated from drywall with one exit door for each classroom on the right side. The window of the classroom is located on the left side of the classroom with no external and internal shading device as well. The classroom is facing towards the northeast. The glazing is only on the northwest of the classroom.

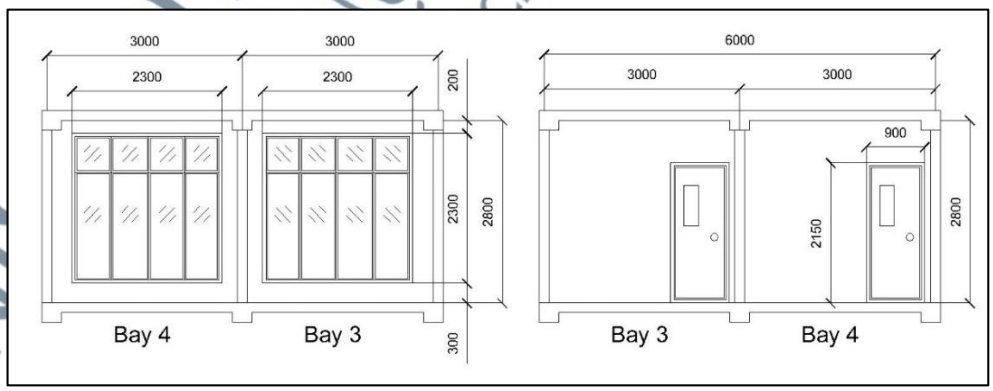


Figure 3.23: Classroom *Tasmi'* 2 Left and Right Elevation

The right and left elevation of the classroom in figure 3.23 shows that the classroom height, window sill height, and the WFR are the same classroom *Tasmi'* 1. The window head height is 2.6m, while the depth ratio is 1.15 times the window head height. Both *Tasmi'* classroom has 59 per cent WFR, which is higher than recommended. Thus, to keep the WFR constant as recommended for all experiments, the window size will be controlled by covering a part of it with a solid material to avoid any daylight penetration.

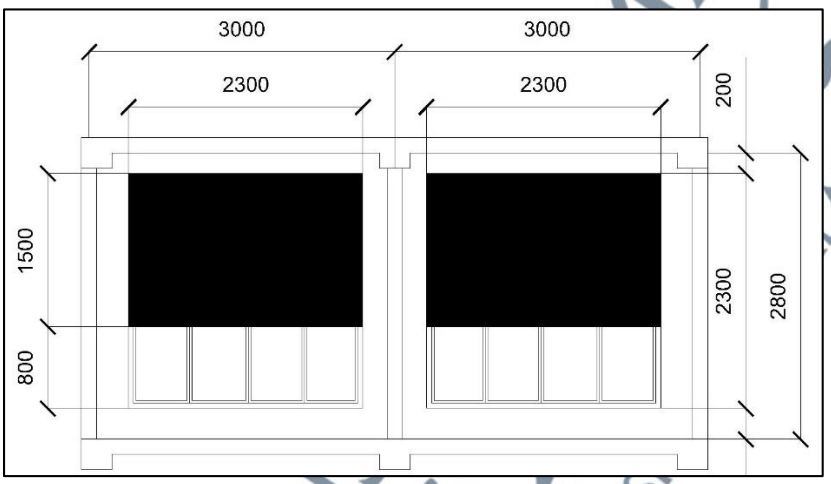


Figure 3.24: Classroom *Tasmi'* 1 and 2 Elevation with 20 per cent WFR

The WFR of the classrooms will be adjusted and controlled to 20 per cent of the current WFR of 59 per cent. The window sill height is still kept at the same level as shown in figure 3.24. The higher part of the window will be covered with a black solid blind material at 800mm from the window sill level, where it reduces the window head height to 1.1m. This also causes the depth ratio increased to 2.5 more than window head height. The 2.3m x 1.5m blind material will cover one-third of the window, leaving the window WFR at 20 per cent.

Data Collection and Classroom Setup

The classrooms selected for the first two experiments have the same constant variables which are the Window-to-Floor Ratio (WFR) of 20 per cent at a constant sill

height of 800mm to 900mm and floor area suitable for 24 students. The first experiment will be tested using a typical table for classrooms, meanwhile, the second experiment uses *rehal*. The third experiment uses a different window sill height of 300mm and uses *rehal* during the data collection. Figure 3.25 shows the students' seating position for every three experiments.

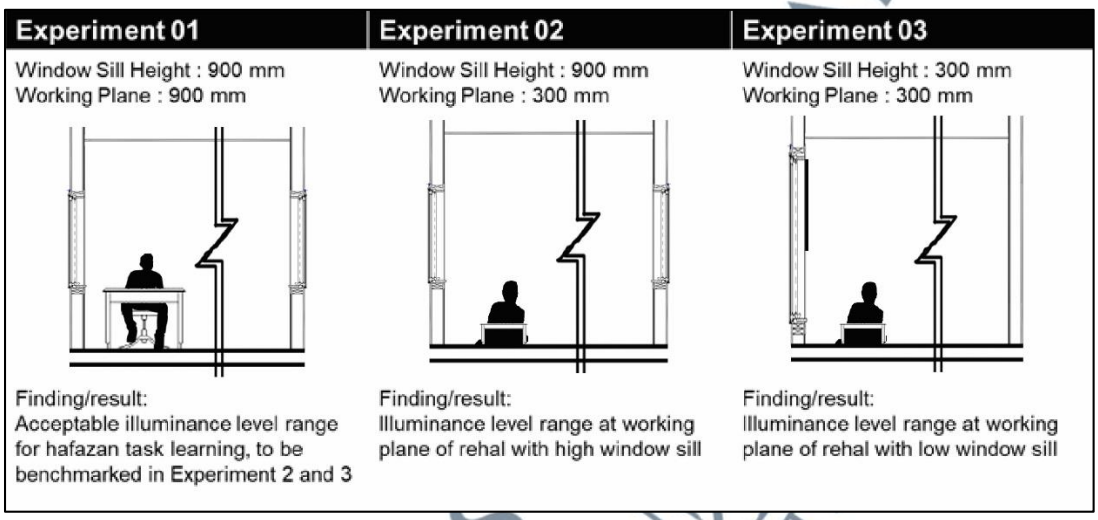


Figure 3.25: Students' Seating Position.

Classrooms for Experiment 1 floor area is approximately 60m^2. Since that GRBP stated that the floor area per student ratio is 2.5m^2 per student, these classrooms will be seated 24 selected students as respondents of the research. The students' seating is arranged in three rows with eight students for each row, where the table working plane height is 900mm. The students in each session for Experiment 1 are arranged as shown in figure 3.26.

