Playgrounds in a New Light

An Exploration of Sustainable Lighting Design for Children’s Outdoor Play Spaces - A case study at Ringmuren preschool

RIKARD HULTMAN
PLAYGROUNDS IN A NEW LIGHT
A CASE STUDY AT RINGMUREN PRESCHOOL

RIKARD HULTMAN 2023
**Digital twin:**
A digital twin is a virtual representation or replica of a physical object or environment. It can be created and presented in a number of ways, but in this case it's a 3D model of an existing space, with accurate models, materials and other characteristics, allowing the user to test (lighting) scenarios and make informed decisions before making changes to the real world counterpart.

**Neural Radiance Fields (NeRFs):**
NeRFs is a machine learning technique that uses neural networks to extract 3D models from pictures and videos.

**Photogrammetry:**
Photogrammetry is a technique used to create 3D models or representations of objects or environments by capturing and analyzing photographs.

**Pilot project:**
A pilot project is a small-scale, preliminary initiative or experiment designed to test and evaluate the feasibility, effectiveness, or potential impact of a concept, idea, process, or technology before implementing it on a larger scale. It serves as a trial or proof-of-concept to assess the practicality, identify challenges, gather data, and make informed decisions about the future implementation or expansion of the project.

**Point cloud:**
A point cloud is a collection of data points in a three-dimensional coordinate system that represents the shape and characteristics of a physical object or environment.
Two phenomena form the basis for this thesis: bad lighting for children and our connection to nature. The former has somehow largely stayed unchanged through the years, the second one is rapidly changing for the worse.

Lighting in spaces designed for children in Sweden often seem like an afterthought focusing on the quantitative aspects, ignoring the qualitative; following standards but often forgetting who the space is meant for. At the same time, cities are becoming denser, making nature something many people actively have to seek out to experience - children's definition of nature is slowly changing.

How can outdoor lighting for children become better? Using the Ringmuren preschool in Uppsala, Sweden, as a case study, this thesis proposes an alternative way of thinking when designing light for children and how it can encourage a connection to nature. The design proposal was made using interviews, site analysis, research and experiments inside a digital twin custom made for Ringmuren preschool.

The direct result of this project is a digital twin and a lighting concept, but it also argues that the practicalities of analysing and designing lighting is one thing; getting the people in power to understand why good lighting is important is the first, and largest, hurdle. Producing good, affordable examples of good lighting design that can be applied to varying situations is a good place to start to at the least initiate a discussion.

Keywords: Preschool children, lighting design, digital twin, sustainability attitudes, sustainability consciousness, nature connectedness
Acknowledgments

Thanks to:

Inger B, Erik A-T and Erik B at Ringmuren preschool for being enthusiastic and welcoming, as well as giving me all the information needed to complete this thesis.

Ute Besenecker for giving me the opportunity to do this project at Ringmuren preschool.

Seren Dincel and Federico Favero at KTH for tips and feedback.

Anna F, Maria W, Zebastian L for research tips and insider knowledge.

Gloria L at Aalto University for the interesting discussion about the workshop.

Anna L at Biotopia for talking to me about the wildlife surrounding Ringmuren.

Katarina H for research tips.

Stavroula Angelaki, my tutor for this thesis. Thanks for all the good points, suggestions and feedback. Sorry for always asking questions at 3.30 on friday afternoons.
INTRODUCTION
Two phenomena form the basis for this thesis; bad lighting for children and our connection to nature. The former has somehow largely stayed unchanged through the years, the second one is rapidly changing for the worse.

A lot of things have happened since I was a child; while my time at daycare mostly consisted of free play and occasional timeouts, my son is getting an education. He is learning good values that will hopefully make him a good and considerate person, he is eating healthy food and he is receiving tools to solve real-world problems. The toys and spaces he uses are more thoughtful and sophisticated. But one thing still conspicuously missing is good lighting. Preschools follow the lighting standards (Standard - Ljus Och Belysning, 2021), but often seem to not realise that it can be used as a teaching/learning tool.

Well designed playgrounds that are fun to use during the day are dark and/or badly overlit during the darker hours, creating glare, worsening light pollution, affecting ecosystems and making play uncomfortable; big spaces that much of the year stand unused, as seen in Figure 1, 2, 3 and 4.

