

Stavroula Angelaki

A design handbook

ACTIVITY-BASED LIGHTING FOR SCHOOLS

Edited by:
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All illustrations, if otherwise not mentioned: Stavroula Angelaki
This work is part of LiSE, a research project on Lighting in School Environments.

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Introduction

A

The following work focuses on lighting design strategies for educational spaces, and more specifically primary schools. This handbook outlines proposed steps and phases of analysis for classroom activities to understand and create a basis for design directions, concepts and criteria. In this case, the analysis and design focus on electric lighting for indoor spaces. The starting point for creating this handbook is the need and lack of design oriented output linking lighting to design and, specifically, educational spaces (Dudek, 2007). There is usually a misconception when referring to design disciplines as being more abstract focusing on aesthetics, without addressing technical criteria. The presentation of a design proposal without the structured analysis leading to it, results in a miscommunication of goals between the designer(s) and users. Even though that misconception is true, in some examples of design research, it is not a norm. The following work aims to explain, decode and communicate the steps and analysis, leading to design directions and design decisions within a research project. Rather than sharing the end result in the form of photographs, illustrations and measurements, it seems more appropriate to communicate and share the design process and the parameters that shaped the lighting design proposal. The information, photos and floorplans presented in this booklet are the result of several observation studies at a primary school located


in east-central Sweden. Therefore, the main limitation is related to the number of pupils and teachers. Nine study visits were performed across three academic years (2021-2024) at a Swedish school¹ to gather input for lighting related design choices. The observations focused on three grades (4-6 årskurs) during these years. As a result, the lighting proposal corresponds to the classrooms used by these grades. Additionally, the analysis and definition of the activities presented in the following sections are based on the teaching model (cooperative learning) used at this school. Cooperative learning is based, primarily on group work, and discussion sessions among pupils (Lee Manning & Lucking, 1991). Therefore, these activities might be different within the context of another school and a different educational approach (Abramczyk & Jurkowski, 2020)(Attle & Baker, 2007). The analysis describes the various activities taking place in the classroom, presenting how each one is initiated, what type of equipment is required, and which are the task areas the pupils need to focus on during a given assignment. The analysis results in outlining practical implications for practitioners interested in lighting for educational spaces. The aim of this handbook is to show the variability within a school classroom and not to create a basis for universal design solutions.



L I S E

Lighting in School Environments

LiSE is a research study focusing on the development of school environments. The current study is the result of the collaboration between KTH, Arkitektur skolan, Gävle Universitet and SWECO arkitekter. KTH is the project leader and the institution responsible for the main research study. Professors from Gävle are in charge of the pedagogic aspect and SWECO Arkitekter are responsible for the renovation of the school complex.



G O A L

Our goal is to develop knowledge and evidence how classroom design can support teachers and students.

O B J E C T I V E S

- Moving away from panel lighting.
- Lighting the various task areas instead of having the same amount of light in the space.
- Support alertness and relaxation through different colours in light.
- Placement and distribution of lighting for enhancing students' focus.
- Lighting that is energy efficient.
- Use of electric light in moderation and combination with daylight when the latter is available.

Figure 1: Leaflet summarising the research project's goal and objectives.

¹ Etikprövningsmyndigheten 2022-03601-01-340745 2022-12-08

B

Design process

A design process within a project can be both creative and systematic. However, it is fundamental to understand and communicate the reasons leading to a proposal. The future users of a space need to be able to comprehend, familiarize and identify themselves with the proposed design. To achieve this, the designer her/himself should be able to articulate and present the reasons and stages leading to their proposal. The process model in Figure 2 illustrates a series of proposed steps described in this handbok. Design criteria that should be considered by the lightign designer are proposed in official documents related to lighting standards, such as the EN 12464-1:2021 Standards and the ANSI/IES RP-3-20 (IES, 2020).

The starting point is the definition of the various activities that the classroom is used for throughout the day over the course of the year. These descriptions are the outcome of the observation visits at the school. The second step describes the analysis of each activity and in the following step each activity is the basis for defining the required lighting qualities. The final step, is a combination of different lighting directionalities to achieve these qualities. Further development on the lighting proposal should focus on the lights' placement and distribution, brightness, contrast, uniformity, CCT, CRi and color.