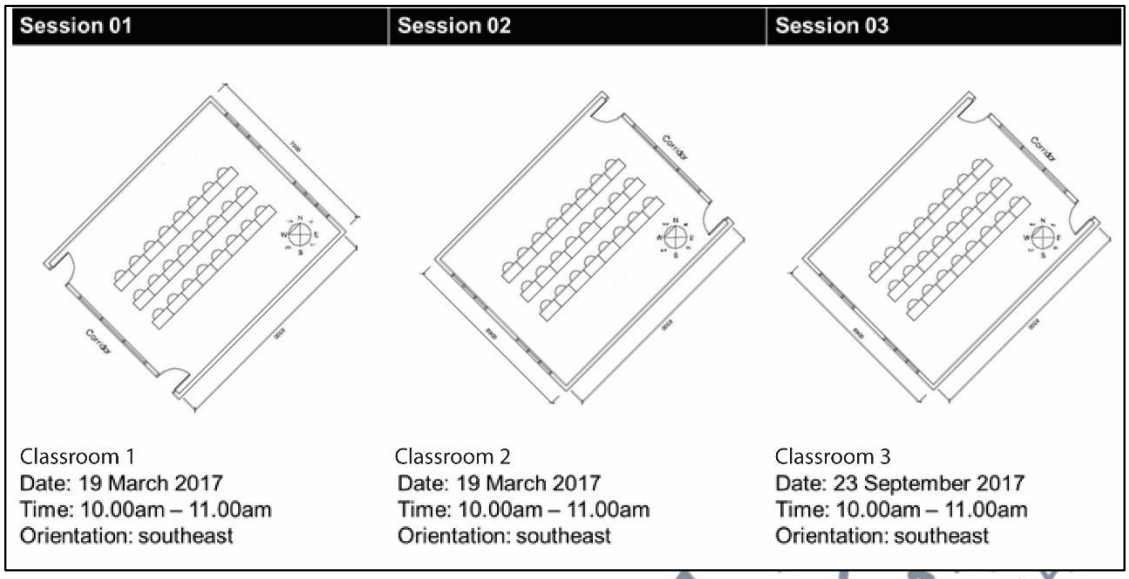


Figure 3.26: Experiment One Students Seating Arrangement

Session One and Two are conducted on 19 March 2017 between 10.00 am to 11.00 am simultaneously in Classroom One and Two respectively. The third session is conducted on 23 September 2019 at the same time of 10.00 am to 11.00 am as session one and two. The time selected is the most suitable time to test the students' performance due to their high alertness and optimum daylight availability during that period. The table used for Experiment 1 is at 900mm working plane height and is arranged as shown in figure 3.27.

Figure 3.27: Students' Seating Arrangement in Experiment 1

Classrooms for Experiment 2 floor area is approximately 60m^2, similarly with Experiment 1. Since that GRBP stated that the floor area per student ratio is 2.5m^2 per student, these classrooms will be seated 24 selected students as respondents of the research. The students' seating is arranged in three rows with eight students for each row. The students in each session for Experiment 2 are arranged as shown in figure 3.28. The working plane height of the *rehal* used in Experiment 2 is 300mm.

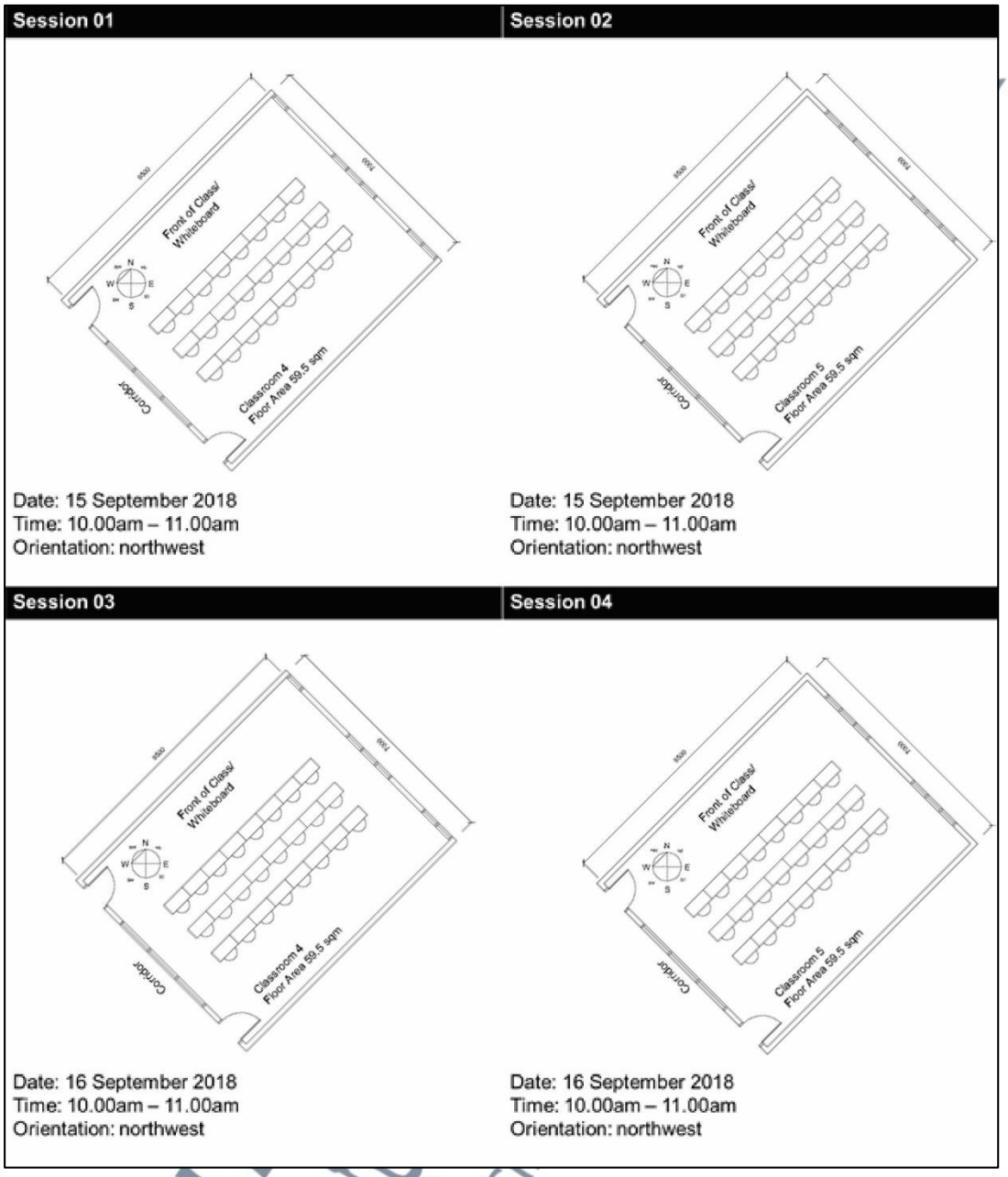


Figure 3.28: Experiment Two Students Seating Arrangement

The same classrooms are used at a different date for Experiment Two. Session One and Two are conducted on 15 September 2018 between 10.00 am to 11.00 am simultaneously in Classroom Four and Five respectively. The third and fourth session is conducted on 16 September 2019 at a similar time as session one and two in Classroom Four and Five respectively. The table used for Experiment 2 is at 300mm working plane height and is arranged as shown in figure 3.29.

Figure 3.29: Students' Seating Arrangement in Experiment 2

Experiment 3 uses classrooms that are specifically designed for *hafazan* task learning. However, the WFR and layout design of the classroom is not based on the recommendation of standards and guidelines. Both classrooms selected floor area is approximately 18m^2, where a total of six students can be seated in two separated bays based on the ratio recommended. The students are arranged in one single row facing the front of the classroom as shown in figure 3.30.

