Sudan University of Science and Technology
College of Graduate Studies
M.Sc. Arch (Building services)

Optimum Lighting For School Classrooms In Khartoum State
(Case Study: Cambridge Primary School and Imtidad Nassir School)

الاضاءة المثلى لحجرات الدرس بالمدارس بولاية الخرطوم
(دراسة حالة مدارس كامبردج العالمية و مدرسة إمتداد ناصر)

A Thesis Submitted for The Partial Fulfillment of the Requirement of
(M.Sc) in Architecture (Building services Specialization)

By:
Manal Altahir Abd Almalik Abo Khiar

Supervisor:
Professor: Dr. Saud Sadig Hassan

April / 2022

الآيـــــة

(وَاللَّهُ جَعَلَ لَكُمْ مِمَّا خَلَقَ ظِلَالًا وَجَعَلَ لَكُمْ مِنَ الْجِبَالِ أَكْنَانًا وَجَعَلَ لَكُمْ سَرَابِيلَ تَقِيكُمُ الْحَرَّ وَسَرَابِيلَ تَقِيكُمْ بَأْسَكُمْ كَذَلِكَ يُتِمُّ نِعْمَتَهُ عَلَيْكُمْ لَعَلَّكُمْ تُسْلِمُونَ (81) فَإِنْ تَوَلَّوْا فَإِنَّمَا عَلَيْكَ الْبَلَاغُ الْمُبِينُ (82) يَعْرِفُونَ نِعْمَةَ اللَّهِ ثُمَّ يُنْكِرُونَهَا وَأَكْثَرُهُمُ الْكَافِرُونَ (83).

سورة النحل

الآيات (81-83)

Dedication

To My lovely parents …

To My soul mate my husband …

To My sisters who stand with me in every second …

To My little angels Mohammed , Al-Waleed & Noor …

To all around me…. I present this research

Acknowledgement

*This work would not have been possible without the valuable guidance and great support of my supervisor **Professor Saud Sadiq Hassan**… So, I'm expressing my thanks and gratitude to him... Furthermore, I would like to thank all my teachers and colleagues who helped me during this research... I want to extent my gratitude to my family for their patience and support…*

Abstract

The research is concerned with the optimum lighting for school classrooms in Khartoum state, and the study of natural lighting, artificial lighting and the integration between them.

The research aims to investigate visual comfort for occupants of educational buildings in Khartoum state, also it aims to examine ways that reduce energy consumption, and study the ways to use natural lighting to solve the lighting problem such as the electricity outlet in the study area, and the bad distribution of natural lighting.

The methodology used is the analytical descriptive approach, using the case study method, which has been chosen according to the criteria, (Cambridge Primary School – Almamora, Khartoum, and Imtidad Nasser primary school), the study takes the measurement of light in deferent situations in classrooms (student desks, teacher desk and blackboard) by using ordinary camera and (lux meter) phone application, and comparing the measurements with the standards.

The research concluded with some results, the most important of which are to use the maximum amount of daylight by studding the openings areas and orientation, also the design of the artificial lighting will lead to an optimum situation for classroom lighting.

In conclusion, the research has recommendations to achieve the optimum lighting for school classrooms in the case study area such as taking into account the school classrooms design requirements in Khartoum, school maintenance and provide support for application of sustainability concepts in the area of study and make it part of the basic laws either in designing process or planning.

المستخلص

البحث دراسة لتوفير الإضاءة المثلى في الحجرات الدراسية بمدارس الاساس في مدينة الخرطوم ، ويتناول دراسة الاضاءة الطبيعية والاصطناعية وكيفية التكامل بينهما.

يهدف البحث إلى توفير الراحة البصرية للتلاميذ والمعلمين في المدارس في مدينة الخرطوم، كما يهدف إلى دراسة الطرق التى تقلل من إستهلاك الطاقة، مع دراسة كيفية الاستفادة من الاضاءة الطبيعية للوصول الي حلول لمشاكل الاضاءة في المدارس كانقطاع التيار الكهربائي بالمنطقة، والتوزيع الغير الجيد للاضاءة الطبيعية.

طريقة البحث تعتمد المنهجي الوصفي التحليلي، وذلك بدراسة الاضاءة الطبيعية والاصطناعية بحجرتي درس في مدرستين مختلفتين تمثلا جميع مدارس الأساس بمدينة الخرطوم، وتمت الدراسة بقياس كمية الضوء بأسطح العمل داخل الفصل (طاولات التلاميذ، مكتب المعلم، وسبورة الفصل) ومقارنتها بكمية الإضاءة القياسية، وذلك باستخدام تطبيق الهاتف (lux meter) وكاميرا بعدسة البانوراما.

خلص البحث إلى نتائج أهمها الاستفادة من الإضاءة الطبيعية وذلك بدراسة الفتحات ومساحتها وتوجيهها وتصميم اضاءة اصطناعية تتناسب مع الحجرات الدراسية لتحقيق الراحة البصرية.

وفي الختام قدم البحث توصيات لتحقيق الإضاءة المثلى بمنطقة الدراسة منها : الأخذ بعين الإعتبار متطلبات التصميم الداخلي بالمدارس، وصيانة المدارس ، وتقديم الدعم لتحقيق وتطبيق مفاهيم الإستدامة في منطقة الدراسة وجعلها جزءا من القوانين الأساسية في عمليتي التصميم والتخطيط.

list of contents

List of pictures and figures

List of tables

Chapter one

GENERAL INTRODUCTION

Chapter one

GENERAL INTRODUCTION

1.1. Background:

Learning is a life-long process. In modern societies, in a world becoming increasingly complex and high tech, we need to be prepared to keep on acquiring new knowledge and learning new skills.Successful learning in the right educational environment provided in a school which recognizes talent and ability, encourages active and independent learning which makes education an enjoyable experience and motivates both students and staff. Since a good quality of light plays a significant role in the psychological and biological processes of human beings, architecture, lighting and good visual conditions are closely connected with efficient learning. From literature we know that performance of students increase by a good visual environment.

The use of electric lighting in schools is one of the important energy costs, so the research aims to find design possibilities for the optimal use of daylight; however, a classroom is a difficult space to be lighted with daylight, because of the depth of the classroom and the different tasks which must be performed in it. A few years ago 'TNO Built Environment and Geosciences' conducted a research about electric lighting in schools by order of NOVEM.

The primary objective to be oriented toward the use of natural lighting when possible, or complementary artificial lighting with natural lighting, is giving a comfortable educational and working environment in an energetically efficient way.

1.2. Title:

Providing lighting in school classrooms by integrating daylight with artificial lighting and taking into account other services: ventilation, air conditioning, acoustics and design aspects of classrooms.

1.3. Research problem:

i.Classroom is a difficult space to be lighted with daylight, because of the depth of the classroom and the different tasks which must be performed in it.

ii.Lack of electricity in schools that negatively affect the activity within the classroom.

iii.Lighting problems in the class such as glare and bad reflections.

1.4. Research goals:

iv.Increase the efficiency of the educational process by providing a comfortable learning environment for the students and teachers.

v.Achieve sustainability, save energy and reduce electricity consumption in schools during daytime working hours.

vi.Dealing with the problems of power outage by finding alternative solutions to get energy.

vii.Natural light provides psychological comfort and positive feeling and generates the necessary activity for the educational process.

viii.Minimize visual problems caused by poor lighting, glare and reflections.

1.5.Research questions:

i.Is there proper lighting in school classrooms in Khartoum City?

ii.Have lighting requirements been considered when the classrooms are designed and finished?
iii.Is electricity regularly available in schools, and what are the possible alternatives to get energy?
iv.What are the problems of lighting in classrooms: glare, reflections, shadows and colors, and what are logical solutions?

1.6. Research limits:

- Location boundaries: Khartoum City.
- Time Limits: May 2019 - December2022.
- Research community: basic public and private schools in Khartoum city.
- Study of lighting in classrooms only.

1.7. Research hypothesis:

1. Most public schools rely on daylight which not completes all the need of lighting in the classroom and causing glare and reflection problems.
2. Most private schools rely on artificial lighting because of the shortage of the space, the problem will appear when power outage in the school. It's also have a high costs.
3. There are schools that use both artificial light and daylight
4. The imbalance between lighting requirements and other services (such as setting a window that provides daylight but brings hot air inside the classroom).
5. Classrooms design and finishing.

1.8. Research Methodology:

The methodology used is the analytical descriptive approach, using the case study method, which has been chosen according to the criteria. Case Study: Cambridge Primary School and Almamora , Khartoum and Imtidad Nassir primary school, And comparison between case studies and standard requirements.

1.7.1. This will be conducted by describing the classrooms in terms of:

i.The place and orientation of the classroom.
ii.Weather on the day of the case study.
iii.Dimensions and finishes of the class.
iv.Daylight and intensity of lighting.

1.7.2. Analysis criteria:

i.Conditions and standards of lighting in classrooms.
ii.Daylight effect on classrooms.
iii.Effect of external factors on classroom lighting (power failure - ventilation).

1.7.4. Presentation and analyses of the study case:

- **Presentation:**

i. Show the classrooms spaces, dimensions, furniture distribution, windows, doors and the lighting elements in floor plans and sections.
ii. Present the quantitative data of artificial lighting and daylight in tables, drawings and diagrams.

iii. Show lighting qualitative data (brightness distribution, glare, illuminance, shadowing, modeling, colors and reflections) in points and pictures.

- **Analysis:**

i. Analyzing spaces in classrooms, vertical and horizontal levels of lighting and comparing them with standards.

ii. Making statistical tables for comparison with standard.

iii. Determining the lighting problems in classrooms and their relation to ventilation, air conditioning and acoustics, and what optimal solutions are.