A child often can't put their finger on, much less express, why they don't like something or why they feel a certain way. Why do they feel tired, anxious or uncomfortable? This is often hard to know as an adult, but children usually have no point of reference, nothing to compare to, no concept of how things should be or what would make them feel good. They trust us to decide what is best for them, and we often fail them, especially when it comes to lighting.

The second phenomenon is our degrading relationship to nature. As more and more people move into the cities - resulting in environments with higher density - the definition of “nature” is changing. For many people experiencing nature is an active choice, something they have to seek out, to leave the city to do. As access to nature shrinks, so does our definition of what constitutes “nature”; as each generation is born, their baseline of what counts as nature shifts, usually lowering the bar (Giusti et al, 2014; Kahn, Jr., & Weiss, 2017; Schultz, 2002). While physical and mental wellbeing has been shown to benefit from spending time in nature (Dyment & Bell, 2007), another more systemic problem is that disconnecting from nature also affects our understanding of and empathy for it. Several studies have shown that an early connection to nature is related to caring for it later in life (Kareiva, 2008; Price et al., 2022; Wells, & Lekies, 2006; Zaradic et al., 2009). We have known for a long time that our current way of living is unsustainable and it is also nothing new that we have all we need to change the current downward spiral; what needs to change is our attitude to climate change, to nature and how we fit into what is happening. As with previous generations, current adult generations are doing little to turn the boat around and as a child or adolescent it’s all too easy to feel a deep hopelessness; how can I possibly make a difference now? A number of studies have identified what some of them call “eco-anxiety”
(Crandon et al., 2022; Hickman, 2020; Marks et al., 2021; Olsson & Gericke, 2016), which can lead to “depression, anxiety, and extreme emotions like sadness, anger, and fear”, resulting in denial or, in a “best” case scenario, hope as a coping mechanism (Léger-Goodes et al., 2022). Current studies have no answers on how to address this, and it’s unfortunate that the “solutions” seem to be emotional support to cope, but a good place to start would be to let children spend time in nature, to give them tools and knowledge to understand and develop empathy for nature, creating incentive to try to solve the problem instead of letting it overwhelm them.

The current discourse on climate change and what to do about it seems to be telling people what not to do and what to give up - stop eating meat, stop consuming, stop travelling - all good things, but without giving viable alternatives probably only leads to apathy and antipathy (Dodds, 2021).

This project aims to address the following UN Sustainable Development Goals: goal 3 (Good health and well-being), goal 4 (Quality education), goal 11 (sustainable cities and communities), goal 13 (Climate action), goal 15 (Life on land) (THE 17 GOALS | Sustainable Development, 2015).

Trying to fix this with lighting is undoubtedly a tall task, but it’s my firm belief that sowing seeds as early as possible is the best way to create lasting interest and change. This thesis will focus on one preschool, Ringmuren, in Uppsala, Sweden - one small corner of the world - but I can think of no better place to start. I will explore how to create an environment that promotes play and exploration, a place that hopefully instils some sense of wonder and lasting memories.

Ringmuren preschool in Uppsala, Sweden, have been requesting lighting for their outdoor play area for almost ten years. When the municipality at long last responded, they did so by putting up strong spotlights - seemingly at random - that flood the small forest with light at night, arguably making the situation worse (Figure 5). With Ringmurren as a central point this thesis will explore the topics mentioned above, but it should also be seen as a pilot project. While Ringmuren is a perfect site for this kind of project with its access to nature and a staff that is sympathetic to making these changes, the end result of this investigation will be a concept and an example of better lighting design for children.

As a tool to achieve this a digital twin of the Ringmuren site will be created. It will be used to analyse the space and explore potential lighting solutions.
METHODS
DESIGN DECISIONS
3.1 Making design decisions: introduction and limitations

Many people care about the Ringmuren preschool; the principals (former and current), the teachers, artistic directors, researchers and now the author of this thesis. Ringmuren preschool teaches according to the Reggio Emilia principle (Reggio Emilias Pedagogiska Filosofi, 2023), that teach according to a set of principles, including (but not limited to):

- “the child is capable of constructing their own learning”
- “humans are natural communicators and children should be encouraged to express themselves”
- “the environment is the third teacher and must be enriching and supportive”
- “teachers are partners, nurturers and guides to children and help them explore their interests through projects” (Fide Digital, 2021), which means that, for example, the children work with long term projects and are a part of deciding what to focus on.