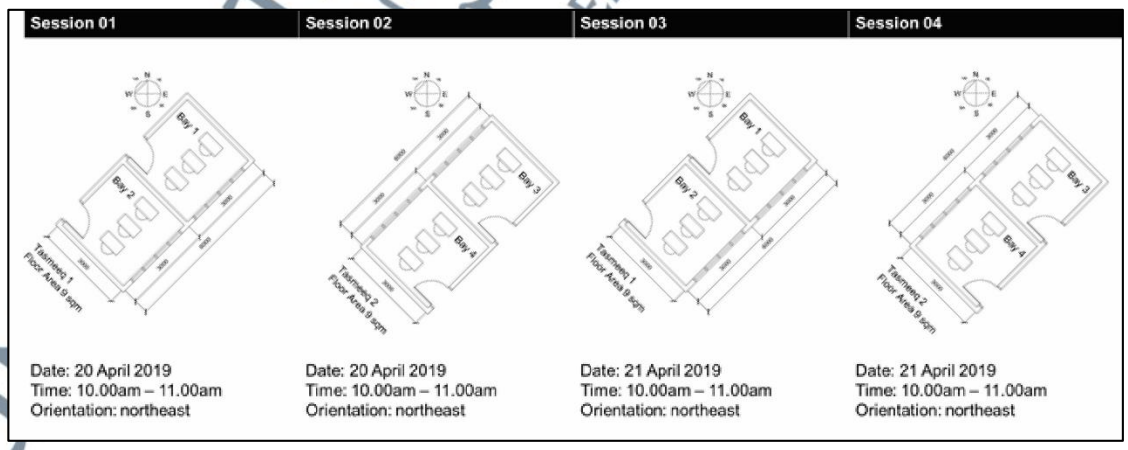


Figure 3.30: Experiment Three Students' Seating Position

The same *Tasmi'* classrooms are used at two different dates for Experiment Three. Session One and Two are conducted on 20 April 2019 between 10.00am to 11.00am simultaneously in Classroom *Tasmi'* One and Two respectively. The third and fourth session is conducted on 21 April 2019 at a similar time and same classrooms as session one and two.

Figure 3.31: Students' Seating Arrangement in *Tasmi'* Classrooms

Experiments 1, 2 and 3 have different variables that are changed to test and compare the effect of illuminance level for each experiment and to justify the results and findings for each. The variables are working plane height and window sill height. The illuminance level measurement procedure will be discussed further.

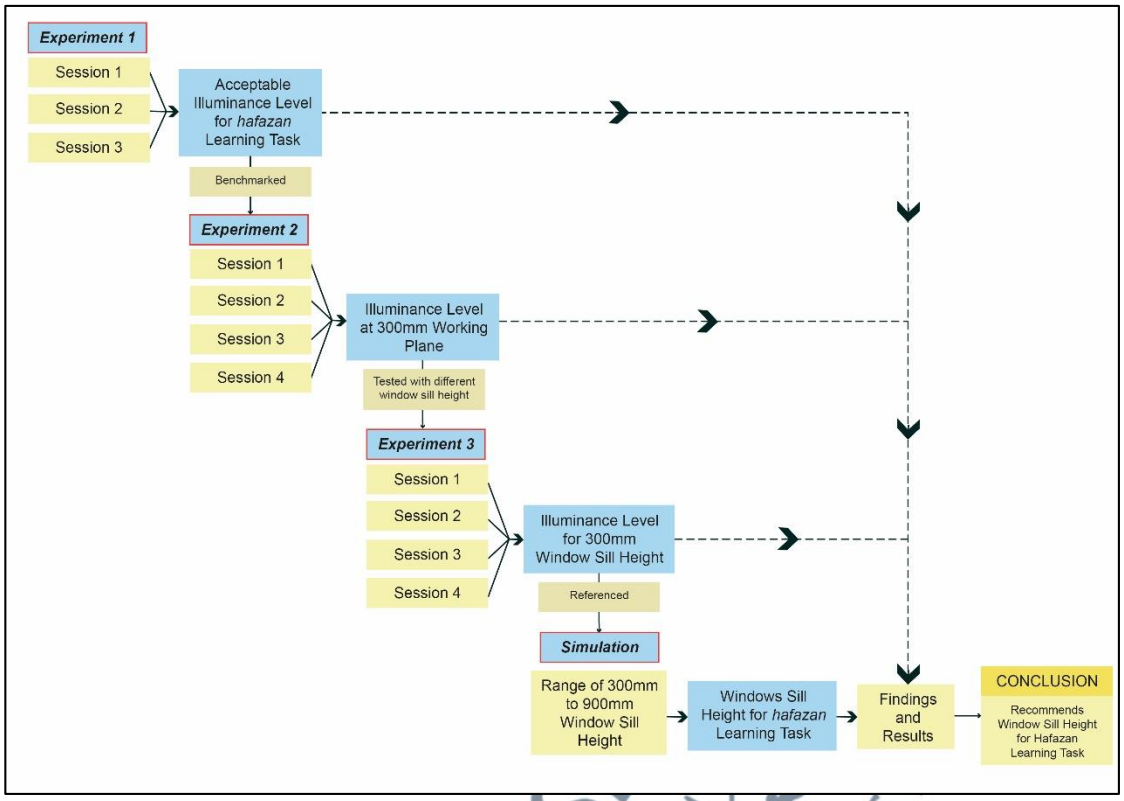


Figure 3.32: Experiment Framework

Figure 3.32 shows the framework for the research experiments. Experiment One consists of three sessions with a similar classroom design layout and table with 900mm working plane height. The results of illuminance level and student performance in Experiment One are compared to each other to identify the acceptable illuminance level for *hafazan* learning task.

The acceptable illuminance level in Experiment One will be used as the benchmark for Experiment Two, where the findings and results of four sessions conducted in Experiment Two are also compared to identify the illuminance level at 300mm working plane with 900mm window sill height.

Differently, Experiment Three is to identify the illuminance level at 300mm working plane with 300mm window sill height. The classroom layout selected for Experiment 3 differs from Experiments 1 and 2, where the layout is smaller by approximately 70 per

cent. Thus, the number of respondents seated are also smaller compared to Experiment 1 and 2.

The findings and results collected in Experiment One, Two and Three will be used as a reference and benchmark to identify the parameter for the different window sill height simulation in IESVE. The result of the simulation will identify the optimum classroom window sill height for *hafazan* learning task on 300mm working plane height.

Illuminance Level Measurement

Biesele, et al. (1953) introduced a method that only considered the average, maximum and minimum illuminance level in the space, which are sufficient to identify the average illuminance level in a non-open planning layout spaces (Wu & Ng, 2003). This method can be applied in various spaces such as classrooms and other learning spaces. The method is similar to luminance spot measurement on the grid of the classroom at the working plane height level, according to Theodorson (2009) and Zomorodian, et al. (2016). The lux meter is set up within the classroom based on a 1mx1m grid plan. The lux meter is set at a working plane height of 900mm for Experiment 1. Figure 3.33 shows the illuminance level lux meter position in each classroom for the data collection session, where the total sum illuminance level measured was divided with the total lux meter point to obtain the average illuminance level of each sessions. Research by Mathalamuthu & Ibrahim (2014) and Husini, et al. (2017) shows that a learning space without outdoor overhang similar to the selected classroom in this research will create unacceptable illuminance level 2 m away from the windows and openings.