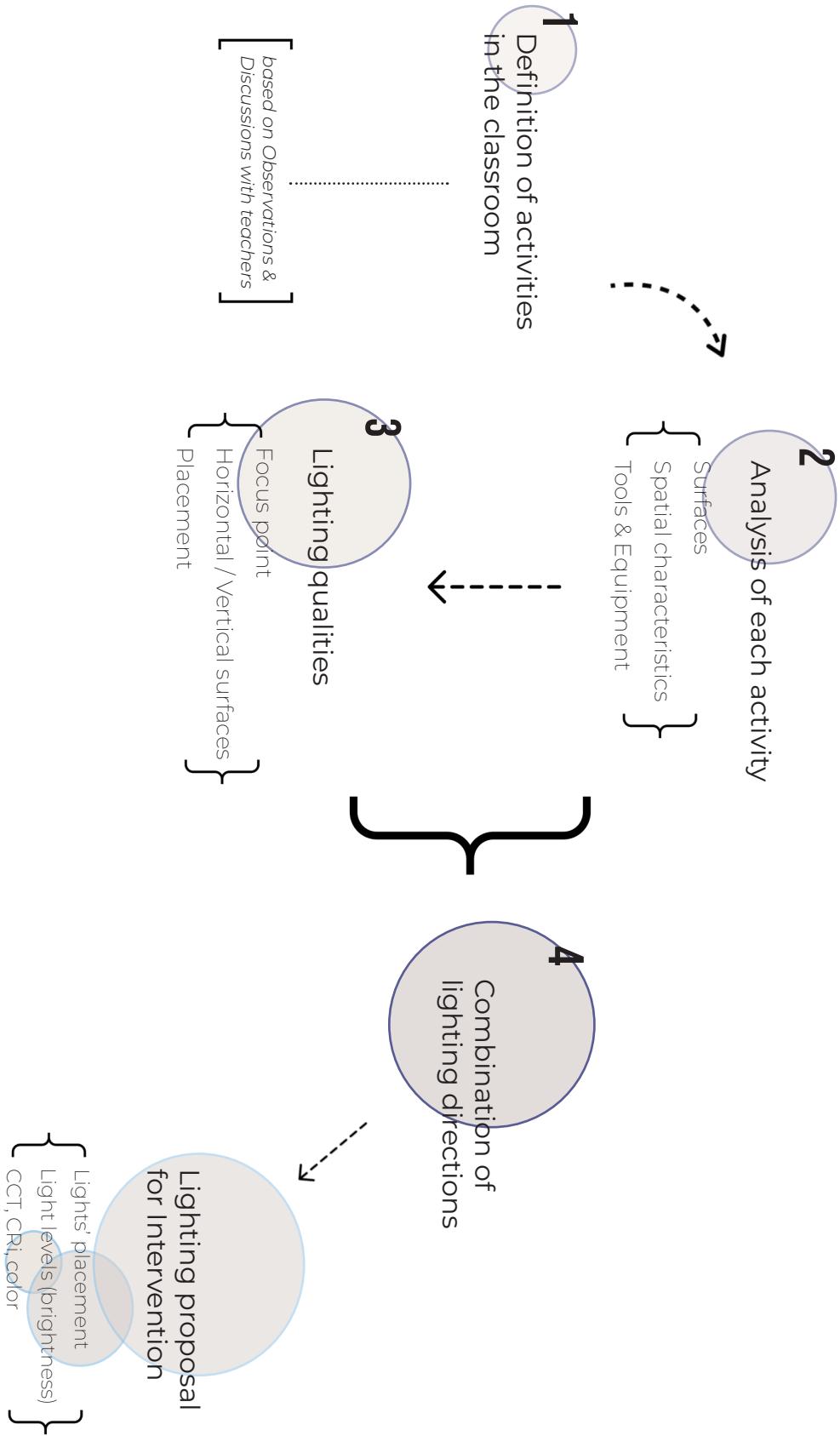


Figure 2: Process model describing the steps from educational activity to lighting requirements for the design process.

What about the lights' placement?

Lights are usually placed on the ceiling, and the primary reason for this choice is practicality. There is a tendency to perceive indoor lighting as “coming from above”, hence the ceiling appears to be the the right option. Typically, in most schools classroom lighting is distributed in a regular grid pattern or in equally spaced rows. This is done to provide an even distribution and to address different possible layouts in the space. However even in that case, the lighting layout does not need to be linear or grid-based. Classroom configurations are not stat-

ic and therefore a static lighting solution does not necessarily correspond to the classroom's need for flexibility (OECD, 2009). This need can be seen by comparing the 2023 plan and the 2024 plan of the same spaces (Figure 3) showcasing the differences in the same classroom's configurations over a few months.

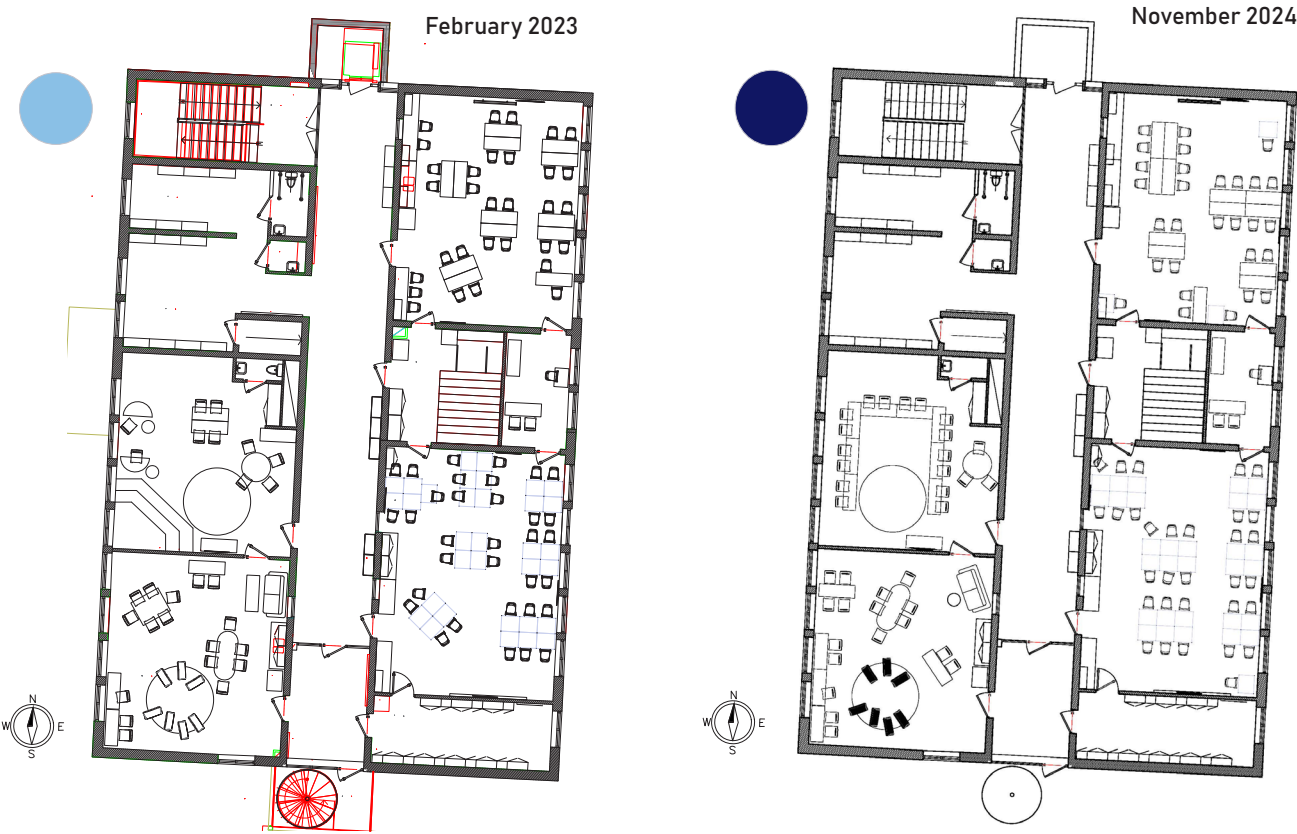


Figure 3: Second floor plans. These spaces/classrooms are used by grades 4-6. The left plan illustrates the furniture configuration in 2023 and the right plan illustrates the changes in 2024.