While designing the lighting for the schoolyard, there were a few aspects that needed to be taken into consideration. Some of them are practical, others more abstract; the physical layout of the space, the needs of the children and the teachers, the school curriculum and the surrounding nature are some of them.

3.1.1 Informal interviews

Informal interviews were conducted with the former principal of the school, recently retired, and with the current principal as well as with the artistic director of the school. Because this was a small group of people, the format of “informal interviews” (conversations, basically) - which allowed for a much more organic exchange of information - was chosen instead of surveys or questionnaires. The usage of the yard, the preferences and habits of the children, the general philosophy of the school, its history, the current and desired lighting was discussed, among other things. Contact with the staff was initiated even before the real project officially started, as all other decisions would depend on the information they yielded. The information was invaluable for understanding both the current use and the desired use of the yard. Attempts were made to talk to behavioural psychologists and lighting designers with relevant
experience, but due to time constraints and other circumstances this proved hard to achieve within the time frame of this thesis; a few answered that they were unable to help, others offered to have meetings at a later date. After several attempts, the initial intention to rely on these interviews shifted to a more scaled down version. While other views undoubtedly would have given different perspectives and ideas, the current situation is still a good one; as stated before, the staff of the school care deeply about the school and provided a good foundation for the project. There were also brief talks with a biologist familiar with the area and its wildlife, and a researcher at Aalto university that has previously conducted a workshop with the children of the school. Both were contacted after the first round of interviews; the staff mentioned that they had previously been in contact with the school.

The results of the interviews are presented, along with other information, below.

3.1.2 Decision parameters

After sorting through the collected information, a few areas were selected as interesting and will form the basis of the final lighting solution:

3.1.2.1 Encouraging exploration

During talks with the staff at Ringmuren, certain patterns emerged. Different parts of the schoolyard are used in different ways and some parts are rarely used at all. From the information gathered in the informal interviews, the yard was divided into zones (Figure 8):

A: Hide-y hole. This area contains more low vegetation in the form of young trees and bushes, as well as benches and a small grill, and according to the staff the children use it to hide things and themselves. The design should enhance this feeling of mystery.

B: The stage. Currently this area contains a small stage, or a flat surface, used for reading and relaxing. The physical stage might be removed in the future, but the space sits in a tiny clearing in the midst of a group of pines. This creates a natural room that can be utilised in many different ways and is a perfect spot for controllable lighting; colour temperature and intensity can completely change the mood and create opportunities for learning or play.

C: Along one edge of the fence is a collection of smaller trees that often function as a corridor of sorts while the children are playing. On one side is the preschool itself, on the other a tree stump (that the children often use a “motorcycle”) and a sandbox made from old logs. The connection between these points will be enhanced, also adding more pathways.
D: A more traditional sandbox with two playhouses. The teachers mentioned that the playhouses become very dark in late afternoon and evening, leaving an opportunity to make this space more interesting and exciting.

E: There are also spaces where the children usually don’t play that are mostly unused. One of the reasons it's not used as much could be that it's slightly harder to access and play in because of relative darkness, roots and a slight incline in the ground. This is a good opportunity to make this area more inviting and accessible.

Besides the site specific information, research into children and their interaction with playgrounds and nature was conducted. (Sumiya & Nonaka, 2021; Kyttä, 2002; Kyttä, 2006; Herrington, S. & Lesmeister, C., 2007; van Liempd et al., 2020)

3.1.2.2 Connection to nature

As mentioned in the introduction, an important part of this project is to encourage a connection to nature where possible. Where possible, the natural elements of the space should be highlighted and enhanced.

3.1.2.3 Interactivity with lighting

Creating a modern lighting solution also opens up to the possibility of using it as an educational tool. Adding lighting controls for selected lights and areas would give the teachers, and the children, the chance to create different moods, “rooms” and settings using light colour and intensity that could reflect what they’re learning or are interested in that particular day. The possibility to play with light and shadow will add opportunities for storytelling and exploration of the surroundings (Cavicchi et al., 2001; Fleer, 1996; Segal & Cosgrove, 1993).