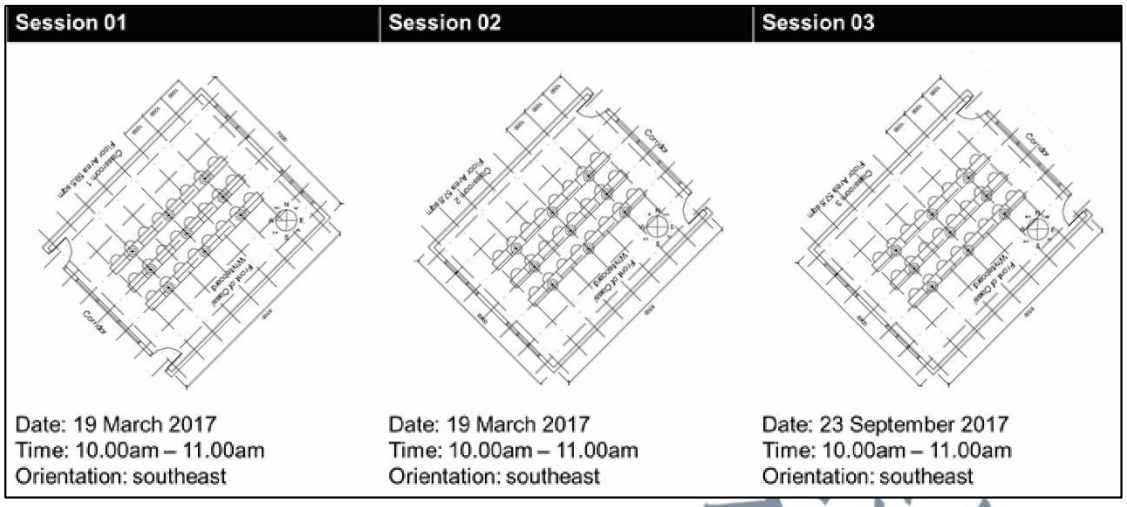


Figure 3.33: Experiment One Illuminance Level Lux Meter Position

The lux meter is placed 2 m away from the windows and openings on both sides. Nine lux meter are located in three rows with three measurement points each. The lux meters are placed 2 m away from each other in each row. The illuminance point measurement is recorded to calculate the average illuminance level in the classrooms. The average and minimum illuminance level recorded for each classrooms identifies the illuminance uniformity ratio, where the minimum illuminance level is divided by the average illuminance level. The value recommended for optimum uniformity ratio is between 0.6 to 0.8.

Experiment 2 lux meter is set up within the classroom similarly based on a 1mx1m grid plan. The difference is that the lux meter is set at a working plane height of 300mm to identify the average illuminance level at *rehal* height. Figure 3.34 shows the lux meter position in each classroom for the data collection session.

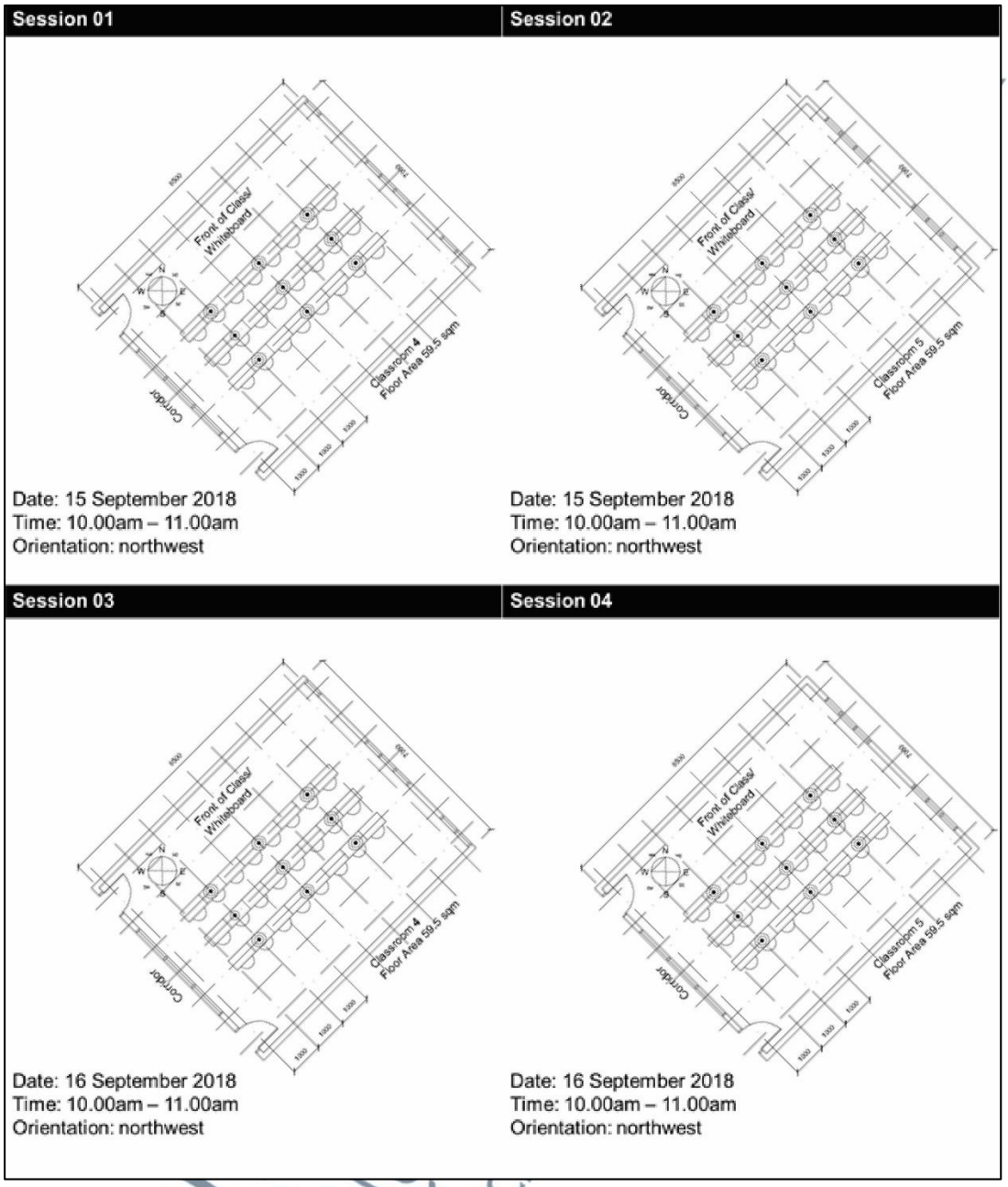


Figure 3.34: Experiment Two Illuminance Level Lux Meter Position

The lux meter is placed 2m away from the windows and openings on both sides. Nine lux meters are located in three rows with three measurement points each, which are placed 2m away from each other in each row. The average illuminance level is measured in the classroom for every session.

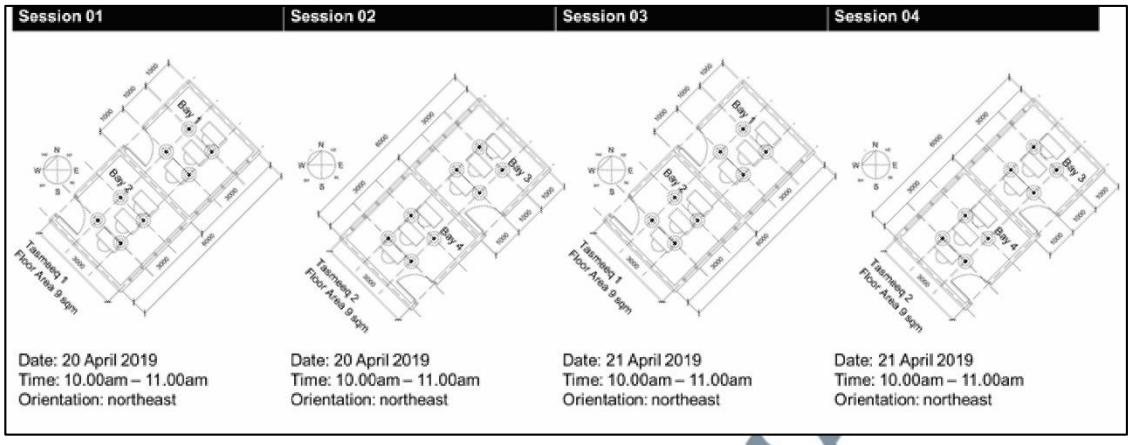


Figure 3.35: Experiment Three Illuminance Level Lux Meter Position

Figure 3.35 shows the illuminance level lux meter location in each classroom during the session. Due to restriction of space, the lux meter will be placed nearer to the window and each measurement point compared to Experiments 1 and 2, where the lux meter be placed in a 1m x 1m grid of each bays. Four lux meters are located in two rows with two measurement points each in every bays. These lux meters are placed 1 m away from each other in each row. The average illuminance level is measured in the classroom for every session.