1.7.4. Tools and measurements used in the case study:

- **Tools:** Observation, measuring tape, luminance camera, ordinary camera and lux meter application.
- **Measurements :**

i.Luminance: (lx)

ii.Light sources: lamps description – power (watt)

iii.Daylight factor: relative (%)

iv.Dimensions and levels of class: meters (m)

1.7.5. Conclusions and recommendations:

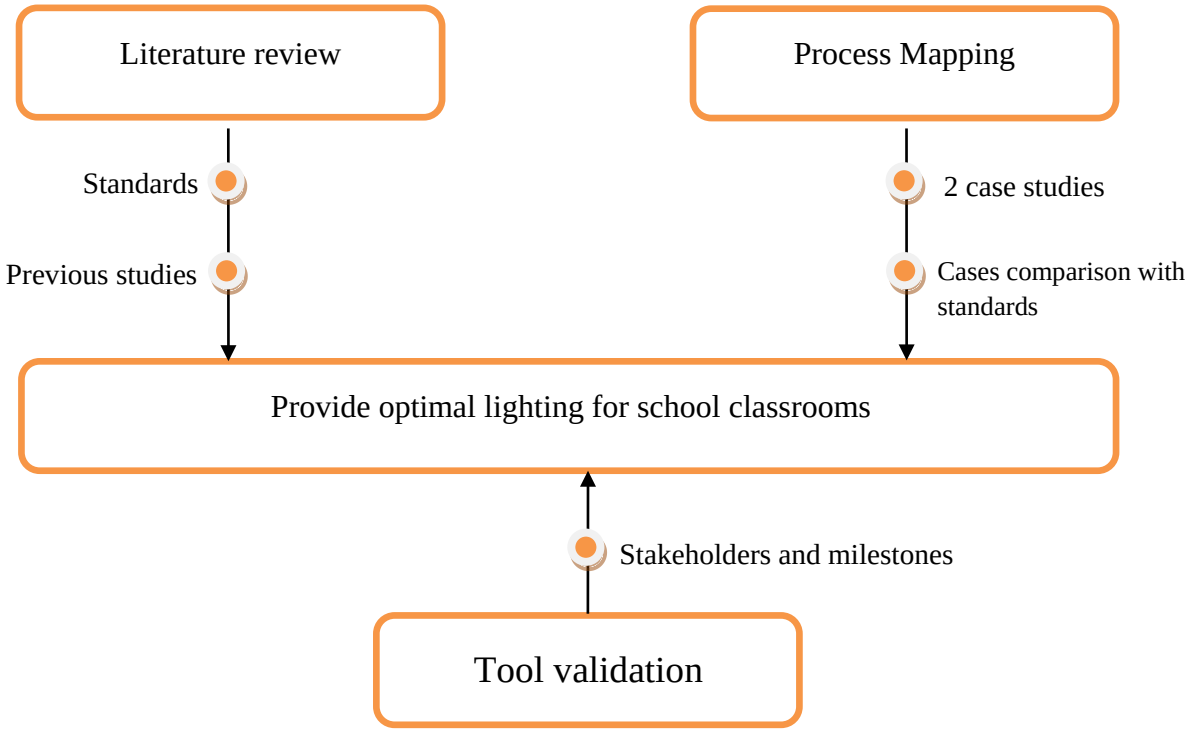
i. Conclusions:

Present the study conclusions and in tables and points.

ii. Recommendations:

1. Recommend how to maintain positive results and solve problems in classrooms.
2. Recommend a future study for optimal solutions to treat lighting problems in classrooms.
3. It shows in points.

1.9. Research framework:



Chapter two

LITERATURE REVIEW

Chapter two
LITERATURE REVIEW

2.1 Introduction:

Many educational establishments today consist of large complexes of buildings with lots of special classrooms, events and sports halls, cafeterias and refectories, administrative offices and conference zones. Schools, in particular, meet this description because a growing number of them now spread classes throughout the day.

Every room in a school or educational establishment serves a particular purpose, for which there are special architectural solutions with special lighting requirements.

For any room in a new or refurbished building, the aim should be to find the best way of harnessing natural daylight and the requisite artificial lighting. Here, however, the importance of artificial lighting is often underestimated, although it plays a major role in most classrooms. In winter especially, the available daylight is generally not adequate.

For media work with projectors, windows need to be darkened. And for scientific experiments, a special lighting situation is frequently necessary. However, planning artificial lighting involves more than just ensuring adequate brightness in a room. A differentiated lighting design incorporating various separately controlled luminaries systems permits the creation of lighting scenes tailored to requirements. With dimmable room lighting, separate wall washers at the front of the room and additional luminaries at the entrance. (Gutes Licht)

Fig 2.1- lighting in classroom

Source: google.com/images.2018

2.2 Classroom design standards:

The design, location and orientation of the classroom primarily affect the design and selection of lighting quality in the classroom. Therefore, the classroom design criteria must be defined to achieve a good lighting design that reduces energy use and achieves the required comfort for users.

2.1.1 Locations:

- Classrooms shall be located on the lower floors to minimize the amount of traffic that uses elevators or stairways.
- Larger capacity classrooms should be located closest to the building entry.
- Building codes should provide criteria that would determine the numbers and locations of building entrances.
- The building design shall provide for ease of access and for convenient vertical mobility of students.
- A directory that identifies classroom locations should be provided at each entrance along with a directory of other programs and activities located in the building.
- Classrooms should be located away from noise generating areas such as mechanical rooms, elevators, vending machines, and restrooms. If physical separation is not feasible, increased acoustical treatments may be needed. (UConn's Design-2016).

2.1.2 Hallways/Corridors :

- Hallways should not only be part of the building design and aesthetics, but should also be viewed as an extension of the learning environment. They should always be as visually interesting as possible.
- Egress hallways should be sized to accommodate at least double the loads identified in code due to the large number of students leaving and entering the rooms, and provide gathering space during class changes.
- Hallways should be viewed as an opportunity to improve classroom acoustics.
- Non-recessed doors that open into the hallways are to be avoided. (UConn's Design-2016)

2.1.3 Classroom interior design:

- Classrooms should be developed and designed from the "inside out". The following items should be considered when creating a new classroom:
- The optimum orientation and of the classroom should be determined by the primary expected teaching style, the capacity of the room, and the level of mediation.
- Generally, classrooms should be sized in a 2:3 or 3:4 widths to length ratio. Long, narrow, style rooms are not acceptable.
- The total square footage of each room is to be based on the type of classroom, the specific capacity and the type of seating
- Classrooms with a capacity of 49 or less are to be as square as possible to allow for greater flexibility in furniture arrangement, and better sight lines.
- In classrooms where the instructor's workstation is movable, adequate space must be provided to allow the workstation to be positioned at least 3 feet away from the teaching wall.
- In classrooms with fixed tables and/or fixed seating, the front edge of the instructor's workstation must be at least six feet from the front row. (UConn's Design-2016).

2.1.4 Doors and windows:

2.1.4.1 Doors:

- Doors should be located at the back of the classroom to ensure that students who are entering or exiting the space will not disturb instruction. Exceptions include large tiered classrooms or auditoriums, since those kinds of spaces can require multiple doors. In rooms that require two or more egress points, the doors should be located as far from the presentation area as possible while still meeting current building codes.
- Each door leaf to be a minimum of 36” wide, including those used in pairs at double doors.
- Occupancy within the classroom should be clearly (but discretely) visible from the hallway.
- The area of the glass shall not exceed 100 square inches and should be double-paned with acoustically rated seals. Doors without vision panels shall have either a viewer peep hole installed to provide a view into the room to check activity or have a separate sidelight.

2.1.4.2 Windows:

- Daylight is an important part of most learning environments. Windows should be included in classrooms whenever possible.
- Design for easy accessibility. Window coverings shall be manually operable, chain driven roller shades. Where roller shades are not feasible, manually operated window treatments are acceptable. .
- When necessary due to window height, a fixed valance or sun blocking panel can be hung at the top of the window, and an adjustable height, manually operated roller shade can be hung at the lower termination point of the fixed valance/panel

Use of a light diffusing roller shade in conjunction with a room darkening roller shade is recommended whenever possible. Percentages of light diffusion will be determined for each window by evaluating the individual window’s orientation and the intensity of the exposure.

- Use of a light diffusing roller shade in conjunction with a room darkening roller shade is required. Percentages of light diffusion will be determined for each window by evaluating the individual window’s orientation and the intensity of the exposure. (UConn’s Design-2016).

Fig 2.2- Light diffusing roller shade

Source: google.com/images.2018

- All window treatments are required to have a non-reflective matte finish and unless otherwise specified, the color selection should match or blend with the window frame. The blinds should be installed so they cover the window opening as completely as possible. (UConn's Design-2016).

2.3 Lighting in classrooms:

Too much or too little light, glare or distorted colors impact on what we perceive, distract our attention and cause visual fatigue. In all areas of life and throughout the working world, good and appropriate lighting is a prime requirement for enabling us to see clearly, enjoy a sense of wellbeing, perform concentrated fatigue-free work and perceive and interpret important information and our surroundings correctly. This calls for good, professional lighting design. (Gutes Licht-2016)

Figure 2.3- lighting quality diagram

Source: google.com/images 2018

2.1.5 Lighting for human needs:

Below are some of the key factors that need to be considered for good lighting design:

i. Illuminance

In daylight, the illuminance of an illuminated surface is between 10,000 lux (overcast sky) and 100,000 lux (bright sunlight). Indoors, we need to make do with much less light. For writing and reading, it is generally enough if artificial lighting provides 500 lux illuminance; for drawing or other visually demanding tasks, illuminance should be at least 750 lux.

The values set out in the standard, however, are minimum requirements. Most people find a higher level of illuminance more agreeable and more motivating. In winter especially, when the levels of daylight entering a room are lower, more light is needed to avoid fatigue and loss of concentration.

ii. Glare:

Glare is one of the most disturbing side-effects of lighting. Direct glare caused by marked contrast differences between very bright and very dark surfaces or due to unshielded lamps in our line of vision place a strain on our eyes and lead to fatigue and mistakes through loss of concentration .

iii. Shadowing:

Where there is light, there is also a shadow. To ensure that shadows do not impede our view when writing, the light should fall - for a right-handed person - from the left. If the light comes from the right, we write in the shadow of our own hand. (Gutes Licht-2016).

iv. Brightness distribution:

When we are in a room, our gaze incessantly switches from near (desktop) to far (walls). Where there are marked differences in brightness between these two zones, our eyes face the constant need to re-adapt and thus get tired more quickly. Visual performance and sense of wellbeing diminish.

Where the differences in brightness are not marked enough, however, the room makes a monotonous impression. It is recommended here that desktop luminance should not be less than 1/3 of the luminance in the immediate surroundings.

v. Glare limitation:

Glare is one of the most unpleasant visual problems of all. Being dazzled by a general-diffuse lamp or the reflection of a window on a computer screen affects our visual acuity and impedes our performance. Direct and reflected glare can be largely avoided by good room and lighting design.

vi. Modeling:

Without light we cannot see an object at all, without shadow it is just a two-dimensional image. Only where light comes from the right direction and where the depth of shadow is correct can we perceive objects as 3D images and gauge distances. To recognize three-dimensional objects, surfaces and structures, we need light and shade.

vii. Light and color:

The way we perceive colors under artificial light depends on the color rendering properties of the lamps. Lamps with good color rendering properties produce natural colors, lamps with poor color rendering properties cause color distortion.

viii. Reflections on paper:

Especially where glossy materials are used, poorly shielded luminaires cast disturbing reflections. Well shielded luminaires avoid this effect and permit all materials to be studied with ease. (Gutes Licht-2016).

2.1.6 Tasks and zones:

In order to get a good lighting concept, knowledge of the different tasks in classrooms is important. Each task needs its own light conditions. During the day there are a number of different visual tasks in a classroom. So, high requirements for the light quality are important. (Truus de Bruin-Hordijk, Ellie de Groot)

Students and teachers have benefit by a lighting which supports them optimally in doing their activities. Important for a good lighting design is that the needs of the human being are central, but in the same time the energy efficiency may not be neglected.