3.1.2.4 Wildlife and light pollution

In a talk with the researcher of Aalto University, they said that the children had pretended to be animals, exploring imaginary warrens, holes, nests and lairs. This created some interesting questions; can light be used to emulate different “animal houses” or simulate the world as seen by animals. Can light even be used to teach the children about the habits and lives of actual animals - is there an opportunity to create feeding stations, perches and safe spaces where animals can be observed? In later talks with the biologist, however, despite desperately trying to find a way, the answer to the last question is “no”: The best lighting for wild animals is no artificial light at all. Because of this, this thesis will follow the general guidelines of minimising ecological impact and light pollution. This is of course a huge subject, but in general these are the guidelines followed:

- Avoid uplights
- Shield lights to make sure light trespass is minimised
- Dim lights and use warmer light temperatures
- Control lighting to limit its use to only when it’s needed.

(CORDIS | European Commission, 2023; Heathcote, 2019; Irwin, 2018; Ljusföroreningar Och Biologisk Mångfald, 2021; The Ecolight Project, 2023)

3.1.2.5 Who are the users of the space?

While the main focus is on the children, there is also the need for the teachers and staff to see what the kids are doing and making sure that everyone is safe. Therefore, the design will need to take both the children and adults into account. While the children are mostly concerned with play and exploration, the teachers will also, besides being able to observe the children, use the lighting controls to adjust lighting according to what activities are planned for that particular day, or for creating “scenarios” or direct play to certain areas.

3.1.2.6 In summation

Every one of the subjects chosen to be included in this project is a big one, but boiling all the information down to these basic points will act as a guide book for the lighting design.
3.2 Digital twin: introduction and limitations

Since this project is theoretical at this stage, and because the site itself is in use, making alterations and testing on site difficult, the lighting design will be made in a digital twin. This project will serve as a proof of concept for this workflow, an opportunity to test different tools and techniques.

Replicating structures and built environments in 3D is relatively easy to do, but making exact copies of nature is very complicated and time consuming and in this instance the time constraints for this thesis makes it impossible to do. Aerial laser scans, AI “photogrammetry” (or “Neural Radiance Fields” (NeRFs) (Neural Radiance Field (NeRF): A Gentle Introduction, 2023; NeRF: Neural Radiance Fields, 2020)), photos and videos has been utilised to get the basic layout of the site and positions of individual components, but because the data was collected with cheap equipment and under less than optimal conditions, the raw data could not be used in the actual model. Therefore the whole environment needed to be recreated by hand. This gives more control and detail, but it also means that the work is more time consuming. The model presented in this thesis is an approximation of the area around Ringmuren preschool; the important landmarks are created, but details will differ from reality.

3.2.1 Technical details on creating the digital twin

Before settling on the combination of software and data that was used in this thesis, research into different alternatives was done. Without budget, this narrowed the options, as later discussed in the “discussions” section.

3.2.1.1 Aerial point cloud

To be able to build a digital twin it was very important to get the basic site in place, to get points of reference for the areas of interest for this project. Several techniques were considered, including photogrammetry (GISGeography, 2020) using drones. The pros of photogrammetry include giving much more detail, and most importantly, visual data close to, or at ground level, while the biggest drawback is the amount of time and work it takes to post-process the captured data, most of which has to be done manually. Instead, the fastest and simplest solution was to purchase aerial laser scan data from Uppsala municipality. By far the
biggest drawback of this solution is the resolution of the data and the fact that it doesn't capture details under trees and structures obstructing the view from above. This means that while the basic layout of the area is present, all detail below the trees will have to be added by other means. The data delivered by Uppsala municipality is a "point cloud" of the area (Figure 10), which means that every point that the laser scanning device hits is represented as a point in 3D space, which also contains greyscale colour information (sometimes it contains colour information, but not in this case). It also means that the data has to be processed, cleaned and categorised by hand, which takes time, albeit much less than would have been the case with photogrammetry. To be able to use the data in a 3D program, the points have to be converted into a regular 3D model (Figure 11). This was done using "CloudCompare" (Girardeau-Montaut, 2023), an open source software designed for this purpose, "Houdini" (Houdini - 3D Modeling, 2023), a commercial software most often used in the VFX industry for final scene assembly and large scale effects.