All results and findings of the illuminance level from the three experiments are compared to each other to evaluate the difference and correlations between illuminance level, working plane height and window sill height. The comparison will lead to a theoretical layout that is suitable for optimum illuminance levels at different working plane height. The results and findings will be supported by the surveys obtained from the respondents during the experiment.

3.3.2 Questionnaire

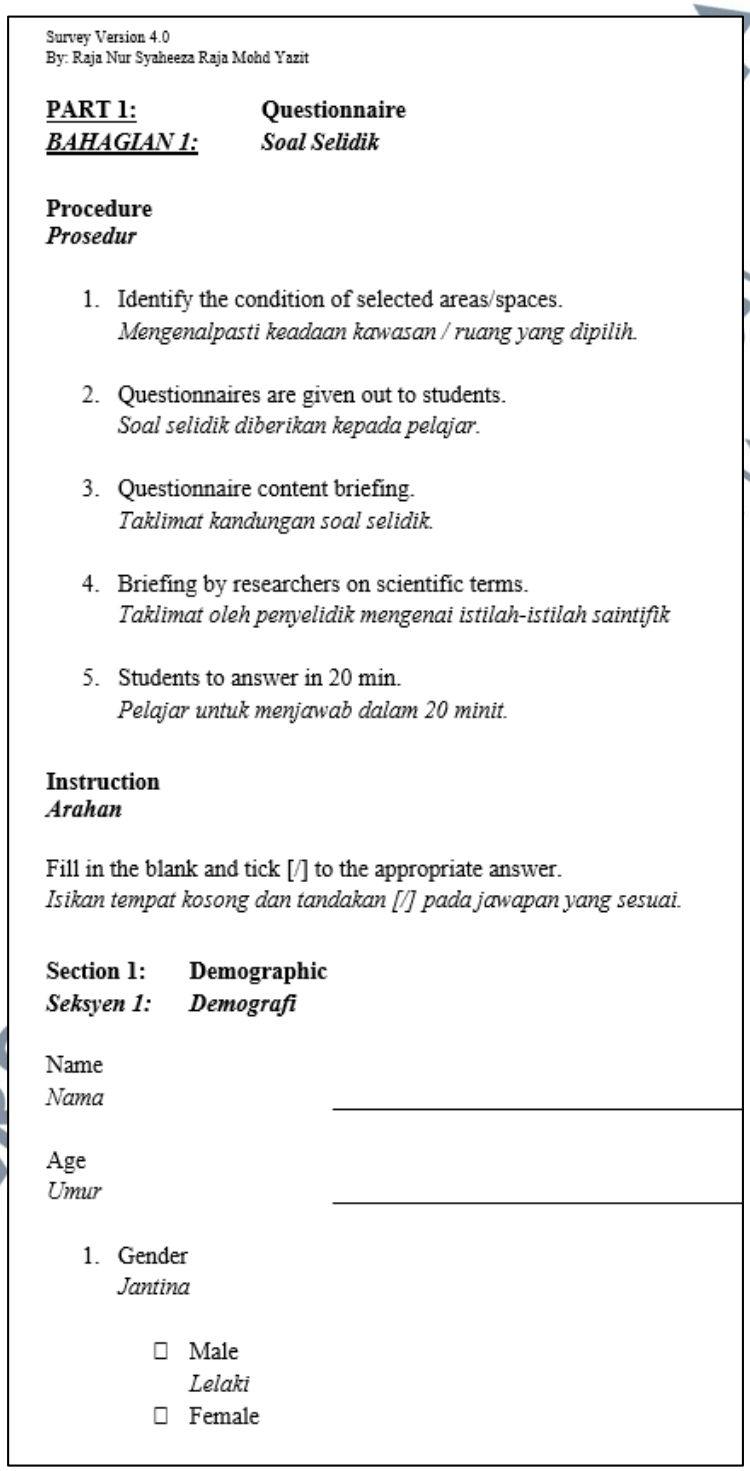
Structuring a Likert-type scale questionnaire for social science from scratch based on Trochim's principles consumes time. However, the Likert-scale scale

questionnaire will have more internal consistency (Croasmun & Ostrom, 2011). The questionnaire was prepared to reference Hirning (2016) and Doulos et al. (2007) questionnaire, where it is constructed in responses of the students' space visual environment such as locations, time, general lighting questions, demographics, comments on the visual condition and task performance. Other factors include sky condition, viewing direction and location of the student. Other references such as the brightness level of the space (Cauwerts & Bodart, 2013) and daylight environment (Bian & Luo, 2017). The respondents' perception of the classrooms and visual environment quality questionnaire is adapted from Erell, et al. (2014) questionnaire. The sizes of the windows based on the respondents' perception taken form Doulos, et al. (2007) is also included in the survey.

The earlier versions of the questionnaire were conducted for Fundamental Research Grant Scheme (FRGS) pilot study in the same school (Husini et al., 2017). The first part of the questionnaire involves questions based on the students' perception of daylighting in the classroom, where the second part emphasized on the students' perception on their Arabic handwriting performance. Likert Scale is used to identify the respondents' range of visual comfort or discomfort, perceptions on daylighting and visual comfort during Arabic handwriting tasks. There are five levels on the scale, where the lowest number represents very disagreeing with the question and the highest number represents very agreeing with the question. The questionnaire procedure will be discussed further. After the students have been seated down in the arranged positions, the students are required to understand the procedure and objectives of the survey. The brief will be given to the students by the researcher. Students will write their numbers in order of the seating for recorded purposes. These numbers are also the code for each answered questionnaire.

Part One; Section One: Demography

Figure 3.36 shows the content of the demography questionnaire. Descriptive Statistic Analysis is used to evaluate this section.



Survey Version 4.0
By: Raja Nur Syaheeza Raja Mohd Yazit

PART 1: **Questionnaire**
BAHAGIAN 1: ***Soal Selidik***

Procedure
Prosedur

1. Identify the condition of selected areas/spaces.
   Mengenalpasti keadaan kawasan / ruang yang dipilih.
2. Questionnaires are given out to students.
   Soal selidik diberikan kepada pelajar.
3. Questionnaire content briefing.
   Taklimat kandungan soal selidik.
4. Briefing by researchers on scientific terms.
   Taklimat oleh penyelidik mengenai istilah-istilah saintifik
5. Students to answer in 20 min.
   Pelajar untuk menjawab dalam 20 minit.

Instruction
Arahan

Fill in the blank and tick [/] to the appropriate answer.
Isikan tempat kosong dan tandakan [/] pada jawapan yang sesuai.

Section 1: **Demographic**
Seksyen 1: ***Demografi***

Name
Nama _____

Age
Umur _____

1. Gender
   Jantina

   ☐ Male
   Lelaki
   ☐ Female

Figure 3.36: Sample of Questionnaire Part One; Section One

Part One; Section Two: Daylight Condition

Section two is to identify the daylight condition of the classrooms based on the students' perception. The questionnaire consists of two factors, which are Daylighting Condition Perception and Task Performance Perception questions. The first component consists of three variables and the second with two variables. Each factor identifies certain data and responds by the students required for the research as shown in figure 3.37. Both sections of part one will be analysed using Statistical Package for the Social Sciences (SPSS) statistics software for descriptive statistical analysis.