The following values for luminances and contrasts have been required: the luminances must be below 3000 cd/m² and the luminance contrasts in the (wide) visual field must be lower than 1:30.

Table 2.1- Overview of tasks in a classroom together with the requirements for the illuminances

Source: Truus de Bruin-Hordijk, Ellie de Groot.

Task	the teacher	the student	Standard Illuminance	
			In the class	In general
1	Writing on blackboard	Reading on blackboard	500 lux (vertical)	200 lux
2	Talking to the students	Paying attention to the teacher	300 lux	300 lux
3	Showing a presentation (slides, powerpoint, television program, etc.)	Looking onto the screen	300/10 lux	10 lux
4	Paying attention to working students	Writing, reading drawing, etc.	300 lux	300 lux
5	Coaching computer activities	Looking to the computerscreen and the paper	50 lux	300 lux above the computer
6	Preparing lessons	Not present	300 lux	50 lux

According to the tasks of teacher and student and the light requirements for the different activities the classroom has been divided in zones: A blackboard zone and a classroom zone. The classroom zone has again been divided in two zones parallel to the facade in order to create the possibility to optimize the use of daylight: a window zone and a corridor zone.

2.4 Natural lighting:

Natural daylight has enormous physiological benefits and there is much research evidence of a positive correlation between concentration, performance, results and improved natural daylight within educational facilities.

Natural day lighting should always be the main source of lighting in schools, supplemented by electric light when light fades later in the day or during overcast weather. (UK and Ireland Sales Enquiries).

2.4.1. Daylight for classrooms:

The daylight factor, which is the percentage of the illuminance outdoors received at a point indoors, has three components (fig 2.4):

- The sky component received directly from the brightness of the sky.
- The externally reflected component received by reflection from external surfaces.
- The internally reflected component.

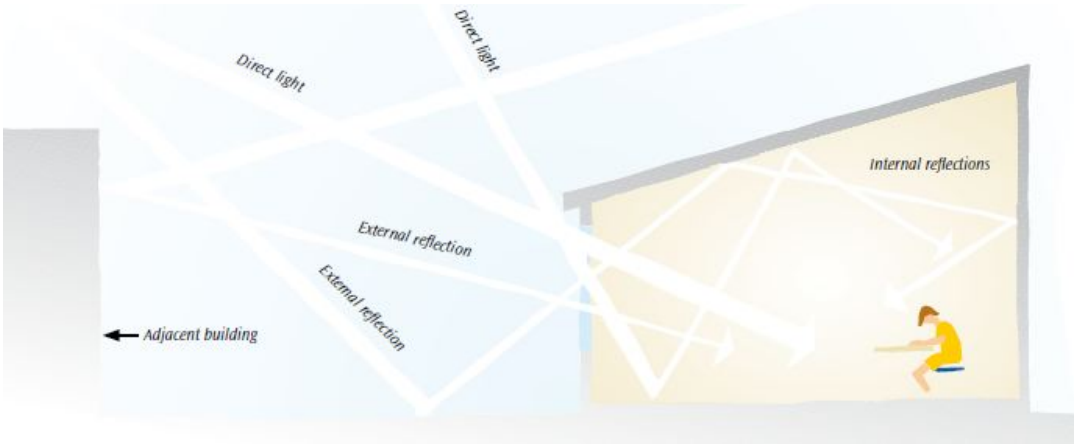


Fig 2.4- the main components of day light

Source: BRANZ Ltd-2007

i. Sky component:

Being able to see part of the sky is important for classroom occupants. Those who are in a part of a room without a sky view tend to think the natural light they are getting is unsatisfactory. Extra electric light may be needed to overcome this.

ii. Externally reflected component

Light reflected from external surfaces forms a great proportion of the light available inside a room, especially if a large portion of the sky is obstructed by nearby buildings. The reflected light component will be higher if the obstructing building is light colored. (BRANZ Ltd-2007)

iii. The internally reflected component:

Light reflected by the ceiling, walls and floor helps to spread daylight to the darker areas of a room which are furthest away from a light source. Using surfaces with more reflectance (lighter colored) can greatly improve lighting efficiency (Figures 2.5 and 2.6). A lighter colored room also provides better daylight distribution, improves brightness ratios and is visually more comfortable.

Dark colored pin boards or fabric wall coverings can reduce internal daylight levels because they absorb light.

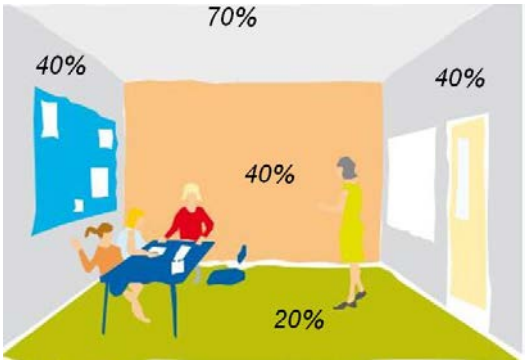


Figure 2.5- room with darker colored surfaces which reflect less light

Source: BRANZ Ltd-2007

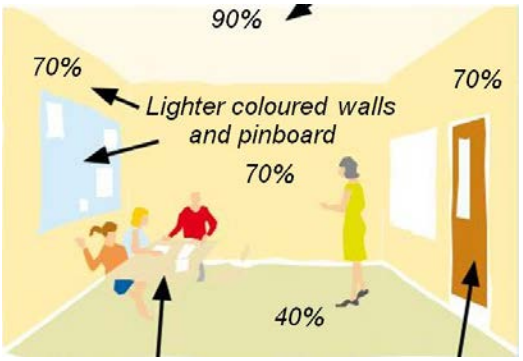


Figure 2.6- lighter colored surfaces improving light efficiency

Source: BRANZ Ltd-2007

2.4.2. Good Daylight :

The main principles to follow for day lighting for classrooms are:

1. Avoid direct sunlight
2. Avoid over-glazing which can create excessive solar heat gain in summer and major heat loss in winter
3. Ensure light sources are balanced to give even but interesting lighting
4. Provide windows with a view
5. Eliminate glare

Give users control when needed. (BRANZ Ltd-2007)

2.4.2.1. Avoiding direct sunlight:

Direct sunlight is an extremely strong source of light and heat. It has no place in classroom day-lighting design and should be avoided because it can cause visual discomfort, glare and thermal comfort. Below are the practical methods of excluding direct sunlight:

- Correct window orientation
- Fixed solid overhang for shading
- Horizontal or vertical louvers, depending on orientation
- Landscaping
- Interior blinds.

2.4.2.2. Avoiding over-glazing :

For new buildings careful expert design for daylighting will ensure windows are the right size and in the right place. The amount of light and heat can be controlled by:

- Methods described above for excluding direct sunlight.
- Correct window placement.
- Correct window size.

2.4.3. Types of windows :

Because daylight illumination falls off with distance from the windows, adding clerestories, roof lights or borrowed lights can improve the level and distribution of daylight. Additional sources of natural light also enhance and enliven the room (see fig 2.7).

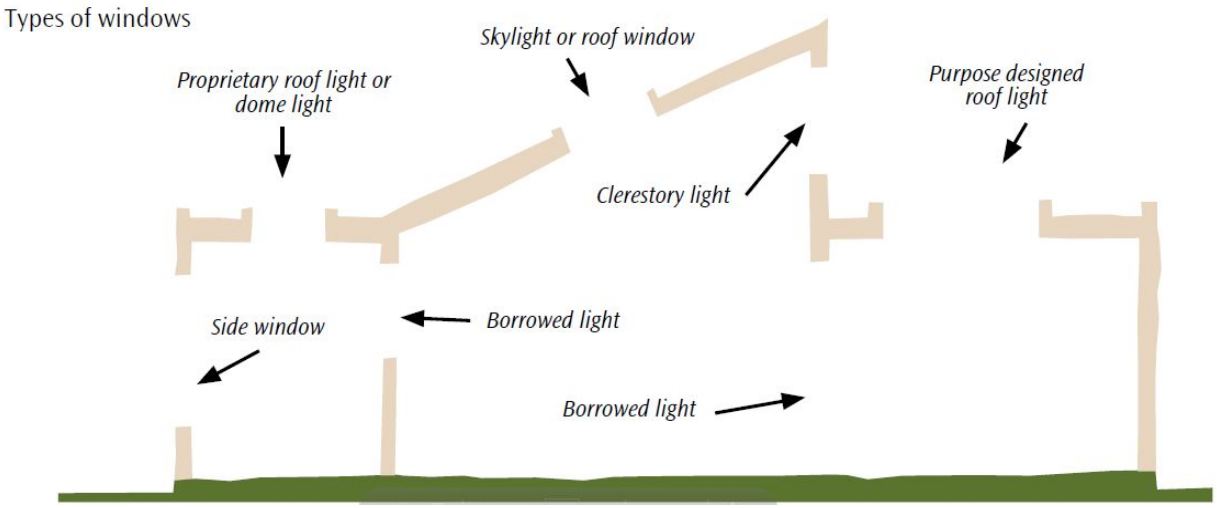


Fig 2.7- type of windows

Source: BRANZ Ltd-2007

i. **Roof lights:**

- Admit light from the brightest part of the sky
- Can provide a more even distribution of additional light across a space
- Allow you to see the sky
- Need careful design to avoid glare
- Need careful design if black out is required
- Require careful design to avoid direct sunlight and solar heat gain
- Need regular cleaning and maintenance.
- Need careful design to prevent accidents with maintenance workers or students accessing the roof.(fig 2.8)

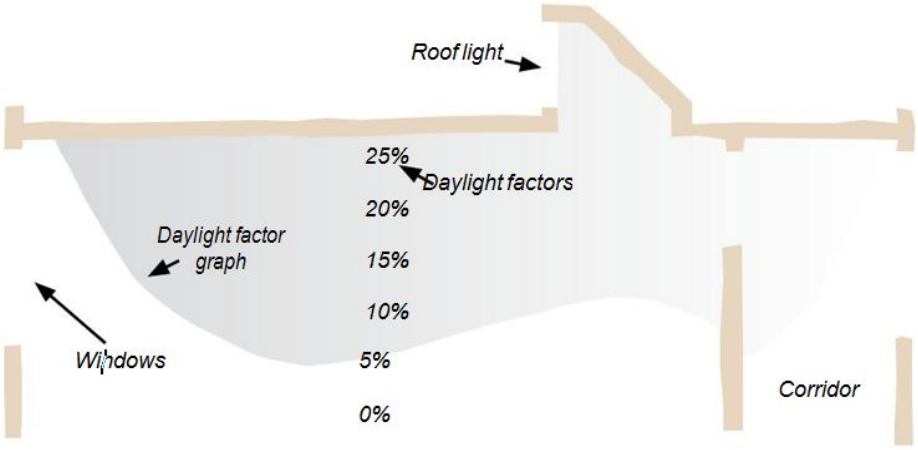


Figure 2.8- Roof light concentrates light on the horizontal plane

Source: BRANZ Ltd-2007

ii. **Clerestory windows**

The advantages of clerestory windows are they:

- Are high up and so let in light from a bright part of the sky
- Are unlikely to be obstructed by trees or other buildings
- Can provide light to the darker part of a room
- Give you some idea of what it's like outside
- Can provide extra ventilation.