How does the lighting layout relate to the classroom's configuration?

The floor plans (Figure 4) presented below showcase the current lighting situation (left plan) and a light layout based on the desks' configuration (right plan). Considering the variability of furniture configurations, lighting should be designed to be able to adjust based on different furniture layouts and activities.



Figure 4: The left floor plan illustrates the existing placement of lighting. The right floor plan is a proposal on how lighting can be placed based on the furniture configuration.

C1 DEFINING CLASSROOM ACTIVITIES

Colour coding

- Teacher led activities (the teacher is the facilitator of the activity and, therefore, the person in focus)
- Pupils are in focus. They work either individually or in groups using a variety of equipment.
- The monitors are in focus. The pupils need to watch a movie. Low light levels are required.

Types of intermediate activities

- Pupils work on laptops individually
- Pupils work on books both individually and in groups
- Working in groups mean that pupils need to use additional spaces to the the main classroom. Therefore the number of pupils in the main classrooms is lower compared to other scenarios.

The information from the observation studies were compiled and used to categorise a series of classroom activities. These activities were then grouped based on their facilitator/main actor. Their description is as follows:

Teacher-led activities (grey): the teacher is the primary facilitator of the activity and, therefore, the person in focus.

Activities: The teacher presents, asks questions, and discusses with pupils using information presented on the monitors/smartboards.

Pupil-led activities (red): The pupils are in focus. They work either individually or in groups using a variety of equipment, and there is minimal interaction with the teacher.

Activities: Pupils work with books and/or paper; pupils work on laptops.

Monitor-based activities (purple): The monitors are in focus. The pupils usually are asked to watch a movie or video on the monitors. Low light levels are required to attract attention to the monitors by increasing the contrast.

Activities: Watch the movie/video, and pause to discuss.

In the following Figures related to this categorization, a color coding system distinguishes each group. As indicated, the colors showcase who leads the activity (teachers or pupils) or whether it is monitor-based. Seven distinct activities are mapped out. Six will be analysed in the following sections, after combining some of the activities.

How many different activities are there in the classroom?

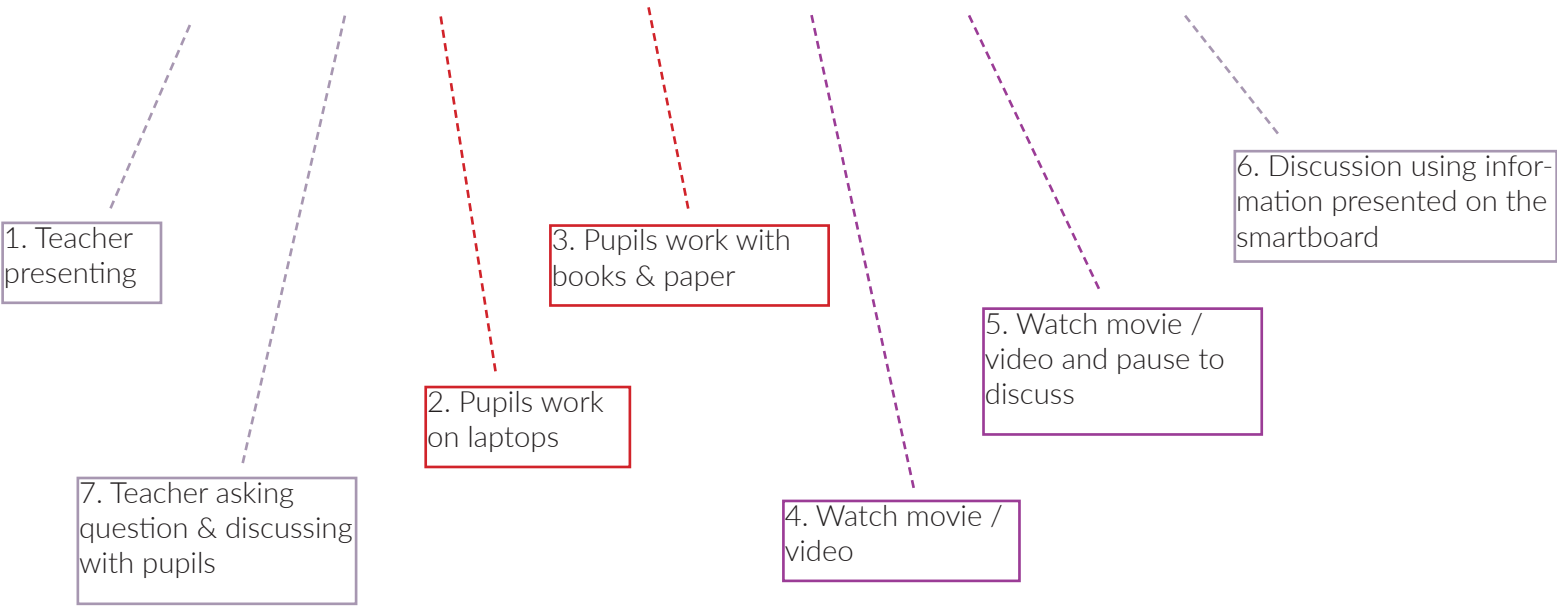


Figure 4: Mind map outlining the various classroom activities.

2 ANALYSIS

How to “read” this section

The following symbols/illustrations are used to help illustrate the analysis of the teaching and learning activities and their spatial needs. Each activity is then described in detail in the following section resulting in the outline of the recommended lighting qualities.

Colour coding

Teacher led activities (the teacher is the one facilitating the activity and therefore the person in focus)

Pupils are in focus. They work either individually or in groups using a variety of equipment.

The monitors are in focus. The pupils need to watch a movie. Low light levels are required.