Survey Version 4.0
By: Raja Nur Syaheeza Raja Mohd Yazit

Section 2: Daylight Condition
Seksyen 2: Keadaan Pencahayaan

No	Question	1	2	3	4	5
		Too dim *Terlalu gelap*	Dim *Gelap*	Neutral	Bright *Terang*	Too bright Terlalu terang
1	The brightness of the room *Keterangan cahaya bilik darjah*					
2	The size of the classroom window *Saiz tingkap bilik darjah*	Too small *Terlalu kecil*	Small *Kecil*	Normal *Biasa*	Big *Besar*	Too big Terlalu besar
3	Amount of daylight in classroom *Tahap cahaya di dalam bilik darjah*	Too low *Terlalu rendah*	Low *Rendah*	Normal *Biasa*	High *Tinggi*	Too high Terlalu tinggi

Figure 3.37: Questionnaire Part One; Section Two

Descriptive Statistics Analysis

Each answered questionnaire from each experiment is evaluated using Statistical Package for the Social Sciences 25 (SPSS) basic descriptive analysis. The analysis is based on the Frequency and Descriptive functions of SPSS. The questionnaire is evaluated based on Section 1; Demography and Section 2; Daylight Condition Perception.

The descriptive analysis for Section One; Demography and Section Two; Daylight Condition Perception evaluates the standard deviation, where the standard deviation value between -1 to 1 is considered in the analysis. The results are cross-referenced with the average illuminance level and students' performance for each experiment to identify the relationship between the students' daylighting condition perception and the average illuminance level.

3.3.3 Arabic Handwriting Performance Procedure

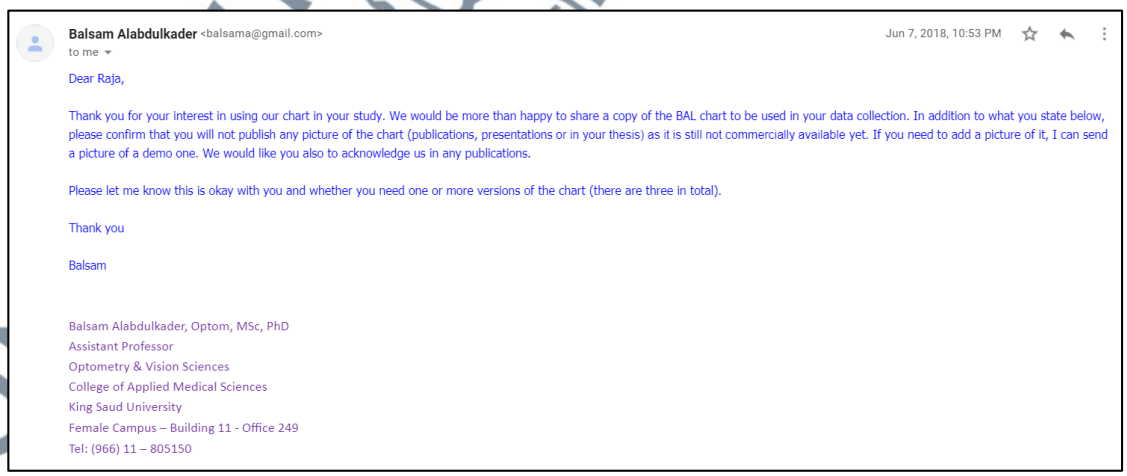
The students' performance is measured based on their time speed on learning task which is Arabic handwriting. Since the research is evaluating students' performance based on Arabic handwriting for *hafazan*, the typical visual eye acuity chart with the English alphabet is not reliable. Therefore, the eye chart is replaced with a modified Balsam Alabdulkader-Leat (BAL) chart.

After the students have answered part one of the survey, they are required to read and rewrite the provided BAL chart. The students are not given any time limitation to rewrite the BAL chart. The students are provided a stopwatch in front of the classroom for time recording purposes.

Once all of the students have rewrite and recorded the time speed for the BAL chart writing task, the students are required to answer the second section of the students' performance measurement which consists of four Likert Scale questions. The experiment ends when all the students have answered all the content of the survey and the questionnaires have been returned and collected by researchers for further discussion and analysis.

Modified BAL Chart

Alabdulkader & Leat (2017) has developed the first Arabic reading acuity chart that is used to evaluate a person's reading acuity and ability. This research adapted and modified the BAL chart to fit the evaluation of the students' Arabic handwriting performance. The BAL chart format is similar to the LogMAR chart or Anter's Method used for the visual eye acuity test. The modified BAL chart adapts the sentence and words from the original chart with the permission of the patented BAL chart from the owner. However, the format has been modified into a Jaeger chart and Colenbrander chart format due to the data required for this research. Figure 3.38 shows the email for permission to use the eye chart from Balsam Alabdulkader.



Balsam Alabdulkader <balsama@gmail.com> Jun 7, 2018, 10:53 PM

to me

Dear Raja,

Thank you for your interest in using our chart in your study. We would be more than happy to share a copy of the BAL chart to be used in your data collection. In addition to what you state below, please confirm that you will not publish any picture of the chart (publications, presentations or in your thesis) as it is still not commercially available yet. If you need to add a picture of it, I can send a picture of a demo one. We would like you also to acknowledge us in any publications.

Please let me know this is okay with you and whether you need one or more versions of the chart (there are three in total).

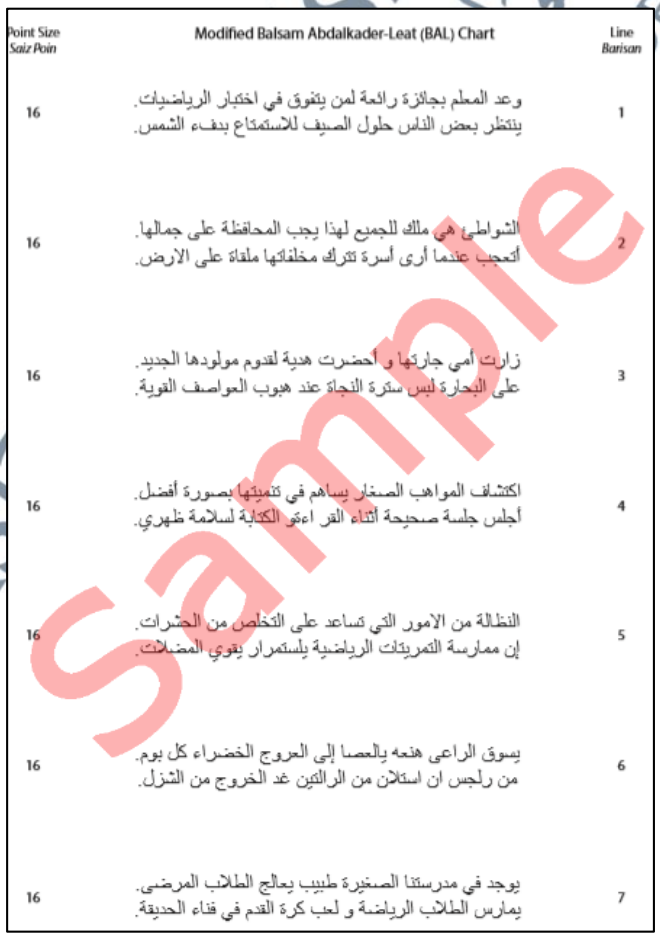
Thank you

Balsam

Balsam Alabdulkader, Optom, MSc, PhD
Assistant Professor
Optometry & Vision Sciences
College of Applied Medical Sciences
King Saud University
Female Campus – Building 11 - Office 249
Tel: (966) 11 – 805150

Figure 3.38: Approval to use the patented BAL eye chart

The modified BAL chart consists of seven different two-lined sentences with the same length. The space between the two lines in each sentence is eight-point size, whereas the gap between each sentence is approximately 35 mm. The Arabic font used is Microsoft Traditional Arabic alphabet with 16-point size for the modified BAL chart. The Arabic font point size 16 is equivalent to a Times New Roman font point 12. The Arabic alphabet was with different words, similarly constructed as "the fox jumps over the lazy dog". The total Arabic letters in the BAL chart are 700, where there is an average of 100 Arabic letters in each paragraph. There is an average of 20 Arabic words per paragraph, where the total Arabic words in the BAL chart is 140 words. Figure 3.39 shows the modified BAL chart.