However, they:

- Need careful design to avoid glare
- Can be difficult to black out
- May require shading to avoid direct sunlight and solar heat gain.

iii. Borrowed lights

Windows between interior spaces can:

- allow you to see between spaces
- improve lighting levels where light is borrowed from a well-lit space eg, a top-lit corridor or an atrium
- provide a pathway for sound to travel between rooms.

iv. Windows with a view:

It is essential that people can see out of the buildings they spend much of their day in. Windows with a view allow us to keep in touch with changing weather and the time of day – this avoids a feeling of being shut in. A view allows us to break from close work, this is important for students and teachers especially when working on computer or doing fine art, and can be good for relaxation and learning.

With traditional windows in the long wall of a classroom care must be taken to:

- Position the sill at a suitable height
- Exclude direct sunlight to avoid unwanted solar heat gain

- Ensure satisfactory ventilation.

v. **Additional sidelight windows:**

Lighting from supplementary sidelight windows, especially on the opposite wall to the main source of light, can greatly improve the quality and distribution of light. They can also look good from the outside. Figures 2.9, 2.10, 2.11 and 2.12 show the lighting effect of various types of windows.

Figure 2.9 -wide distribution

Source: BRANZ Ltd-2007

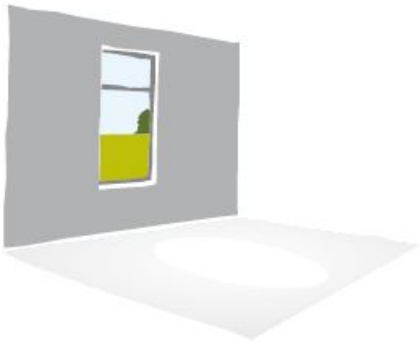
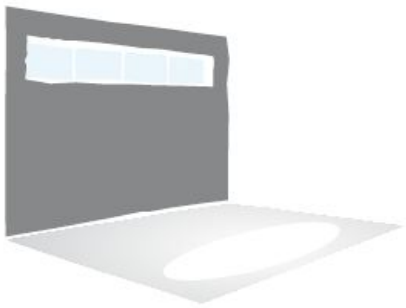


Figure 2.10- deep distribution

Source: BRANZ Ltd-2007



Fi

from the window

Source: BRANZ Ltd-2007

t

the walls and reduce contrast

Source: BRANZ Ltd-2007

vi. **Light shelves:**

A light shelf is a single large horizontal louver which cuts out direct sun and reflects light from its top surface deeper into the room, improving light distribution. Light shelves are suitable for north-facing windows in rooms with high ceilings. Ideally, a light shelf should project through the window plane so there is a small clerestory window above. The top surface of the shelf should have a high light reflectance and be kept clean and clear (fig 2.13).

Light shelves are suitable for new buildings, but can be installed as part of a major refit. (BRANZ Ltd-2007)

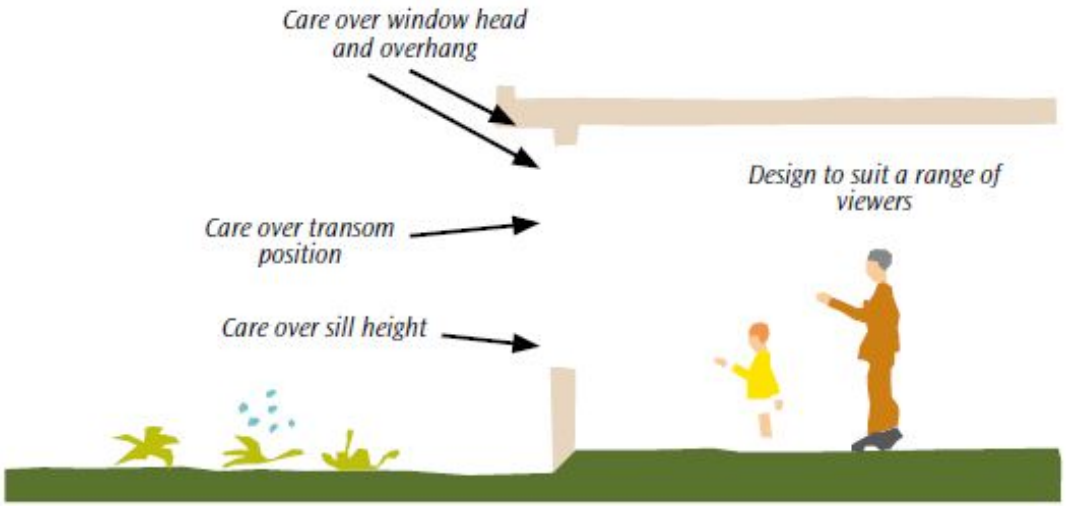


Figure 2.13- A light shelf helps to spread light evenly into the room

Source: BRANZ Ltd-2007

3.4.4 Window light transmittance:

Different types of glass transmit a different proportion of the available light. Glass used to limit heat gain or provide insulation will also transmit less light.

Sometimes it is better, and costs less, to use clear glass in a smaller window that will transmit the same amount of light as tinted or reflective glass in a larger window. Table 2.2 shows the transmittance and insulation values of some types of glass.

Table 2-2: light transmittance

Source: BRANZ Ltd-2007

Type of glass	Light transmittance
No glazing	1.0
Single-glazing	0.87
Double-glazing	
• Clear glass	0.75
• Low-e glass	0.65
• Tinted glass	0.30

2.5 Artificial lighting:

Even if the school is well day lighted, an electric lighting system is needed for inclement days, early and late winter hours, and evening classes. The challenge is to provide a lighting system that is energy efficient, has a long life, and requires minimal maintenance. (James R. Benya-2001)

The main aims of artificial lighting (as for day lighting) are:

- Functional – so tasks can be carried out accurately, comfortably and safely
- Amenity – to provide a pleasant, stimulating environment.

Fig 2.14- electrical lighting in a classroom

Source: Google.com/images 2018

2.5.1 Illuminances:

The illuminances in the classroom zone have been simulated at desktop level at a 16-points grid, in order to make a differentiation for the different student places in the classroom. The vertical illuminances on the blackboard are simulated too, with a 15- points grid. The simulations have been done for a cloudy sky (CIE-overcast sky) at 21 December at 12 o'clock. The walls and the ceiling of the simulated classrooms have been chosen ‘off-white’ with reflection coefficient of 67% and the floor 'yellow' with reflection coefficient 37%.

Figures (2.15 and 2.16) show the the illuminances on a line at the middle of the classroom. All the models show illuminances below 500 lux on the blackboard; figure 2.17 shows the illuminances on the blackboard for the reference model and the three classroom models which receive daylight from two different sides.(Truus de Bruin-Hordijk, Ellie de Groot)

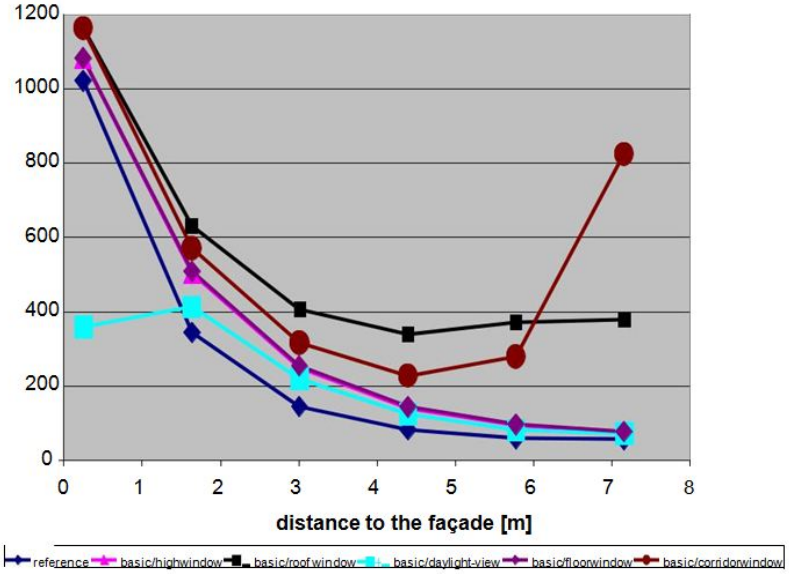


Fig 2.15-: Illuminance distribution for the reference model and the five basic models

.Source: Truus de Bruin-Hordijk, Ellie de Groot

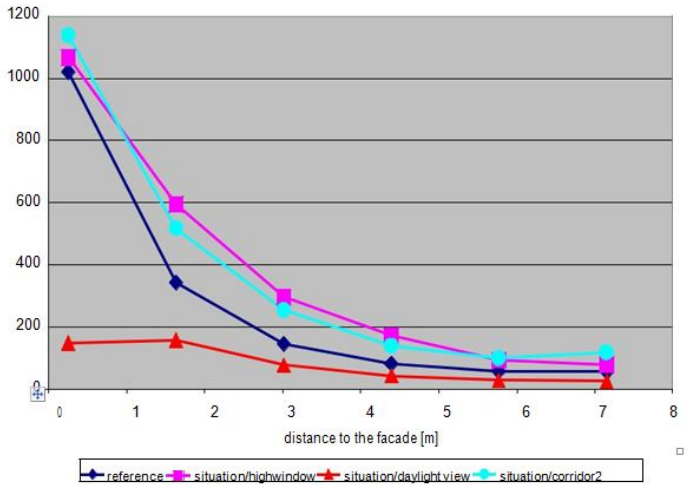


Fig 2.16-: Illuminance distribution for the reference model and the three situation models

Source: Truus de Bruin-Hordijk, Ellie de Groot

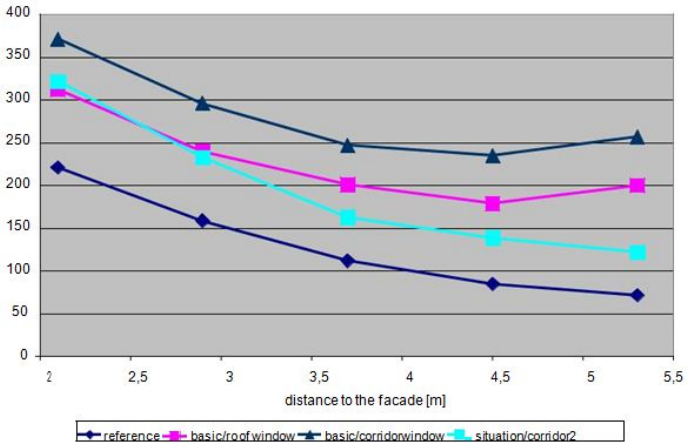


Fig 2.17-: Illuminance distribution on the blackboard for the reference model and the three models with two-side daylighting

Source: Truus de Bruin-Hordijk, Ellie de Groot

2.5.2 Electrical lighting design for school classrooms:

Basic electric lighting quality will depend on the:

- Amount of light.
- Color appearance of the light.
- Ability of the light to make color look correct.
- Amount of glare.