3.2.1.2 Neural Radiance Fields (NeRFs)

Traditionally, the most common technique used for capturing 3D representations of reality relatively cheap and simple is with photogrammetry (GISGeography, 2020), which as mentioned, is time consuming. With the advent of AI/machine learning tools this has changed and for this project the decision was made to test a new (at least in an end-consumer sense) technique referred to as NeRFs, "neural radiance fields" (Neural Radiance Field (NeRF): A Gentle Introduction, 2023; NeRF: Neural Radiance Fields, 2020), which uses machine learning to extract 3D models from pictures and videos (Figure 12, 13 and 14). The end result is much the same as with photogrammetry, but the big advantage of NeRFs is that it is much faster and involves much less manual work; the tool used for this project is "Luma AI" and runs entirely in a web browser, with all calculations done on a remote server - the user only uploads a series of images or a video sequence. This technique is still very crude and still requires the photos and videos to be captured in a specific way, but it's quickly
becoming better and more accessible. In any case, neither photogrammetry nor NeRFs work well for small details, of which there are many in nature. This was acceptable, since the purpose of using this technique was to get information on the layout of the area and positions of individual elements. Once the positions of these are determined, they will be recreated by hand.

3.2.1.3 Digital details

Digital representations of trees, grass and bushes were created in “SpeedTree” (SpeedTree – 3D Vegetation Modeling and Middleware, 2022), a commercial software for creating vegetation, used in VFX and games (Figure 15). Buildings, playground elements and small details were modelled by hand in “Modo” (Modo, 2023), a 3D modelling software.

3.2.1.4 Assembling the pieces

After all the data is collected and processed, the individual pieces are assembled in Unreal Engine (Unreal Engine | the Most Powerful Real-Time 3D Creation Tool, 2023) to create the final digital twin. Unreal started as a game engine, a program to create games in, but is more and more used in architectural visualisation and VFX.

3.2.1.5 Calibrating the software

Even though this project is a concept, a theoretical proposal without specific luminaires or technical details in mind, for the sake of ease and consistency it was important to calibrate Unreal Engine (UE) to correspond as closely as possible to the real world. To do this several IES files were downloaded and loaded into both Dialux and UE. Since Dialux is well known for its accuracy, lights rendered in Dialux using the downloaded IES files were used as a reference and settings in UE were calibrated until the same look was achieved, in terms of light levels and CCT. As stated before, UE began as a game engine, where real world accuracy is not a priority and it’s unfortunately not trivial to make UE behave like the real world or traditional 3D renderers. However, with UE becoming more widely used in a number of industries, this will hopefully be addressed.

Figure 16 on the next page shows example views from the digital twin.
Figure 16: Four different views of an early version of the digital twin in daylight.
Figure 17. The “stage” seen from afar
4 Results

4.1 Design

When thinking of design meant for children it’s easy to think of shapes and colours, something that immediately grabs attention. The focus of this project is different in that the focus is on nature and how to keep/restore a connection to it in children and because of all the reasons mentioned in the methods section, as well as my personal preference, the design will be more low key and have a more natural feel. The decision was made to exclusively use white light, only changing colour temperature, and to not use any sort of gobos or moving light. The lighting will also not be a feature in itself, but will instead only highlight the natural or permanent features of the play yard itself. The current lighting at Ringmuren preschool is very harsh, creating big contrasts between lit areas and shadows, and this is also often a feature of playground lighting in general in Sweden (as stated in the introduction), therefore I aim to soften the light when possible; dim, diffused light will be the base of the design. In the methods section I briefly described the zones of the yard and while the design will have slight differences between them, they also work together as a whole.

The final lighting solution proposal is a patchwork lighting that together covers the entire area, if needed, but in everyday use leaves some areas darker than others. The patchwork approach gives a more visually interesting look, with some contrast than an even cover of light. To cover a larger area, wires are hung between existing (converted) light poles and luminaires added in a pattern. These luminaires are “two-headed”, with lights pointed in opposite directions, angled downwards at 45°. This way a bigger area can be covered with light than one downward facing light, while also allowing the users to turn individual lights on or off as needed. Different angles of light and different light distributions were tested and the combination that gave the best coverage was selected. In a scenario that allowed for real life testing, this would have to be compared, tested and confirmed. The catenary lights also light up the path outside the preschool. (Figure 18+19)
Zone A is a slightly overgrown area with seating and a grill. Here I replaced the existing benches with wooden mushrooms that besides working as seating are also downward facing luminaires illuminating the ground around the central section. The rest of the area will be slightly dimmer, keeping the feeling of a place where you can hide and play. (Figure 20)

Again, in terms of minimising the impact on the surrounding nature and sky, these general guidelines were followed:

- Avoid uplights
- Shield lights to make sure light trespass is minimised
- Dim lights and use warmer light temperatures
- Control lighting to limit its use to only when it's needed.