Focus point

Task on desk

Multiple points (discussion)

Laptop

Monitor, board

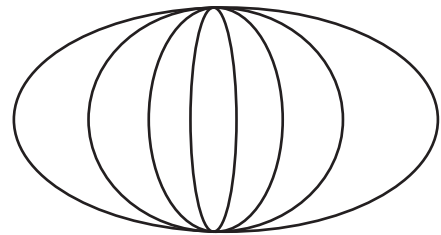
Working surface

Vertical plane

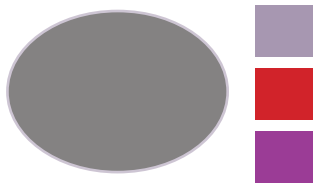
Horizontal plane

Each color represents a category of activities. These colors are used across the document.

The double ended arrows are used to highlight the main working surface for each task/activity.



The globe-shaped outlines are used to showcase a 3D representation of the head movements the pupils are required to perform in each activity.



The shaded areas indicate the focal points in space. Each photo sketch has different focal areas based on the activity.

Focus points: The areas in colour indicate the focus points during specific activities. The elliptical lines represent the potential range of head movements/visual field of pupils during certain activities.

Teacher led activities (the teacher is the one facilitating the activity and therefore the person in focus)

Figure 5: Classroom illustration with the task areas and focus areas corresponding to teacher-led activities.



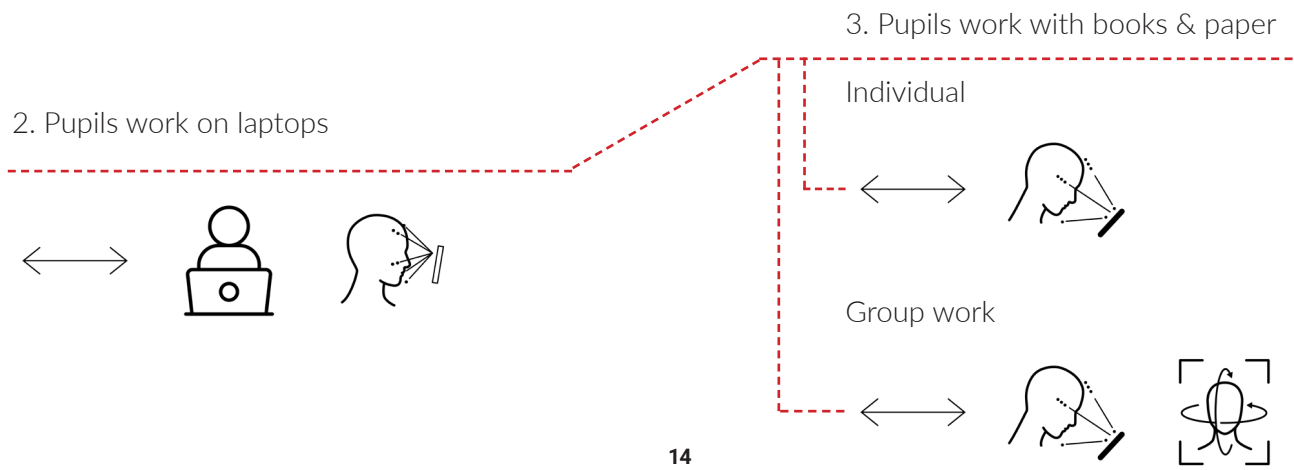
1. Teacher presenting

6. Discussion using information presented on the smartboard

7. Teacher asking question & discussing with pupils

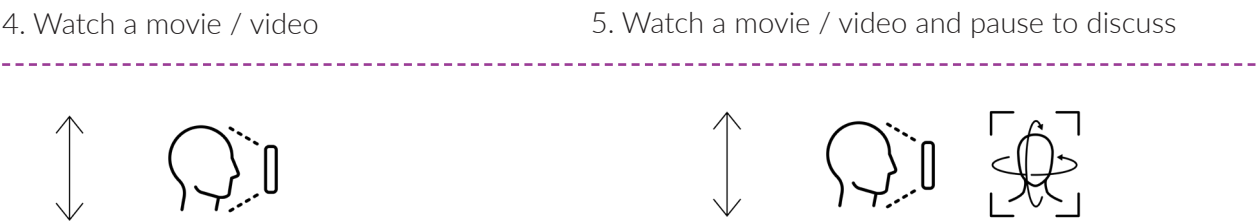
■ Pupils are in focus. They work either individually or in groups using a variety of equipment.

Figure 5: Classroom illustration with the task areas and focus areas corresponding to pupil-led activities.



■ The monitors are in focus. The pupils need to watch a movie. Low light levels are required.

Figure 6: Classroom illustration with the task areas and focus areas corresponding to monitor-based.



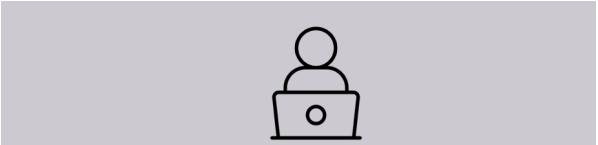
3 DEFINING LIGHTING QUALITIES

The following section presents each classroom activity and, subsequently, its corresponding lighting qualities. At first the activities in which the main actors are the pupils are presented, followed by the teachers’ activities. The last ones are the activities where the monitors are in focus. This subsection presents in more detail each activity resulting in the description of the lighting that is required based on the working plane, equipment and pupils’ point of view (head movements). At this point the authors did not include references to specific illumination levels and colour qualities of the lighting and related metrics. This analysis aims at describing the desired result for each activity unrestricted by quantitative requirements.

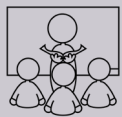
- 1. **Group activity:** The first type of activity is group assignment or group work. According to the school’s current teaching model, that is co-operative learning, group work is promoted in all courses, and the classroom layout is tailored to facilitate group-based working sessions between the pupils. Although certain variations apply to group assignments in different classes, in this study, group work does not consist of further categories. Group work is pupil-led, with minimum interactions between the pupils and the teachers. The teacher provides necessary instructions at the beginning of the group assignment. However, group work itself is performed by the pupils.