2.5.2.1 Amount of light:

As lighting installations age and collect dirt they give less luminance. To compensate, luminance levels are specified as the minimum the installation is designed to give during its lifetime. This is called the 'maintenance illumination' and is expressed in lux.

2.5.2.2 Color appearance and color rendering:

The color of the light given out by different artificial light sources appears to have varying degrees of warmth or coolness. The colors (called the correlated color temperature or CCT) needed for different functions are simplified into three groups: (warm, intermediate, cold).

The ability of the light to make color look correct (compared to daylight) is expressed as the color rendering index (Ra). Lamps are arranged in groups according to their Ra. Table (2.3) shows those groups appropriate for use in teaching spaces. (BRANZ Ltd-2007)

Table 2.3- lamp color rendering groups

Source: BRANZ Ltd-2007

Group	**Color rendering index (Ra approx)**	**Typical applications**
1A	90 and over	where high accuracy color matching is necessary
1B	80-90	where accurate color judgment is required
2	60-80	When moderate color rendering is adequate

2.5.2.3 Glare:

Glare causes visual discomfort when parts of the room are overly bright. Glare index is a numerical index which enables the discomfort glare from lighting installations to be ranked in order of severity. The maximum glare index can be given for lighting installations so they can be designed accordingly.

2.5.3 Task lighting

A luminaire which illuminates only a limited area can be used to supplement background ambient light where:

i. there is a task requiring close work
ii. increased illuminance is only needed over a small area
iii. strong directional lighting is required
iv. the general lighting is obstructed

v. higher light levels are needed by a student with vision impairment

2.5.4 Lighting requirements for classrooms:

Table 4 quantities the factors discussed above and are adapted from AS 1680.2.3: 1994.

Table 2.4- specific recommendations for teaching spaces

Source: BRANZ Ltd-2007

Type of space	**Maintenance illumination lux**	**Lamp appearance group**	**Lamp colour rendering group**	**Maximum glare index**	**Comments**
Multi-purpose halls					
' general use	160	warm or intermediate	1B or 2	19	
' social use	80	warm or intermediate	1B or 2	19	
' examinations	240	warm or intermediate	1B or 2	19	
' theatre use					Special Requirements
General classrooms	240	warm or intermediate	1B or 2	19	
Workshops	240				with task Lighting
Art rooms	400 to 800	warm or intermediate	1A	16	see *Specialist Teaching Spaces*
Laboratories	320	warm or intermediate	1A or 1B	19	
Music rooms	320	warm or intermediate	1B or 2	19	
Textile craft rooms	320	warm or intermediate	1B or 2	19	task lighting
Gyms	320	warm or intermediate	1B or 2	19	see *Specialist Teaching Spaces*
Libraries	240	warm or intermediate	1B or 2	19	see *Specialist Teaching Spaces*

2.5.5 Lighting zones:

As a rule, all classroom spaces will have LED lighting organized into a number of zones and controlled from instructor's station through the AV control system and at the entrance doors. These zones can be combined and dimmed to create any number of different lighting scenarios. Classroom lighting should include day lighting, multi-modal lighting, controllability, and optimize energy performance. A room can be zoned based on the amount of day lighting available, with each fixture responding to the amount of light at any time and location. (UConn's Design-2016)

The zones described below are functional zones. There are five functional lighting zones in most classrooms (Fig 2.18):

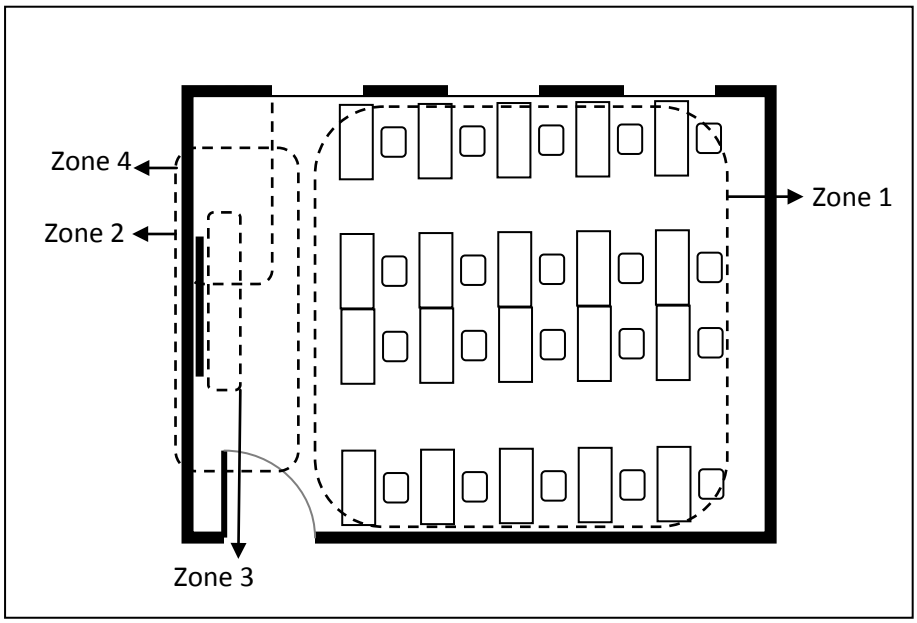


Fig 2.18-: lighting zones

Source: The author

Zone 1: **Main classroom lighting:** (student seating area) this zone services students and allows them to read and take notes in class. Use multi-directional recessed (lay-in) fixtures that cast a modest amount of light downward (35%) and a larger amount of light toward the ceiling (65%), provides a comfortable overall lighting with relatively high efficiency. Avoid pendant mount fixtures.

Zone 2: Instruction area: (front of classroom and lectern area). Design whiteboard and demonstration table lighting to provide visibility when the room lights are at full intensity. The foot candles in this area should be consistent with the overall lighting of the room.

Zone 3: Non-projection white board: (board that is not obscured by a lowered projection screen). Lighting of white boards during concurrent AV presentations allows instructor to write on the board while in projection, without light bleeding over onto the projected image.

Zone 4: Projection white board: (board that is obscured by a lowered projection screen) Use the same requirements as Zone 3 during non-projection mode.

Zone 5: Instructor workstation: The instructor should be able to read notes and use on-board AV equipment with low-light conditions of projection mode.

2.5.6 Selecting lamps:

Fluorescent lamps are suitable to light all teaching spaces.

Table 2.5- lamps types

Source: BRANZ Ltd-2007

1) General lighting (Type T8 or T5):	
• long life	
• high efficacy	
• good color rendering	
• low installation costs	
• can be dimmed	
2) Fluorescent lamp Type T8:	
• good energy efficiency	
• low-cost lamps and controls	
• lower mercury content	
• will run off standard or high frequency control gear	
3) Fluorescent lamp Type T5:	
• more compact than T8	
• highest efficacy	
• will run off high frequency control gear (which is more expensive but recommended)	
4) Use compact fluorescent lamps in task lighting luminaries and in place of tungsten lamps:	
• longer lasting	
• lower energy use	

2.5.7 selecting luminaries :

Luminaries are the total light delivery unit including lamps, lamp holders, reflectors, diffusers and control gear. One of the critical factors affecting the choice of luminaries is the way light is distributed (how much is directed downwards, outwards and upward).

There are three basic types of luminaries suitable for general teaching spaces:

3.5.7.1. recessed box (or trough) type for use in suspended ceilings:

- generally only suitable for suspended ceilings
- generally give direct light
- may be fitted with a range of diffusers
- may have a high degree of glare
- do not light the ceiling

Fig 2.19- recessed box type

Source: Google.com/images

3.5.7.2. Surface mounted box type:

- Suitable for most ceilings.
- May give direct light and some indirect light, depending on the design and type of diffuser used.
- May throw some light on the ceiling.
- Glare is reduced by some indirect lighting.

Fig 2.20- surface mounted box type

Source: Google.com/images 2018

3.5.7.3. Suspended (pendant) type:

- Suitable for most teaching spaces.
- May give direct light and a high proportion of indirect light, depending on design.
- Can light the ceiling.
- Minimum glare and even spread of light.

Fig 2.21- suspended type

Source: Google.com/images.2018

These are available with various types of diffusers, such as:

a) prismatic – which scatters the light
b) Louvered – which shields and directs the light . (BRANZ Ltd-2007)

The light distribution of luminaries may be:

- Direct – all the light is directed down to the working plane as it is with recessed luminaries.
- Semi-direct – some light is directed down and some is allowed to reflect off the ceiling and walls to light the working plane.
- Indirect – all the light is reflected from walls and ceiling to the working plane.

Fig 2.22- direct distribution

Source: BRANZ Ltd-2007

Fig 2.23- semi-direct distribution

Source: BRANZ Ltd-2007

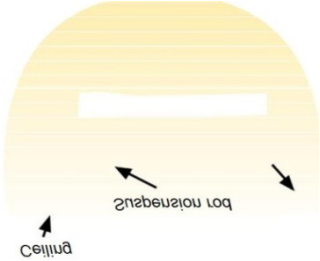


Fig 2.24- indirect distribution

Source: BRANZ Ltd-2007

2.5.8 Lighting controls:

Controlling the level of electric lighting can make large power savings. The simplest, cheapest type of control is manual switching. There is a tendency, though, for lights to be left on when they are not needed.

i. Initiate a power-saving regime and educate all users.
ii. Switching lights in groups.
iii. Manual control switches.
iv. Dimming – ability to reduce the light output from the system.

2.5.9 Classroom lighting layout:

Here are three possible layouts for typical classrooms or similar teaching spaces. They are not to scale and not lighting designs:

Scheme A (Fig 2.25): is an acceptable lighting installation because:

- The recessed lighting fixtures are arranged parallel to the windows to give good integration with daylight
- three rows of recessed directional luminaries will give a good spread of light at the working plane
- the rows of lights are switched separately so artificial lighting levels can be adjusted in zones to suit the level of daylight available
- the board is separately lit by a pelmet-type luminaries
- Occupancy sensor with manual on-switches will save power.