Point Size *Saiz Poin*	Modified Balsam Abdalkader-Leat (BAL) Chart	Line *Barisan*
16	وعد المعلم بجائزة رائعة لمن يتفوق في اختبار الرياضيات. ينتظر بعض الناس حلول الصيف للاستمتاع بدفء الشمس.	1
16	الشواطئ هي ملك للجميع لهذا يجب المحافظة على جمالها. أتعجب عندما أرى أسرة تترك مخلفاتها ملقاة على الارض.	2
16	زارت أمي جارتها و أحضرت هدية لقدوم مولودها الجديد. على البحارة لبس سترة النجاة عند هبوب العواصف القوية.	3
16	اكتشاف المواهب الصغار يساهم في تنميتها بصورة أفضل. أجلس جلسة صحيحة أثناء القراءة و الكتابة لسلامة ظهري.	4
16	النظالة من الامور التي تساعد على التخلص من الحشرات. إن ممارسة التمرينات الرياضية بإستمرار يقوي العضلات.	5
16	يسوق الراعي هنعه بالعصا إلى الحروج الخضراء كل يوم. من رلجس ان استلان من الرالتين غد الخروج من الشزل.	6
16	يوجد في مدرستنا الصغيرة طبيب يعالج الطلاب المرضى. يمارس الطلاب الرياضة و لعب كرة القدم في فناء الحديقة.	7

Figure 3.39: Modified Balsam Alabdulkader-Leat (BAL) chart

The modified BAL chart is distributed to the respondents in the classrooms within the survey. Figure 3.40 shows the space indication for the students to rewrite the chart. The time speed taken for the students to finish writing the BAL chart is recorded at the bottom part of the writing space.

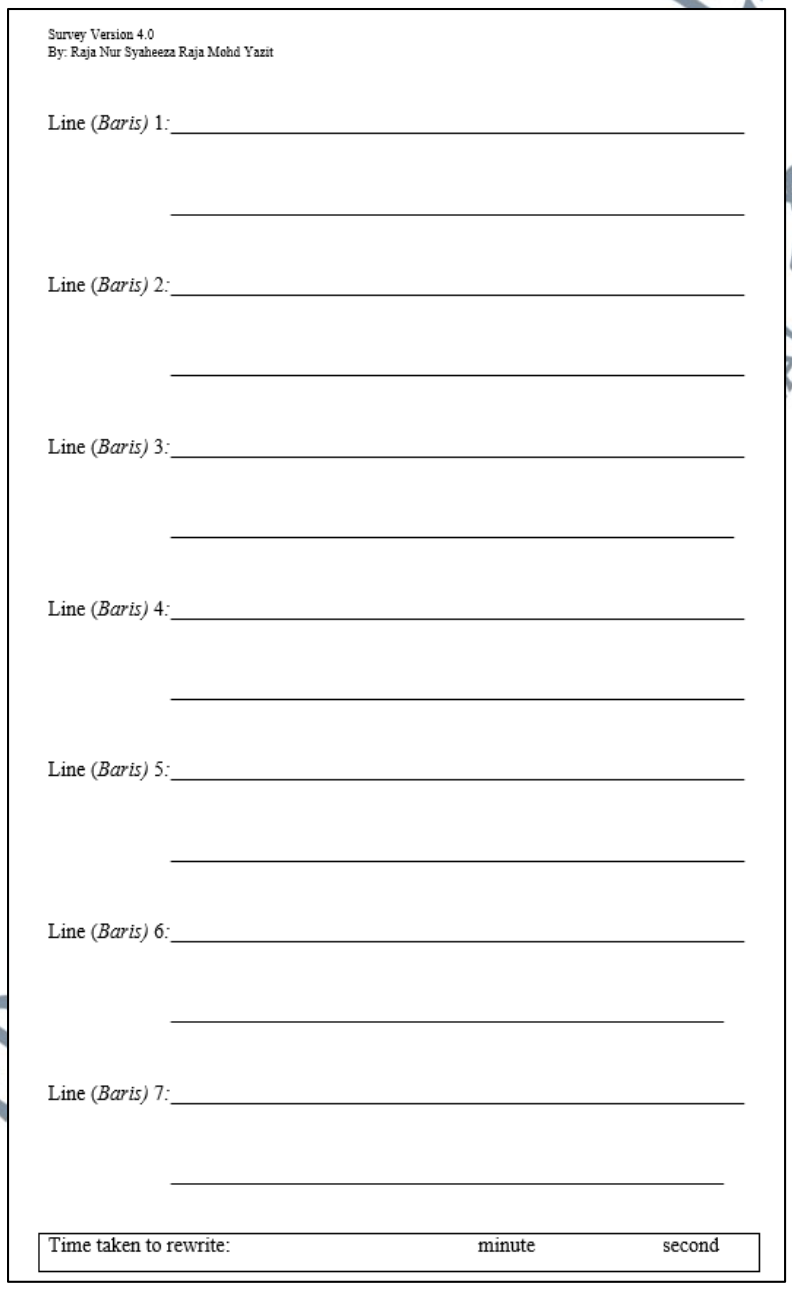


Figure 3.40: Modified BAL chart and Rewriting Space

Part Two; Section Two; Learning Task Perception

The rewriting BAL chart task is complemented by a Likert Scale questionnaire on the students' perception of the visual comfort and daylight condition of the classroom during the Arabic handwriting task in section two of the survey. Each question answered is a respond of the students on their reading and Arabic handwriting experience during the experiments as shown in figure 3.41. The collected answers will be analysed using Statistical Package for the Social Sciences (SPSS) statistics software for descriptive statistical analysis.

Survey Version 4.0
By: Raja Nur Syaheeza Raja Mohd Yazit

Section 2: Questionnaire – Learning Task Performance

Seksyen 2: Soal Selidik – Prestasi Tugasan Pembelajaran

Answer this section based on your task in the previous section.
Jawab bahagian ini berdasarkan tugasan anda di bahagian sebelumnya.

No	Question	1	2	3	4	5
		Very Disagree *Sangat Tidak Setuju*	Disagree *Tidak Setuju*	Neutral	Agree *Setuju*	Very Agree Sangat Setuju
1.	You can read the Eye Chart clearly. *Anda boleh membaca Carta Mata dengan jelas.*					
2.	You can rewrite the Eye Chart clearly. *Anda boleh menulis semula Carta Mata dengan jelas.*					

Figure 3.41: Questionnaire – Learning Task Performance

Students' Performance

The method used to identify the students' writing performance is through evaluating the student's words per minute (wpm) for the writing task, where incorrect words or letter written does not penalize in the evaluation (Keerthi & DeCoste, 2005). The written letters are divided by the minutes taken for the students to finish the task and divide by five to obtain the average word per minute rate of the student. The calculation of the word per minute (wpm) is as shown:

$$\left(\frac{\textbf{letter written}}{\textbf{minute}} \right) / 5$$

The average words per minute (wpm) for students aged 13 to 14 years old is between 14.3 wpm to 15.6 wpm. Although, handwriting for Arabic and Hebrew letters is much lower in comparison with the typical English alphabet as mentioned by Ziviani & Watson-Will (2010). The average words per minute (wpm) each classroom in each experiment will be compared to analyse the correlation between the average illuminance level and the students' performance for different working plane heights.