According to the observations during the study visits, books are used as a tool for most of the group assignments. As a result, the main task requires working on the desk. Therefore, the working surface is on a horizontal plane. Although the main task is placed on the desk, the nature of group assignments includes dialogue between the pupils to cooperate and proceed as a group with the assignment. As a result, there is not one fixed focus point but a combination of writing/reading (task on the desk) and discussing. The first task requires the pupils to be in a position where their head is tilted forward to look on the horizontal surface, while discussions between the group’s members result in various head movements. The lighting requirements are outlined by the type of activity, the required equipment, the working surface, and the number of head movements. Indirect lighting is also needed to illuminate the classmates faces, besides the necessary horizontal illumination so that the desk is appropriately illuminated for the pupils to work, read, and write. Indirect (reflected) lighting is required to support the discussion session through facial illumination so that expressions are visible and not distorted by sharp shadows.



2. Individual activity: The second type of activity is the individual activity. All kinds of individual assignments are included in this category, and more than one type of equipment is used. The pupils are still seated at group tables. However, they work individually. This activity is pupil-led, similar to the group assignment, as the interaction between the pupils and teacher(s) is minimal. For individual assignments, the pupils work using either books or laptops. Therefore, the working surface is mainly horizontal and semi-vertical when laptops are used. The pupils’ focus points are on the desk, and the laptop screen, so their head position indicates that they are looking either at the desk, where the book is placed or at the screen. For this activity directional lighting is prioritised over ambient illumination. However, since screens are in use, the lighting should be tailored so that it does not cause glare.



3. **Presentation:** The third activity is the presentation scenario. During this activity, the teacher is the leading facilitator and the person presenting. Presentations are part of every course in general, although, in some courses, they have a more significant role. This activity is teacher-led, meaning that the teacher performs and regulates it. The pupils refrain from actively participating during the presentation. There is a variety of available equipment related to this activity. All rooms have monitors on the walls, and the teachers can share their material directly using their laptops. Additionally, one of the classrooms has a smart board where the presentation can be shared, and there is the option of altering or editing the material using the board. Lastly, there are whiteboards in each classroom, although they are not widely used. All this equipment is placed on the walls, so the working surface in this activity, on behalf of the pupils, is no longer horizontal but vertical. As a result, the pupils look forward and towards the screen instead of looking at their desks. Since the focus point is now vertical, there is no need for high illuminance levels on the desks. Indirect illumination is primarily needed to have enough ambient and minimum directional lighting to avoid reflections on the screens. Furthermore, vertical illumination can decrease the contrast between the monitors/smart boards and walls, as they are illuminated surfaces.



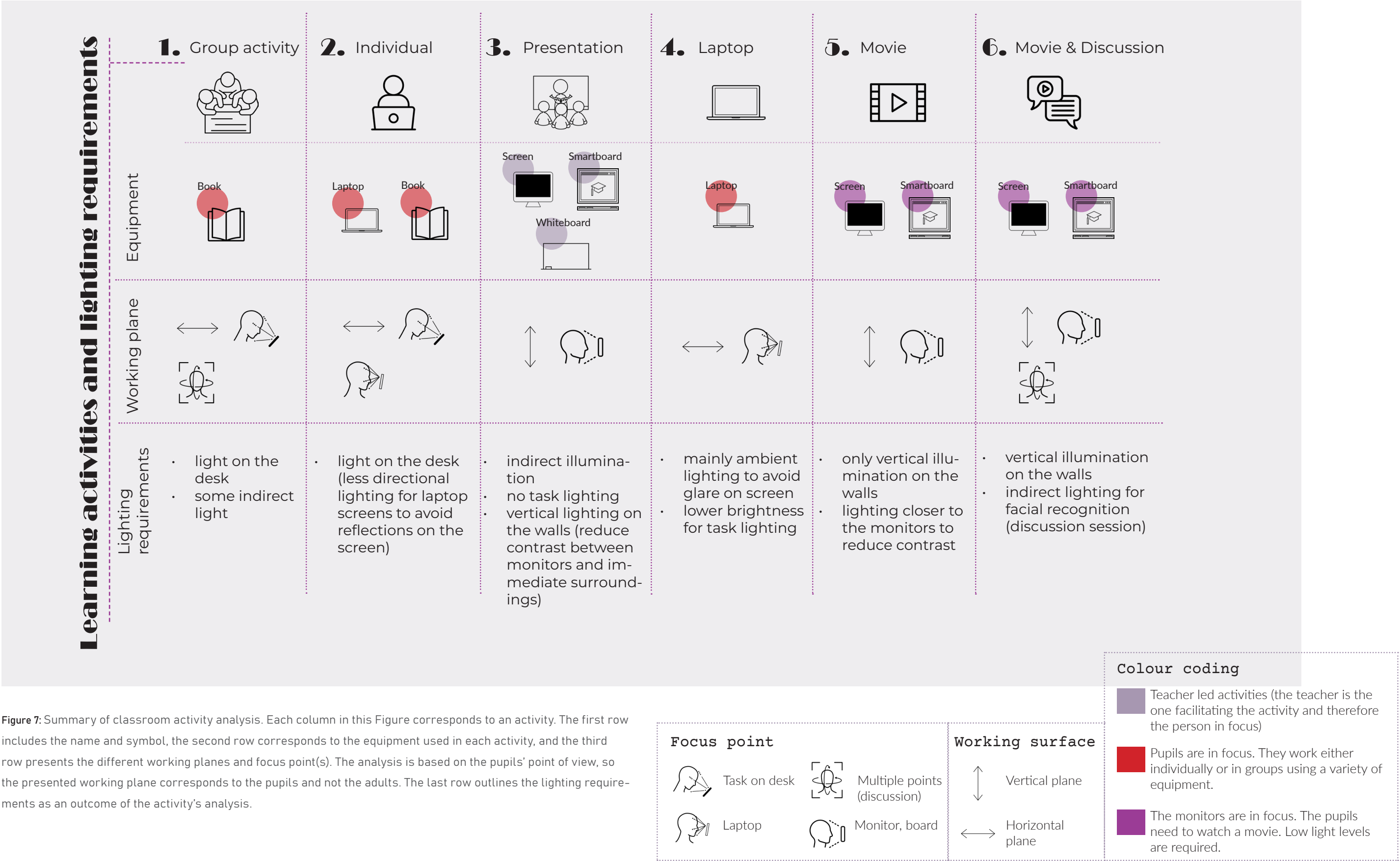
4. **Laptop:** The following activity is defined by the type of equipment. Laptops and screens, in general, are used more frequently today in school classrooms. Even though laptops have been identified as a piece of alternative equipment under the individual activity, it became evident that an additional activity is needed to correspond to the use of screens. It is another pupil-led activity, focusing on the tools the pupils use during the course. The type of screen can correspond to a laptop or a tablet screen, and the variable in this case is the screen's size. The working plane is horizontal, and the pupils' focus is on a semi-vertical surface. Considering that screens are surfaces that emit light, the brightness and contrast in the area surrounding the screen should be taken into account, along with issues of reflectance and glare on the screen. Consequently, the lighting requirements for this activity are primarily targeted at ambient and reflected lighting. Using the surrounding surfaces and, more specifically, the ceiling as an indirect component for ambient illumination, direct lighting can be avoided and, therefore, potential glare issues.