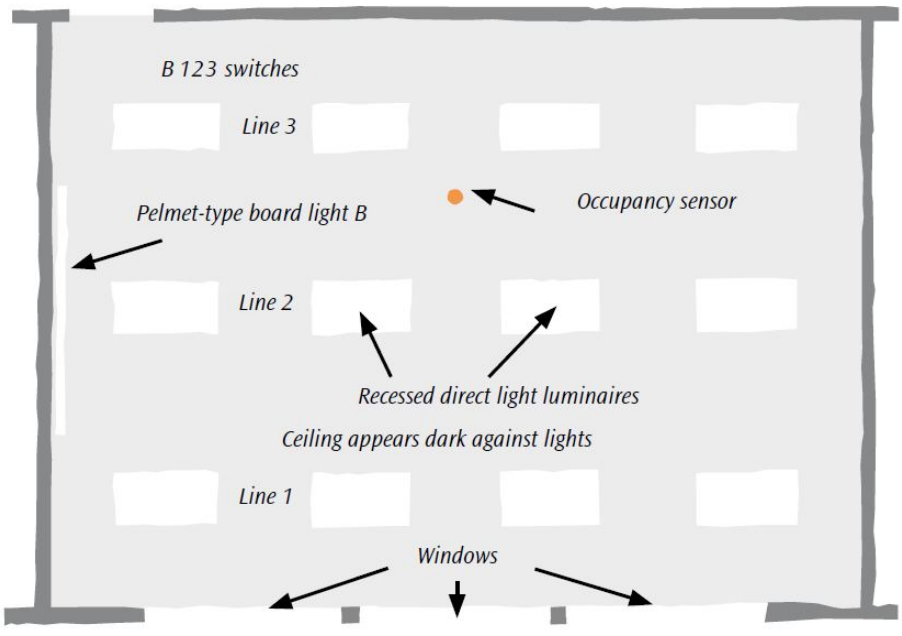


Fig 2.25- classroom lighting layout scheme A plan

Source: BRANZ Ltd-2007

Scheme B (Fig 2.26): is a better lighting installation than Scheme A because:

- surface mounted semi-direct luminaires will give a wider, more even, spread of light
- wider distribution of light will throw some light on the ceiling and walls, reducing glare
- wider distribution of light allows the economy of two rows of fixtures
- continuous luminaries reduce contrast and improve light distribution
- the board is separately lit by a wall washer-type luminaries
- Occupancy sensor with manual on-switches will save power.

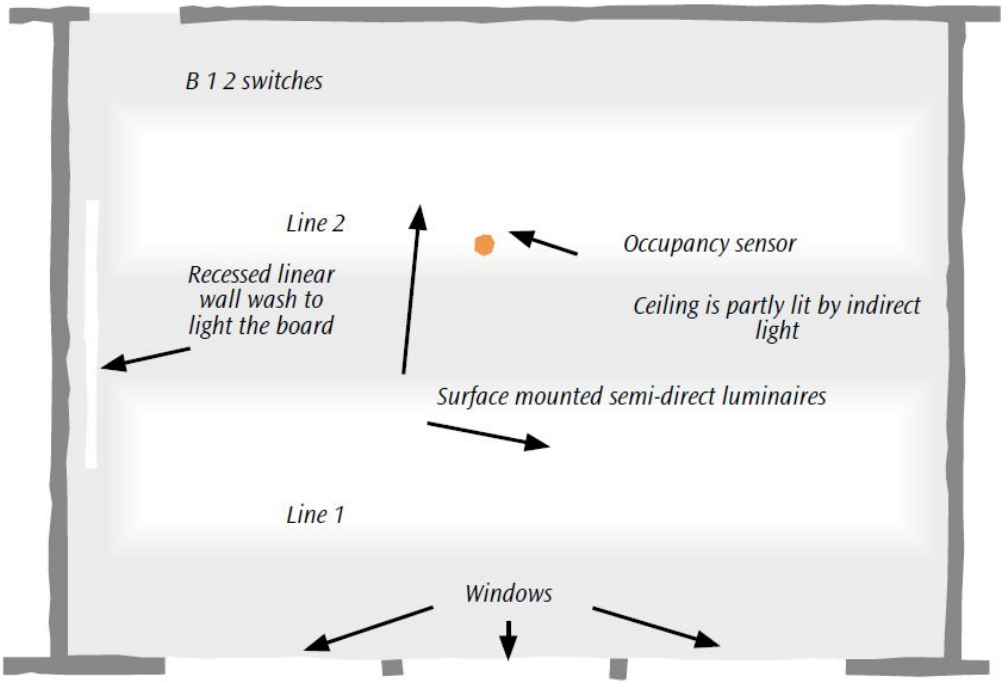


Fig 2.26- classroom lighting layout scheme B plan

Source: BRANZ Ltd-2007

Scheme C (FIG 2.27): is better than Scheme B because:

- indirect/direct pendant luminaries give a more comfortable, more even, spread of light
- the indirect light component lights the ceiling, reducing glare to a minimum
- the board is separately lit by a bracket-type luminaries
- it is the most cost-effective scheme
- occupancy sensor with manual on-switches will save power

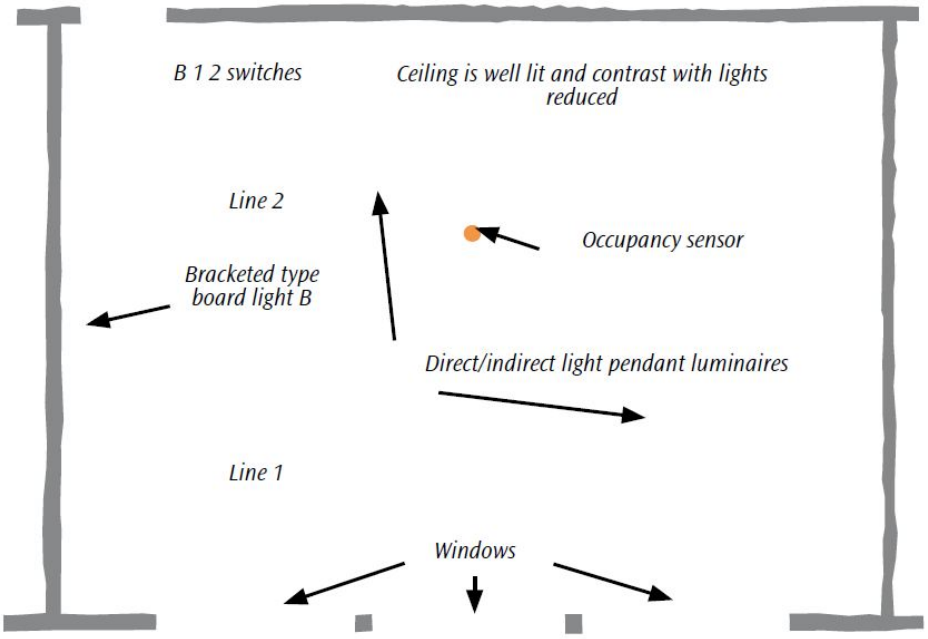


Fig 2.27- classroom lighting layout scheme C plan

Source: BRANZ Ltd-2007

3.5.10. Emergency Lights

Isolate emergency light radiation away from the projection screen.

3.5.11. Color Temperature

The color temperature for all light fixtures should be the same. The color temperature goal is 3200 degree Kelvin. Color temperature range of 3000-3500 degree Kelvin is acceptable as long as all of the fixtures are the same. (BRANZ Ltd-2007)

3.5.12. Motion Sensors:

Motion sensors are preferred in all rooms. When installing motion sensors, be sure to set timer to maximum to avoid light shut off during low-motion activities such as test taking.

2.6 Complementary lighting:

When daylight fades later in the day, on overcast days, or when additional lighting is needed for specific tasks, electric lighting supplements or takes over. This is a staged process.

To perform well and be cost-effective under changing circumstances, electric lighting design must be carefully integrated with day lighting design and be flexible. The installation must provide for:

- Close work lighting – often supplementary to daylighting so specific tasks can be carried out accurately and comfortably.
- Combined lighting – daylighting complemented by artificial lighting where the daylighting is reduced eg, in deep rooms or as daylight fades.

- Full electric lighting – when daylight is insufficient eg, in the evening or at night. (BRANZ Ltd-2007)

Fig 2.28- complimentary lighting in classroom

Source: BRANZ Ltd-2007

2.7 Classroom finishing & furnishing effects on lighting:

2.7.1 Colors/Finishes:

- Specify an anti-static, high traffic, commercial grade carpet tile. No solid or light colors are permitted.
- To accommodate classroom lighting and technology requirements, the ceiling height of all classrooms should be no less than twelve feet above the finished floor.
- Accent walls are desired. Avoid using accent color on front wall or walls that might reflect onto projection screen.
- Specify highly durable finishes that are easy to maintain.
- Use of approved “green” products in all applications is required.

2.7.2 Furnishing:

- Laminated work surfaces shall be constructed of high-pressure plastic laminate applied to solid wood or hardwood plywood. Tops shall have a non-glare. Medium tone surface to reduce eye strain.
- A high-fired, ceramic-covered steel, dry marker writing surface shall be provided in each classroom. (UConn’s Design-2016).

2.7.3 finishes reflectance :

Table 2.6- Approximate reflectance of various surface finishes %

Source: BRANZ Ltd-2007

White gloss tiles	0.85
White semi-gloss paint on smooth plaster	0.8
Light grey paint	0.7
White acoustic ceiling tiles	0.7
Natural radiata pine plywood	0.55
Mid grey paint	0.45
Varnished pine plywood	0.45
Varnished pinus radiata boards	0.3
Varnished particleboard	0.25
Dark grey paint	0.15
Carpet	0.1 to 0.45
Quarry tiles	0.1
Black paint	0.05

2.8 summary:

In order to ensure visual comfort in the classroom, the appropriate amount of lighting should be provided is 240 lux, which is obtained by integrating between natural lighting and artificial lighting.

Daylight is the main and important source for lighting in classroom, therefore the location of the classroom must be chosen correctly and placing the openings at 18% of the walls area with taking into account the light distribution and glare. The finishing of the classroom affects reflections and luminance, therefore the class walls and roof should be finished by light color with reflection ratio 70% for walls and 90% for ceiling, the floor reflection ratio is 40%.

The artificial lighting is distributed on the ceiling lamps, which ranges from 4 to 6 lamps according to the lamp luminance, and distributed it with one of the distribution types for classrooms to achieve the visual comfort.

Chapter three

CASES STUDY

Chapter three
CASES STUDY

3.1 Introduction:

Providing the optimal lighting is one of the major requirements for school classrooms, which is affect on student performance. So that must provide adequate daylight to improve the performance, energy saving and deal with power failure problems. Also an artificial lighting system must be added to get perfect lighting in all ambient environmental conditions.

Schools in Sudan faces allot of problems in lighting applications and power supplying. Lake of standardized criteria for classroom design in Sudan led to a variation in the use of lighting between different schools in the area.