3.3.4 Daylight Simulation

Integrated Environmental Solutions; Virtual Environment (IESVE) 2019 software is selected for the simulation process. The function Day Lighting Analysis (FlucsDL) for daylighting evaluation, where the weather data and internal reflectance value can be modified based on the spaces selected. The daylighting simulation parameter setup follows the classroom design and conditions for average illuminance level measured for every experiment.

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Daylighting Simulation Parameter Setup

The dimension of the model for the simulation follows the classroom selected for the field measurement. The classroom model is 7m x 8.5m, where the widest dimension is facing North. The windows are located on both sides of the classrooms, facing North and South at the widest walls of the classroom model. The margin for obstructions is set at recommended 0.5m, where the illuminance level measurement grid is also 0.5m. CIE intermediate sky condition is selected with provided weather data for Kuala Lumpur, Malaysia. The simulation is set at 10.00am on the 21st March, where there is optimum daylighting during the whole year.

The window sill height varied between 300mm to 900mm, where the WFR and window size is kept constant at recommended 20 per cent and 5m x 1.2m respectively. The height of the classroom is also kept constant at 3.5m with an active false ceiling. The classroom model as shown in figure 3.42 is the basic setup for every simulation, where the working plane height is kept constant at 300mm. The illuminance level is measured at 300mm working plane height to simulate *rehal* height in the classrooms. Only the illuminance level within the students' seating area is considered in the average illuminance level of the classroom, where the daylight average of the simulation result is deducted with the illuminance level within 2m perimeter of the classroom's walls. The lowest illuminance level calculated for uniformity ratio is also taken from within the students' seating area.

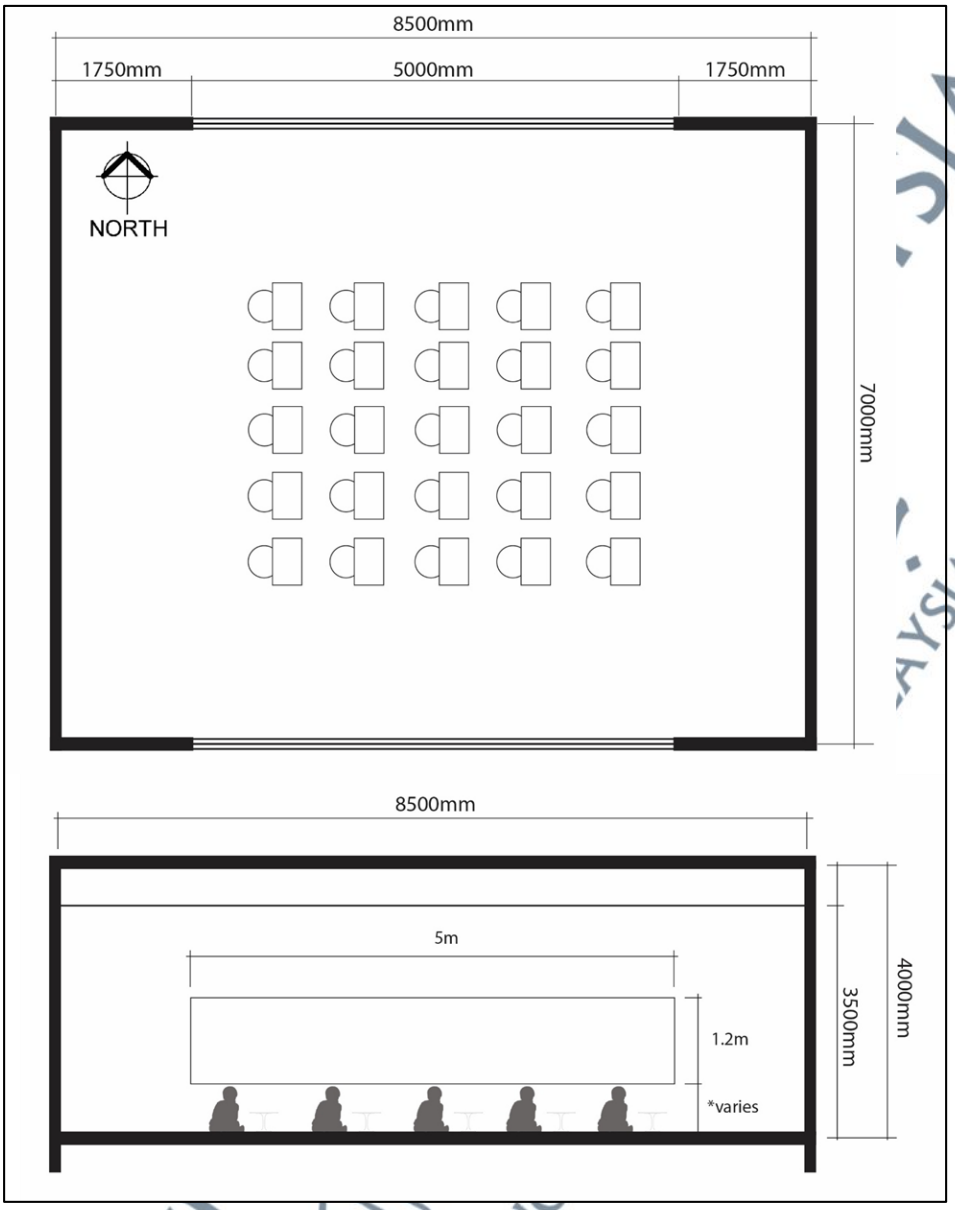

Figure 3.42: Classroom Modelling Setup and Layout

The reflectance value for walls, floor, and ceiling soffit is kept constant at 0.5 (50%), 0.3 (30%) and 0.7 (70%) respectively. The window is a single glazed unit with clear glass panels with a transmittance value of 0.81 (81%). This simulation parameter setup is used for models with different window sill height ranged from 300mm to 900mm, where the interval height is 100mm for each simulation. This influences the window head height when the dimensions and WFR of the window are kept constant, where the range is between 1.5m to 2.1m. The simulation parameter is shown in table 3.3.

Table 3.3: Summary for simulation parameter

Parameter/Variable	Value/Detail
Reflectance	
Walls	0.5 (50%)
Floor	0.3 (30%)
Ceiling	0.7 (70%)
Window glazing	
Transmittance	0.81 (81%).
Orientation	North/south
Shading device	No
Classroom layout	
Classroom width	8.5m
Classroom depth	7m
Classroom height (ceiling)	3.5m
Classroom floor area	59.5m^2
Window design	
Window-to-Floor Ratio (WFR)	20%
Window height	1.2m
Window width	5m
Window area (total)	12m^2
Window sill height/window head height	300mm/1.5m
	400mm/1.6m
	500mm/1.7m
	600mm/1.8m
	700mm/1.9m
	800mm/2.0m
	900mm/2.1m
Date and time of simulation	
Date	21 March
Time	10.00am
Global illuminance and sky condition	
Global illuminance	60,000 lx
Sky condition	intermediate

3.4 Summary

This chapter discussed the data collection methods and procedures of the research. The procedures are field measurement, survey and daylight simulation. The field measurement consists of two procedures, which are classroom layout design and illuminance level measurement. The survey also consists of two procedures, which are questionnaires and visual eye acuity test. The questionnaire is to evaluate the students' perception of the daylighting of the classrooms and the visual eye acuity test is to evaluate the students' performance. The final procedure is daylight simulation.

These procedures are used in three different experiments that are conducted in different selected classrooms for each experiment. The components or variables that are changed between these experiments are the working plane height of the table and the window sill height. Each experiment has different findings and results that lead to the conclusion of the research. The findings and results of the experiments will be analysed and discussed further in the next chapter.