5. **Movie:** This type of activity was observed during specific courses, and the main components are the monitors and smart boards. It is one of the two monitor-based activities initiated by the teachers. The spaces analyzed in this project have 3-4 screens in the classrooms. There is about one monitor on each wall. A smart board replaces one of the three monitors in one of the classrooms. During a movie, what typically happens is that all lights are turned off so that the pupils can focus on the monitors. Based on the observation studies, the movies usually have a longer duration. These activities last for most of the teaching session, or even a whole session. There is no parallel activity during these screenings, so the pupils are asked to watch the movie and focus on the monitors. The working plane is vertical, as everyone's attention is on the wall, and the focus point is no longer on the desk but on the opposite vertical surface. Concerning the lighting requirements, no light is needed on the horizontal surface. Similar to laptop and tablet screens, the monitors are self-illuminated surfaces. Vertical lighting is required to reduce the contrast between the screens, as the only light sources, and the surrounding area. Vertical lighting is needed closer to the monitors and on the wall; there is no need for reflected or directional light throughout this activity.



6. **Movie & Discussion:** This activity is also monitor-based and has certain similarities to the "Movie" activity. During the "Movie & Discussion" sessions, the teacher uses a short video/movie to present a topic or initiate a discussion. In this case, the video's length is shorter compared to the "Movie" scenario, and there are pauses for discussion among the pupils, or questions from the teachers to the pupils. The working plane during this activity is vertical, and the focus point shifts from the monitor or board to the rest of the class and vice versa. As a result, contrast is still needed, so the main focus point is the monitor on the wall. However, an additional task requires adequate lighting for facial recognition. The lighting needed for this activity is a mix of vertical and reflected lighting. The vertical illumination, similar to the previous scenario, reduces the contrast between the monitor and the wall. The reflected lighting creates ambient illumination, avoiding harsh shadows and contrast on pupils' faces.



4 DEFINING LIGHTING SCENARIOS

The description and analysis of the different classroom activities resulted in the outline of the lighting needs. This subsection focuses on how these needs are translated and transformed into lighting scenes, focusing on light distribution and brightness.

The lighting scenes are named after each activity. Six scenes are introduced following the activities’ analysis. Figure 8 illustrates the requirements from the previous section in the first row and the suggested combination of lighting distributions in the second row. The last row showcases the brightness in percentage. The lighting scenes are presented in the order of the activities.

Before describing each scenario, a brief presentation of the chosen lighting equipment is presented. To move away from downlights within the research project, a combination of pendants and spotlights are used to illuminate vertical and horizontal surfaces when needed. The pendants have an uplight and downlight component, which can be programmed separately. The spotlights are used to illuminate vertical surfaces and are aimed toward the wall to avoid glare issues. There are three choices concerning distribution in

the following proposal: vertical illumination of the walls, directional lighting on the desks, and indirect lighting towards the ceiling.

Learning activities – Lighting Needs

- 1. **Group activity:** This activity requires horizontal (on-desk) illumination combined with indirect lighting for the discussion sessions. To balance the contrast between the directional and reflected lighting, vertical illumination using spotlights is added to light the surrounding vertical surfaces, considering that they are part of the pupils’ visual field during the discussion sessions. Indirect lighting is more intense for this light scene than the directional (downlight) component.
- 2. **Individual activity:** Horizontal lighting is prioritized for the second activity since the main task is on the desks. The pupils are expected to focus and work on their individual tasks; therefore, the lighting can be tailored and focused on the task area. The contrast in this light scene can indicate the nature of the activity, meaning that lighting is pointed towards the working surfaces. Therefore, indirect lighting is not the main component.

- 3. **Presentation:** The third activity requires primarily ambient lighting. The pupils focus on the teachers, and there are no tasks on a horizontal level. There is no direct lighting in this case. The desired distribution results from combining indirect lighting from the ceiling and vertical illumination on the walls. Reflected lighting creates more diffused shadows and allows for a more even distribution on a vertical plane.
- 4. **Laptop:** This light scene is tailored according to screens on a horizontal plane. Both laptop screens and tablets are additional light sources in the classrooms. The most common problem related to screens and electric lighting is glare (Winterbottom & Wilkins, 2009). To avoid glare, the directional lighting component is turned off, and the overall lighting is based on the reflected lighting from the ceiling. Part of the vertical surfaces are illuminated to avoid dark spots closer to the classroom’s corners.
- 5. **Movie:** The last two scenes raise questions related to the importance of having options with low light levels in school classrooms. In the Movie scene, only

the spotlights are used. According to the observations at the initial stage of the project, when the monitors are used to show a video/movie, all lights are off. As a result, the contrast ratios between the monitors and the surrounding areas are very high. Since the movie sessions might be as long as 30-40 minutes, the main issue that was addressed was the contrast. It was still necessary to create an environment where the monitors stand out and are the main focal point; however, by illuminating the wall closer to the monitor, the light faded away from the monitors in steps, lowering the contrast.

- 6. **Movie & Discussion:** The last light scene is similar to the Movie scene, although there is additional ambient lighting in this case. The indirect component from the pendants contributes to creating ambient illumination, although the indirect component is of secondary focus. The monitors are the main focal points indicated by the activity.