The stage, zone B, is actually not often used as a literal stage, but as a place to relax and read. It sits at the centre of the yard, slightly higher up than the rest, which gives the people sitting there an overview of everything happening. The four tree trunks framing it gives the feeling of sitting inside a room. Diffuse, dim lights were placed in a pattern meant for comfortable reading and playing. (Figure 17) A controllable spotlight, turned off when not in use, is placed between the “stage” and the school; if the weather permits, it’s possible to hang fabric between two or more of the trunks, creating a screen that can be front- or backlit, allowing for “stage lighting”, colour play using coloured glass/plastic, shadow play and storytelling using natural elements or shapes the children create themselves.

Zone C, or “the corridor” and its surrounding area is used by the children as a transport area (or just playing in general). There is a mixed assortment of thinner trees, thicker trees, stumps and rocks on the ground and right next to it is a gnarled tree stump referred to by the children as “the motorcycle”, as it's often used to sit on. By placing lights roughly along “the corridor”, a path is created, as well as an inside and an outside; a room in the outdoors. The lights can be controlled to create different paths and different constellations of “rooms”, allowing for variety in play and in the education.

The adjacent sandbox will be lit with diffuse overhead light to avoid hard shadows and glare when building sand castles. (Figure 21)

Zone D is a more traditional sandbox with play houses, nets and balance equipment. Since this area already has a function, and because it has to be relatively well lit to allow the children to use the play equipment, the lighting in this zone enhances already existing features. Diffuse, even light will allow the children to play safely. (Figure 25)

Zone E: This area is not favoured by the children. Perhaps because it’s a bit anonymous, perhaps because it’s a bit secluded, compared to the other areas, perhaps because it’s closer to the fence and the road outside. Three cylindrical light tables with a dim, illuminated surface will allow for examining leaves, pine needles, ice and other elements, as well as allowing for playing with transparent shapes and making art projects of different kinds. (Figure 22+23)

Keeping all these aspects in mind, the proposal aims to highlight the nature in the area, without drowning it out. By softly focusing on the already existing elements, instead of adding excessive “artificial” ones, the intention is to make the children interested in nature and to encourage natural play where possible. This will be discussed more in the “discussion” section.
4.2 Lighting controls

The brightness and colour temperature of all lighting can be controlled in groups or individually by the teachers, and lights can be grouped in such a way that it allows the teachers to let the children control and experiment with the lighting in certain areas at certain times.

Since this is a preschool, scheduled activities stop at around 16 - 17 in the afternoon. However, school and preschool play areas are often used by other children outside of school hours, extending the use and making the lighting solution useful several more hours. Ringmuren preschool is unfortunately located in an area that sometimes experiences vandalism and loitering, which unfortunately means that an inviting space late at night should be avoided, for the time being. Because of this, light levels in the entire area dims to about 30% of their original values after the preschool closes and until 19 in the evening. During this time motion sensors react whenever someone enters the area and turns the lighting to “normal” mode, except for the light tables that can’t be turned on after school hours. All levels are adjusted to compensate for snow and other weather conditions to maintain relative consistency in lighting levels. After 19.00, the motion sensors only activate the light(s) closest to the sensor at full capacity of the luminaire, hopefully detering unwanted activities during the night.
+ DISCUSSION
5.1 Ringmuren preschool / Lighting design for children

The main purpose of this thesis is to explore and propose design solutions as an alternative way of lighting children’s playgrounds to what currently seems to be the standard way of lighting many playgrounds; by installing tall posts with spotlights. If we assume “better” in this case means lighting that is focused on the needs and wants of the children using the space, the first takeaway from this project is that designing good lighting for children is a low bar to clear; with just a little effort many spaces could give thousands of children a better and more inspiring everyday environment. This thesis focused on the Ringmuren preschool and the design decisions were based on the specific characteristics of that site, but zooming out slightly, the methodology and individual elements or concepts could be applied to any playground or school/preschool yard in Sweden, or countries with similar season and weather conditions. Another aspect of this thesis is children’s connection to nature and the children of Ringmuren are lucky in that regard; nature is part of their schoolyard, the lighting only needs to strengthen that connection. Other preschools aren’t as lucky, but no matter the situation there is always the possibility of using lighting to focus the attention on what is there. In any case, just focusing on lighting in general, there seems to be many opportunities to use it for good, regardless of the circumstances.