3.2 Methodology:

The methodology used is the analytical descriptive approach, by studying two classrooms in different schools in Khartoum which has been chosen according to the criteria, (Cambridge Primary School in Almamora and Imtidad Nassir primary school) This will be conducted by describing the classrooms in terms of: The place and orientation of the classroom, Weather on the day of the case study, Dimensions and finishes of the class, Daylight and artificial lighting.

The cases have been studied by taking lighting measurements in different places in the classrooms and comparing them with the standards. Ordinary camera and lux meter application were used for taking measurements.

3.3 Study area:

The lighting of classroom; natural and artificial both, was studied at two different schools in Khartoum city, which is located at almost the northeast center of the country 15 and 16 degrees latitude north, and between 31 and 32 degrees longitude east.

Khartoum features a hot desert climate with a dry season occurring during winter. The sky is clear most of the year months, accept rainy months; July, August and September it's cloudy.

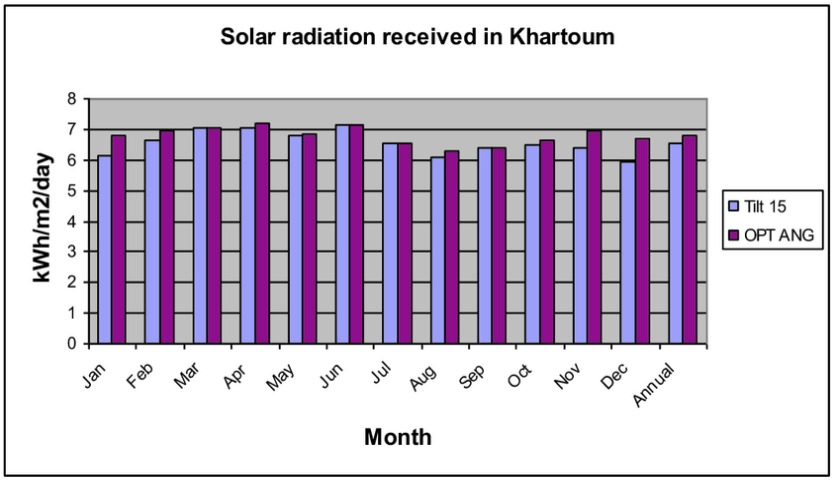


Fig 3.1- solar radiation received in Khartoum

Source: Google.com/images

4.4 Criteria of choosing cases:

The schools in Khartoum can be classified into two types; open space schools and multi-storey schools.

i. The open space schools like governmental schools, private schools in rural aeries and old schools. This type of schools has an open form and most of them are built as a school.

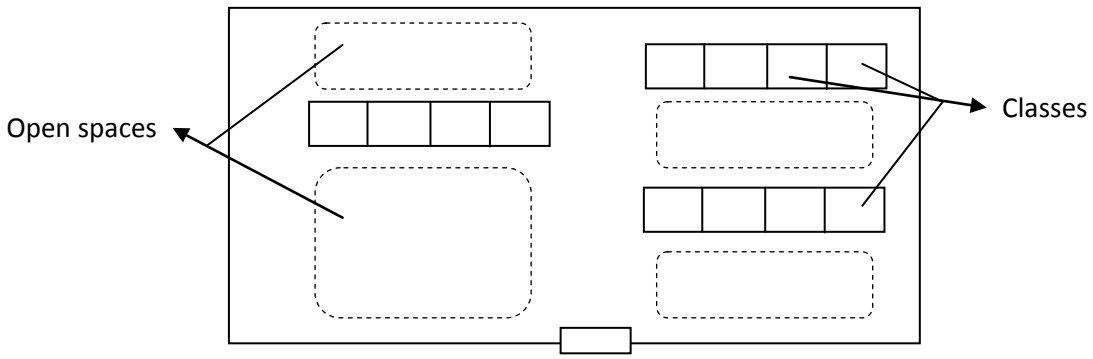


Fig 4.1- open schools form

Source: The Author

ii. The multi-storey schools like most of the private schools and the international schools. It's usually tenant buildings (Originally they were residential buildings).

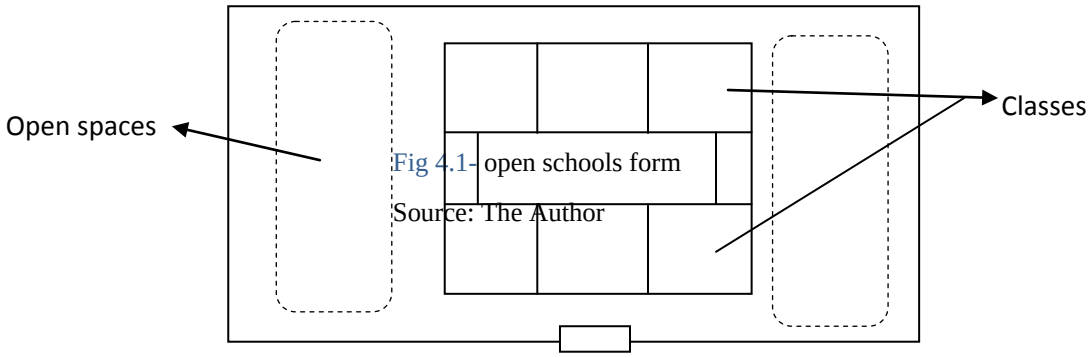


Fig 4.2- multi-storey schools form

Source: The Author

3.5 Case study (1) Cambridge international primary school:

3.4.1 General information:

The school is located in Khartoum – almaamora, in the South part of Khartoum city. The Cambridge Complex is the largest pre-university education complex in Sudan (Fig 3.3). It is located on an area of 4000 square meters and consists of 6 floors containing more than 120 classrooms, in addition to laboratories, halls and external spaces.

Fig 3.2- Cambridge international school

Source: The Author

Fig 3.3- Cambridge international school site

Source: Google.com/Maps

3.4.2 Classroom description:

a) Place and orientation:

The classroom (A) located on the north side of the fourth building, it was facing the outer courtyard from the north and the corridor from the south, that corridor was a part of the internal semi shaded courtyard (Fig 3.4).

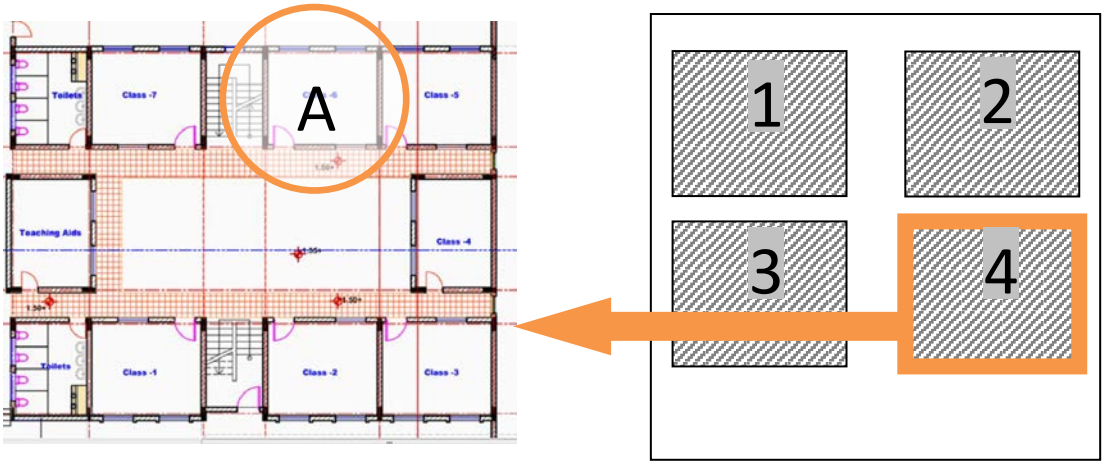


Fig 3.4- classroom (A) location

Source: Eng. Tayseer Musa

b) Dimensions and finishes:

The classroom has a white ceiling and light yellow walls. The measurements were taken with furniture inside the classroom. The classroom has more or less a square shape with dimensions of 6.0 m x 4.75 m and ceiling height 3.15 m. it has two windows on the south side and one on the north side, all of them are made from aluminum (see fig 3.5). It has variable furniture, white board, small cabinet, plasma screen and some accessories (such as a wall clock and junk packet) Fig3.6.

Fig 3.5- classroom (A) plan

Source: The Author

Fig 3.6- classroom (A) finishes

Source: The Author

3.4.3 Lighting description:

a) luminaries:

By using luxmeter application in a Smartphone the luminaries in the classroom has been measured. Table (3-1) shows the luminaries measurement in the middle on the whiteboard and the outer left and right part of the classroom. The measurement was taken with and without electric lamps.

The classroom has four led lamps 60*60 cm (fig 3.7), and there was no asymmetric board lighting.

Table 3.1- classroom (A) luminaries measurement

Source: The Author

	Luminaries (lux)		
	A	B	C
With electric lighting	255	250	154
Without electric lighting	17	12	15

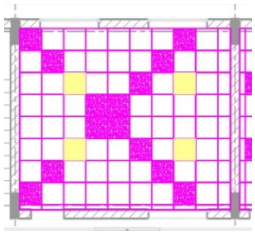
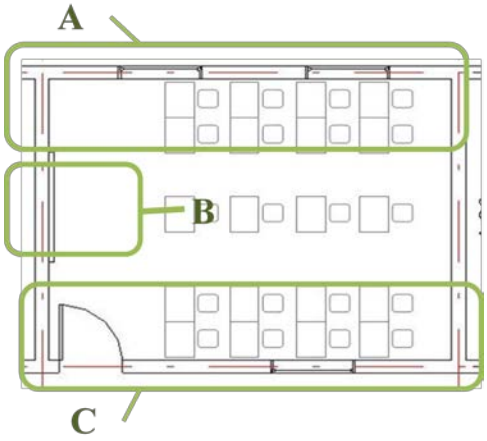


Fig 3.7:- classroom (A) lamps layout

Source: Eng. Tayseer Musa



b) Access to daylight:

The daylight factors were measured on 24 June 2019 in a clear sky. The sun was leaning south because the season was summer, and leaning east because the time was 11:00 am in afternoon.

Table (3-2) show the daylight situation of the classrooms with daylight factors measured on a regular grid on table height (0.75 m)

Table 3.2- daylight factors in classroom (A) in student table height

Source: The Author

	Window zone	White board	Corridor zone
Daylight factor (%)	0.06	0.04	0.05

Figures 3.8 and 3.9 show luminance pictures, taken with a luminance camera with panoramic view, from the back-side of the classrooms. It shows the situation for a sitting student with eye level on 1.2 m. The figures show the daylight situation with and without electrical lighting.

Fig 3.8- classroom (A) with electrical lighting

Source: The Author

Fig 3.9- classroom (A) without electrical lighting

Source: The Author

3.4.4 Results:

- The artificial lighting is well chosen and distributed in the classroom.
- The daylight in the classroom was not enough, due to the lack of opening spaces in the class. This problem is not contributing to energy saving and being affected by the power outage in Khartoum.