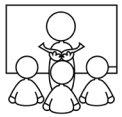



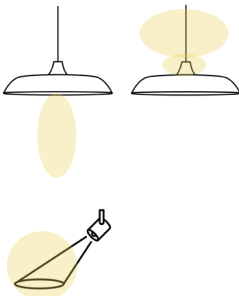
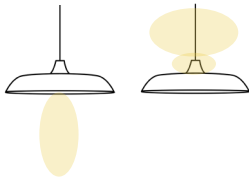

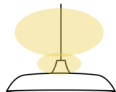




















Definition of lighting scenarios						
	1. Group activity	2. Individual	3. Presentation	4. Laptop	5. Movie	6. Movie & Discussion
						
	Lighting requirements					
	<ul style="list-style-type: none">light on the desksome indirect light	<ul style="list-style-type: none">light on the desk (less directional lighting for laptop screens to avoid reflections on the screen)	<ul style="list-style-type: none">indirect illuminationno task lightingvertical lighting on the walls (reduce contrast between monitors and immediate surroundings)	<ul style="list-style-type: none">mainly ambient lighting to avoid glare on screenlower brightness for task lighting	<ul style="list-style-type: none">only vertical illumination on the wallslighting closer to the monitors to reduce contrast	<ul style="list-style-type: none">vertical illumination on the wallsindirect, ambient lighting for facial recognition (discussion session)
	Lighting Distribution					
						
	Brightness (%)					
	<div> 60</div> <div> 100</div> <div> 60 (wall) 100 (window)</div>	<div> 80</div> <div> 90</div> <div> 0 (wall) 100 (window)</div>	<div> 0</div> <div> 80</div> <div> 80 (wall) 90 (window)</div>	<div> 0</div> <div> 100</div> <div> 0 (wall) 80 (window)</div>	<div> 0</div> <div> 0</div> <div> 70 (wall) 80 (window)</div>	<div> 0</div> <div> 60</div> <div> 90 (wall) 70 (window)</div>

Figure 8: Description of lighting scenes based on each activity.

Before & after photo registration

The photographs in Figure 9 illustrate one of the classrooms before and after the lighting intervention. The lighting is adjusted and programmed according to the scheme presented in the previous section. The “before and after” photos illustrate the visual differences in placement and brightness. Furthermore, it should be mentioned that daylight is present in these instances. Even though daylight is not part of the presented analysis, it should always be studied alongside electric lighting. Research in schools has revealed that daylight is beneficial for pupils and students, for example, affecting hormonal

levels and fatigue (Bellia et. al, 2013)(Mogas-Re-calde & Palau, 2021)(Dunn et al., 1985). Students in daylit classrooms perform better than in classrooms without daylight (Heschong et al., 2002)(Küller & Lindsten, 1992). Furthermore, changes in daylight provide a sense of time and orientation even in indoor spaces (Cuttle, 2003). Daylight can be a source of glare and considering the extensive use of screens in schools today (Edward et al., 1996), it is considerably challenging designing lighting as glare issues are more common (Winterbottom & Wilkins, 2009).

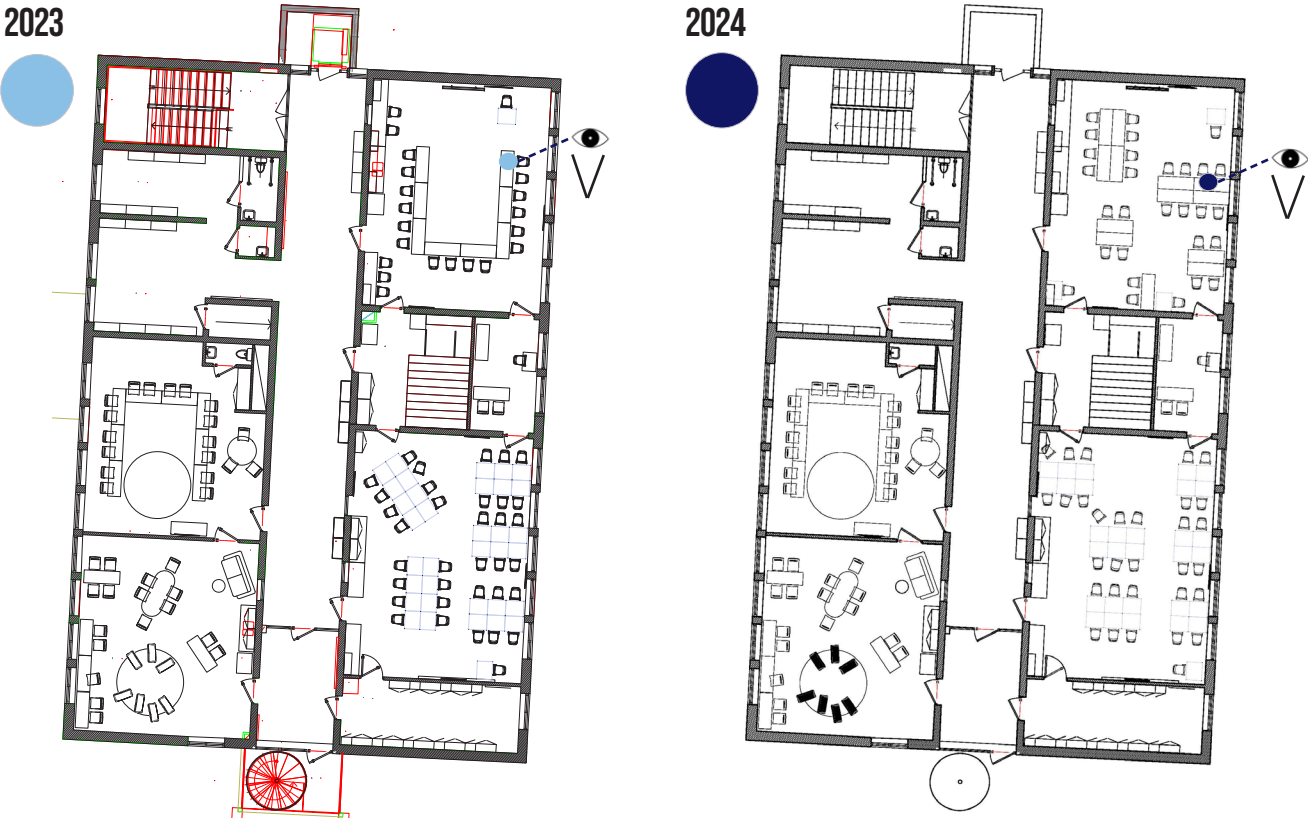


Figure 8: Location of photo registration on floor plan.