If the actual lighting design is the easy part, relatively speaking, the main problem seems to be convincing people making the decisions that the extra cost of a thoughtful lighting design is worth it. In the case of Ringmuren preschool it took ten years of asking the municipality to get any lighting at all, and the lighting finally installed is arguably worse than darkness. If seen in a bigger perspective, the author argues that the cost is worth it - the practicalities and complexity of reality and the will to do good are often at odds, but we should always try. Flipping the coin, designing comfortable, inclusive spaces that aim to make people feel good doesn’t have to be cost prohibitive, some effort is always better no effort. The second conclusion from this project is this: if convincing, or even reaching, politicians is hard, there is a need for a good solution, a frame-work/design concept or a graphic profile for lighting, if you will, that can be presented and used as a preemptive counterpoint to the “it costs too much” argument.

5.1.2 Limitations

Time and budget constraints were by far the biggest limitations of this project. A close second was the author’s inexperience as a lighting designer, which made it hard to plan and anticipate problems. Making the actual design was hard with no prior working experience to draw from. Regarding time, the second part of
this thesis - the digital twin - was supposed to be created merely to support the design process, but turned out to take more time to complete than anticipated and grew to the point where it could (and maybe should) have been a separate thesis. Because of this time constraint, logistical limitations and lack of equipment, testing on site was not feasible for this project. Given more time, comparing the results inside the digital twin with real-life examples would give a lot of interesting information, and would be considered a high priority during the next opportunity to explore a digital twin workflow.

One big aspect of this project is how to encourage a connection to nature with the help of lighting and when analysing the project, this is probably the biggest drawback of not being able to regularly visit the site to physically experience it. Another big problem was the fact that, because of time constraints and privacy reasons, none of the ideas could be discussed or brainstormed with the children at Ringmuren. This could be seen as ironic, considering issues raised previously in this thesis and all decisions were made from lived experience of the preferences and behaviours of children, as well as research. The ideas for creating the connection to nature were by necessity general ideas, not specific to Ringmuren preschool and having closer contact with the children, the staff and the site itself would undoubtedly have helped in creating more clever and interesting solutions.

5.2 Digital Twin

It will take a long time before a digital twin can simulate all aspects of reality; for now the gold standard will be testing and measuring at the physical space itself, but in terms of flexibility and time saving, the pros of using a digital twin in projects that allow it could outweigh the cons by far. This project would not have been possible without a digital twin.

After completing the project it was clear that this way of working is a viable and useful tool in the design process. As stated in the “limitations” paragraph, doing this using free tools and everyday equipment (like a phone and a laptop) had its issues, but being able to do it at all with almost no resources worked surprisingly well. In a project with a slightly bigger budget, being able to use camera drones and more advanced software for scanning the environment, the workflow would have been much smoother and the quality would increase many times while still being on a budget a freelancer working alone can afford. With knowledge, the backing of a larger company or institution and a well developed and tested pipeline, creating digital twins of a very high quality fairly quickly and cheaply is not just possible, but relatively easy. There are several ways to measure and calculate light and lighting in the market, widely used, but creating a lighting solution using a digital twin allows a lighting designer to quickly prototype and design in a real-time feedback loop that besides the quantitative also take
the qualitative aspects into account. Going further in the process, a digital twin could be used as a tool for measuring and analysing lighting correctly, making it not just a design tool, but a complete lighting design toolset.

5.2.1 Limitations

Developing and testing new workflows always mean unforeseen problems, especially in a situation with many steps that all depend on the step before being solved; there were periods where work stopped because a problem had to be solved, steps had to be retraced. Time was an issue, but compounding this was the fact that there was no budget. Using free tools as much as possible meant that the options narrowed significantly.

5.3 Conclusions

When it comes to the lighting design, the next step for this investigation would first and foremost be more research, real-world testing and discussion with preschool children, secondly to produce a set of design principles, practical real-world solutions and recommendations. If not used outright, it could at least inspire discussion and alternative solutions. There is research on children's connection to nature, like Kyttä, (2006), Kyttä, (2002) and lighting for children, for example Angelaki et al., (2022), but not much about outdoor lighting for children in darker parts of the world. Design principles and good examples are a good place to start, but what is needed most is a discussion about lighting for children.