3.6 Case study (2) Imtidad Nassir primary school:

3.5.1 General information:

The school is located in Khartoum – Imtidad Nassir, in the north part of Khartoum city (Fig 3.11). It is located on an area of 6,500 square meters and consists of three ground floor buildings; each one has three classrooms and two offices.

Fig 3.10- Imtidad Nassir School

Source: The Author

Fig 3.11- Imtidad Nassir School site

Source: Google.com/Maps

3.5.2 Classroom description:

a) Place and orientation:

The classroom (B) located on the south side of the school; it was facing the outer courtyard from the north and the corridor from the south (Fig 3.12).

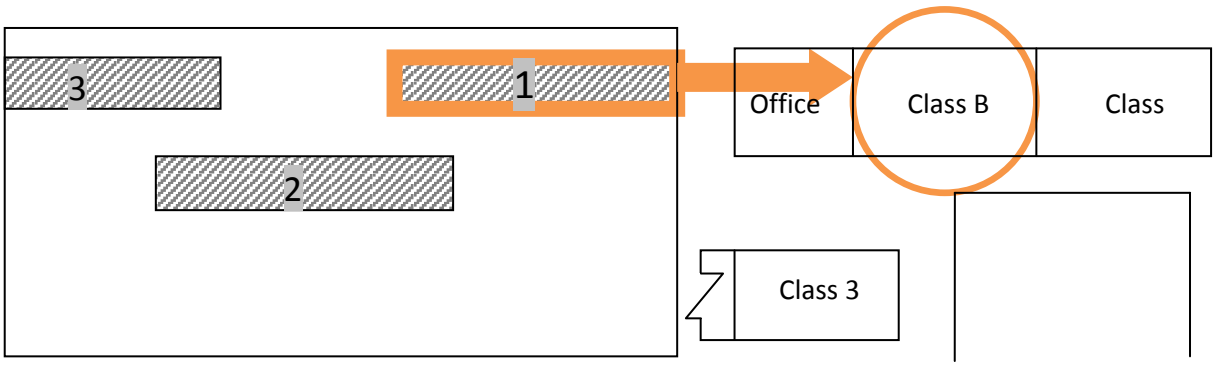


Fig 3.12- classroom (B) location

Source: The Author

b) Dimensions and finishes:

The classroom has an iron roof without ceiling tiles. It has light yellow walls. The measurements were taken with furniture inside the classroom. The classroom has more or less a square shape with dimensions of 7.50 m x 4.70 m and ceiling height 4 m. it has four windows on the south side and three on the north side, all of them are made from iron. It has variable furniture and a black board (see fig 3.13 and 3.14).

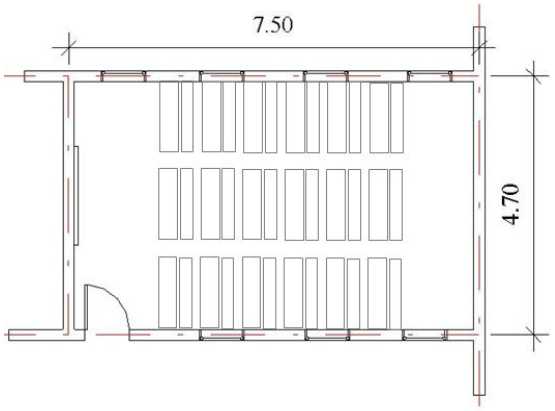


Fig 3.13- classroom (B) plan

Source: The Author

Fig 3.14- classroom (B) finishes

Source: The Author

3.5.3 Lighting description:

a) luminaries:

By using luxmeter the luminaries in the classroom has been measured. Table (3.3) shows the luminaries measurement in the middle on the blackboard and the outer left and right part of the classroom. The measurement was taken with and without opening windows.

There was no electric lighting and asymmetric board lighting; the classroom is totally depending on the daylight.

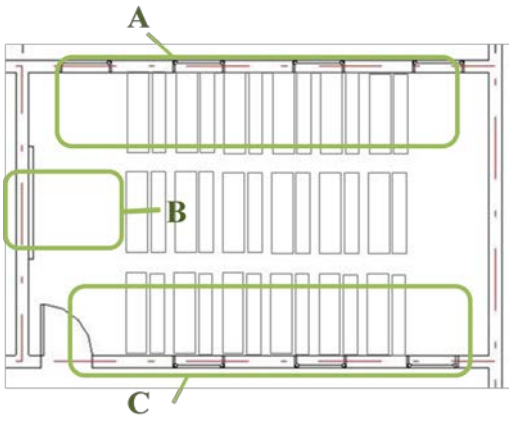


Table 3.3- luminaries measurement

Source: The Author

	Luminaries (lux)		
	A	B	C
Without electric lighting	110	64	170

b) Access to daylight:

The daylight factors were measured on 15 January 2020 in a clear sky. The sun was leaning north because the season was winter, and leaning west because the time was 2:00 pm in afternoon.

Table (3.4) show the daylight situation of the classroom with daylight factors measured on a regular grid on table height (0.75 m).

Table 3.4-daylight factors of classroom (B) in student table height

Source: The Author

	Window zone	White board	Corridor zone
Daylight factor (%)	0.4	0.25	0.6

Figure 3.15 show luminance pictures, taken with a luminance camera with panoramic view, from the back-side of the classrooms. It shows the situation for a sitting student with eye level on 1.2 m.

Fig 3.15- classroom (B) daylight situation

Source: The Author

3.5.4 Results:

- There is no electric lighting in the classroom and the day light is not solved and prepared to be instating of it.
- The daylight in the classroom was enough, but the finishes inside the classroom are lake to use all of this daylight.

3.7 Comparison between case studies:

Table 3.5- comparison between case studies

Source: The Author

	Standard	**Classroom (A)**	**Classroom (B)**
Illumination (LUX)	240 lux	225 lux	113 lux
Daylight factor (%)	1.5 %	0.06 %	0.6 %
Openings	18 %	7.6%	7.3%
Finishes reflection: Ceiling Walls Floor	 90% 70% 40%	 90% 66% 45%	 20% 55% 36%
Lamps	6	4	0

Chapter four

CONCLUTION AND RECOMMENDATIONS

Chapter four
CONCLUSION AND RECOMMENDATIONS

4.1 Summary of conclusions:

1) Most of the open schools don't have lighting system and someone have no lamps in the classrooms. That means they are completely depending on the sun light, and it was not distributed as well, so that the luminance on the classes is between 100 to 150 lux. (Standard luminance of classrooms 240-300 lux).

2) The windows have a big size and low distance from the ground. It hasn't sun breakers, so it causes glare, bad distribution of lighting and other heat problems.

3) The bad finishes of the classrooms reduce the light reflection and there are no solutions to optimum using of the sun light.

4) In multi-storey schools the finishes are good and it solves the light problems, the artificial lighting is well studied and designed, but they have a little space for openings and that is not enough because the electricity problems in the city.

4.2 Recommendations:

1) The researcher recommends that - regarding the basic school's design criteria- not to allow any school that violate rules and regulations to resume teaching .This will lead to better performance quality of the students and teachers.

2) A regular maintenance of the lighting in schools should be maintained and solve the problems in a short time.

3) Students and teachers to take care of the lamps and should report immediately if any problems arise to the competent authorities.

4) A further study should be carried out periodically to catch up the ever evolving technology regarding school classrooms lighting and to find alternative solutions for lighting problems in school classrooms in Khartoum.

4.3 Suggested solutions:

1) Change the color of the classrooms walls to a white color to increase the reflection ratio to 85%.

2) Add a suspended light over the black board to improve the optical performance for the students.

3) Add white ceiling tiles to the roof of the classrooms to increase the reflection ratio.

4) The sun power can be used for lamps in classrooms, it's the perfect solution in Khartoum because of its climate and economical problems, and this solution also helps on saving power and sustainability.

5) Use the sun breakers in the windows to reduce the glare.

6) Use the light diffuser shades.

Fig 4.3- lighting diffuser shade

Source: Google.com/images 2018

Fig 4.4- sun breakers

Source: Google.com/images 2018

List of References

1. BRANZ Ltd.2007: Designing Quality Learning Spaces. Lighting. Berlin. Ministry of Education.

2. Fördergemeinschaft Gutes Licht, 2016: Good Lighting for Schools and Educational Establishments.

3. UConn's Design Standards,2016: Classroom Design Guidelines. University of Connecticut.

4. James R. Benya, P E, 2001: Lighting for Schools. Benya Lighting Design. Washington. National Clearinghouse for Educational Facilities.

5. Brett Martin Daylight Systems Ltd, 2016: Design Guide. Daylight Systems for School Building Programmes. UK, Ireland Sales Enquiries. Close, Aldermans Green Industrial Estate, Coventry, West Midlands CV2

6. Truus de Bruin-Hordijk, Ellie de Groot, 2005: lighting in schools, Climate Design/Building Physics, Faculty of Architecture, TU Delft, The Netherlands**.**

7. Dahlan A. S, Eissa M .A.2015: The Impact of Day Lighting in Classrooms on Students' Performance. International Journal of Soft Computing and Engineering (IJSCE). Blue Eyes Intelligence Engineering & Sciences Publication Pvt. Ltd

8. Hansen E. K, Nielsen S .M, Georgieva D and Schledermann K. M, 2018: The Impact of Dynamic Lighting in Classrooms, A Review on Methods. Lighting Design, Dept. of Architecture, Design and Media Technology, Aalborg University, A.C. Meyers Vænge 15, DK-2450 Copenhagen SV, Denmark.

9. Read A, 2017: Integration of Daylighting into Educational (School) Building Design for Energy Efficiency, Health Benefit, and Mercury Emissions Reduction Using Heliodon for Physical Modeling. Rochester, NY. R I T.

10. James R. Benya, PE, 2001: Lighting for schools. National Clearinghouse for Educational Facilities. Benya Lighting Design**.**

11. Raynham P, 2010: Lighting Guide 5:Lighting Guide 5, Lighting in Education, Iain Macrae, society of light and lighting.

Arabic resources:

12. د. عبد المنطلب محمد علي .د. عبد الرؤوف علي. د.م، العزازي .م. الفيتوري . 2017. التكامل بين الاضاءة الطبيعية والصناعية لتحسين اللأداء البصري بمدارس التعليم الأساسي.القاهرة. مجلة أسيوط للدراسات البيئية.

13. د. سعود صادق. 2007. الإضاءة والصوتيات في المباني. دار جامعة الملك سعود للنشر.

Websites:

14. www.google.com

15. www.citcsudan.org

16. www.sciencedirect.com

17. http://cfo.asu.edu/fdm-ucl-space-mgmt

Interviews:

18. Eng.Almogera, 2019: Cambridge international primary school. Khartoum .almamora.

19. T. Asmaa Hassen, 2019: Imtidad Nassir primary school. Khartoum. Imtidad Nassir.