February 2023



February 2024



March 2023



March 2024



June 2023



May 2024

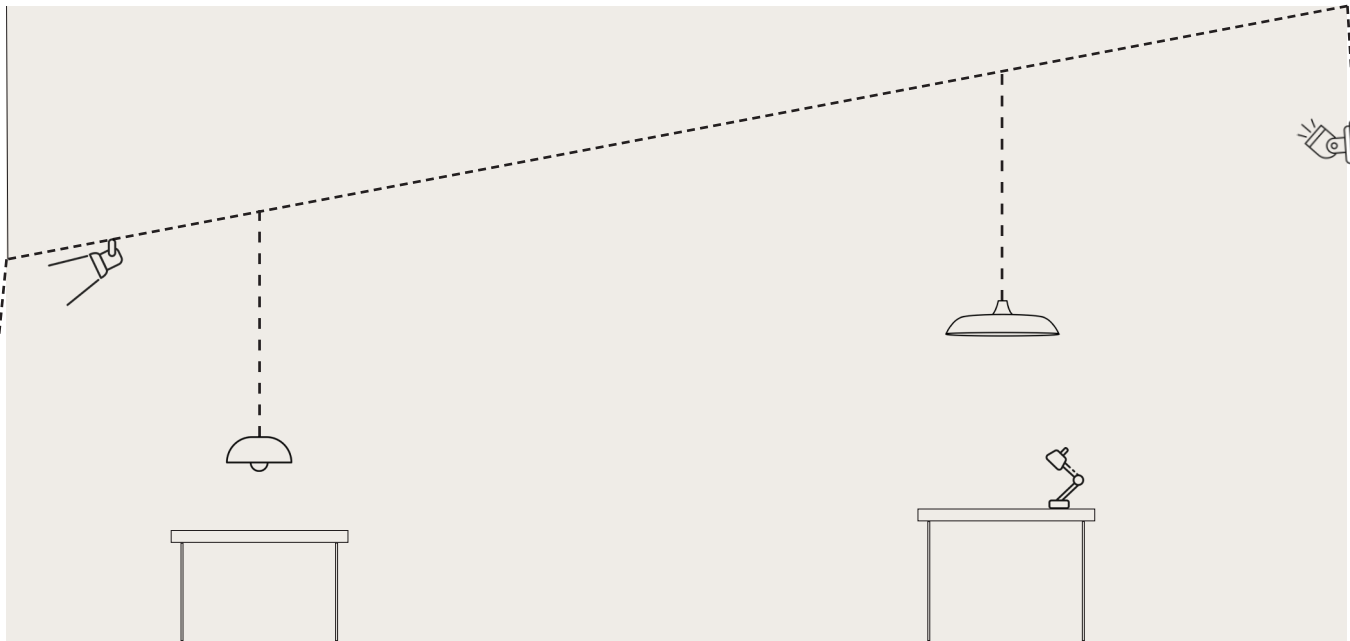


Figure 9: Photos from the fourth grade classroom before (2023) and after (2024) the lighting intervention.

D

Practical implications

How would the room look if we light up the surroundings and not just the desks?



What if we bring the light closer to children?

The analysis presented in this work aims to outline and suggest alternative design paths for lighting interventions in educational spaces. Based on the classroom’s activities the lighting is tuned and designed to support and follow the pupils’ and teachers’ daily rhythms. Considering the technological shift from fluorescent lighting to LED while keeping in mind that LEDs will likely also be replaced sometime in the future by a more advanced technology; we can take a step back to observe, discuss and interact with the pupils and teachers using these spaces. The input we can gain is more informative to address and inform the various needs in the design process than the equivalent replacement of old

lighting technology to the more current solutions. The following key points summarize the analysis steps that can be used by practitioners to inform their design.

- **Define the age group in question.** Within practice-based projects, there is usually limited time for each design stage. An initial analysis of the weekly curriculum and information regarding how often it changes during the year can indicate the number of hours each grade spends in different classrooms. Furthermore, teachers can provide input regarding the number of different classrooms each grade uses throughout the year.

- **Spatial analysis:** How many spaces/classrooms are used on a daily basis? Is there a pattern? The daily schedule can offer preliminary information regarding the use of different classrooms.
- **Furniture Layout:** Monitor the changes in the classroom’s layout. How often do they happen and why? Furnitures’ size varies with age and grade. It is a crucial detail for lighting both in terms of metrics (eg. horizontal illuminance levels) and distribution.
- **Lighting Layout:** Map out potential changes during the year, or ask the teachers or administration staff at the school. Are these changes related to the replacement of faulty

equipment or do they happen for a different reason?

- **Classroom Activities:** How many different activities are there? Register the equipment required for each activity and note the working surface’s orientation. How do these activities differ in each grade?
- **Illumination needs:** What are the lighting requirements for each activity? How can they be achieved?
- **Smart systems & Control:** Overly complex systems require additional time from teachers. Smart systems are beneficial if they do not become an extra daily task that burdens the users.

E

Conclusion

This handbook presents the steps in a design process that were used to develop a lighting proposal for a primary school located in east-central Sweden. The analysis and lighting design process presented in this document was based on a series of observation studies that took place at the school from 2021 until 2024. These observations provided the material to categorise and present a series of classroom activities. The analysis of each activity led to defining lighting requirements and a corresponding lighting scene. As a result six

lighting scenes were proposed to support and follow the activities performed in the classroom. The objective for the design process described in this handbook is to illustrate how these activities can become a basis for lighting design. Furthermore, this analysis provides an insight on the design decisions along this research project. A similar approach is suggested as a starting point to analyze other educational spaces with regard to age, grade and teaching differences.



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