Future research would also need to include more on-site testing of light distribution, intensity and temperature. Without taking the time to compare and match up/calibrate the digital twin to real life, it still leaves a lot of room for error. With more data collected from different projects and different conditions, this aspect could in time become more accurate with less testing, but would always need some sort of hands-on testing.

While there is research on digital twins (Bellazzi et al., 2022; Tabbah, 2021; U et al., 2022), it is still relatively early days and the results currently publicly available often leave a lot of room for improvement when it comes to aesthetics. While the main purpose of a digital twin is to act as a tool for working with lighting, another purpose is to mimic reality, which means that the aesthetics isn't just a superficial aspect. If a digital twin doesn't accurately represent reality in form or looks, it's not an efficient tool and becomes meaningless.

One big hurdle at present is that tools designed for measuring light aren't made to produce realistic imagery and tools designed for producing realistic environments often aren't completely physically accurate and lack the functions and consistency needed for reliable real-world calculations. However, modern software can relatively easily be expanded and enhanced through scripts and plugins and making custom solutions geared toward lighting design is achievable. And just as the tools are designed for different purposes, the knowledge and experience needed for each area are different, meaning that creating digital twins in most cases need to be a multidisciplinary endeavour.

Taking what was learned in this project and applying it to more advanced equipment and software is the obvious next step; defining a workflow and a pipeline, including developing tools and bridges between the two areas that can be finetuned and tested in real-world projects. This might sound complicated, but with previous research and the experiences gathered in this project, the conclusion is that the threshold to creating an efficient workflow is relatively low. It's just a matter of building a few bridges, between people and between software.

In both cases, this thesis has only scratched the surface of these subjects and the end results are a matter of taste and must be seen as proofs of concepts, not finished solutions.
References


Tabbah, A. (2021). Evaluating digital twin data exchange between a virtual and physical environment regarding lighting quantity. DIVA. https://hj.diva-portal.org/smash/record.jsf?aq2=%5B%5D&c=129&af=%5B%5D&searchType=LIST_LATEST&sortOrder2=title_sort_asc&language=sv&pid=diva2%3A1573192&aq=%5B%5D&sf=all&aqe=%5B%5D&sortOrder=author_sort_asc&onlyFullText=false&noOfRows=50&dswid=5344


Figure list

All images created by author, unless otherwise stated.

Figure 1  Example of the lighting in a typical playground in Stockholm, Sweden
Figure 2  Example of the lighting in a typical playground in Stockholm, Sweden
Figure 3  Example of the lighting in a typical playground in Stockholm, Sweden
Figure 4  Example of the lighting in a typical playground in Stockholm, Sweden
Figure 5  Photo of the Ringmuren preschool yard showing the current lighting solution. Photo by Seren Dincel
Figure 6  A flowchart, of sorts, of the process
Figure 7  The view of the sky standing in the playground
Figure 8  The different zones chosen in the playground
Figure 9  The “stage”
Figure 10  An aerial scan of Ringmuren preschool and its surrounding, represented as a point cloud in open source software “Cloud Compare”
Figure 11  The laser data cleaned and only the ground separated from the buildings and vegetation. Quick drafts of buildings and playground details modelled by hand.
Figure 12  Example of a NeRF “scan” from Ringmuren preschool
Figure 13  Example of a NeRF “scan” from Ringmuren preschool
Figure 14  Example of a NeRF that didn’t work, creating an abstract splash
Figure 15  SpeedTree, software used to create trees and vegetation
Figure 16  Four different views of an early version of the digital twin in daylight
Figure 17  The “stage” seen from afar
Figure 18  An overview of the lighting solution, with some lights turned off. All trees are removed for clarity, which means that light distribution is not correct in this image. It is only meant as an overview.
Figure 19  Illustration showing the pole and wire placement for the catenary lighting. Bottom left shows an example of the “two-headed” luminaire used, allowing the user to light up one side or both, according to need.
Figure 20  Zone A: The grill/mushroom chairs
Figure 21  Zone C: The “corridor”
Figure 22  Zone E: The light tables
Figure 23  Zone B, C and E
Figure 24  Colours and contrasts
Figure 25  Zone D: The sandbox
Figure 26  Detail shot from the digital twin
Figure 27  Detail shot from the digital twin
Figure 28  Detail shot from the digital twin
Figure 29  Detail shot from the digital twin
Figure 30  Detail shot from the digital twin
Figure 31  Detail shot from the digital twin

Please see www.rikardhultman.com for any updates to this project