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AGENCY FOR MOBILITY AND EU PROGRAMMES

„TURN OFF THE LIGHTS, TURN ON THE STARS“

IO2: Manual for VET schools about implementing new methods in preventing light pollution in everyday classes

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1. EFFECTS OF LIGHT POLLUTION

1.1. An overview and effects of Light Pollution

Definition of Light Pollution

The last two centuries have seen a broad and abrupt change in the world's way of life. The fact that many human activities are now centralized in population nuclei has brought the need for a standard of energy consumption and usage, especially when it comes to the use of light during the night. We need to move on such environments without the risk inherent to darkness. Our eyes can not provide the detail we need in these conditions, and we need to come up with lighting solutions. The lack of understanding about the impact of such fixtures and of light usage in general has brought us a lot of problems that we can categorize under the Light Pollution topic.

Light pollution can be defined as the excessive, misdirected, or obtrusive artificial light produced by human activities, which brightens the night sky and disrupts natural darkness. It occurs when artificial light sources, such as streetlights, buildings, outdoor advertising, moving vehicles, etc. emit light that scatters and spreads far beyond its intended target, creating a luminous haze in the nighttime environment.

Far from being minor, such effects cause heavy disruption within our coexistence with natural environments, creating adverse and unwanted situations that affect both humans and ecological equilibria.

Some of the most direct effects of light pollution, which have direct visual impact, can be classified as:

1. **Skyglow**: The brightening of the night sky over populated areas, obscuring the view of stars and celestial objects. Its effect can be noticed on the general number of stars that can be seen in a given observation environment.
2. **Light Trespass**: The unwanted or intrusive illumination of outdoor spaces or areas where it is not needed or intended, such as residential areas or nature reserves. Many industrial areas and mobility means (highways, high transit roads,...) justify requiring 24hrs lighting for security reasons, causing high impact on their direct environments.

3. **Glare**: Excessive brightness that causes visual discomfort and reduces visibility, often caused by unshielded or overly intense light sources. In this case some sort of haze can be appreciated due to the light scatter happening when the light from the source finds suspended particles in our atmosphere.
4. **Clutter**: The excessive grouping of bright, competing light sources, such as numerous signs and advertisements, which can contribute to visual confusion and discomfort. More usual in urban active environments.

Light pollution has adverse effects on various aspects of the environment, including disrupting ecosystems, impacting human health and well-being, interfering with astronomical observations, wasting energy, and diminishing the beauty of the natural night sky. Efforts to combat light pollution include using shielded lighting fixtures, implementing lighting ordinances and regulations, adopting energy-efficient lighting technologies, and promoting public awareness and education.

In this document we will provide a short overview on such topics so that the broad line of the issue can be understood in a general manner.

Significance of Studying Its Impact on Wildlife and Nature

We elaborate on the importance of studying light pollution in the context of its impact on wildlife, ecosystems, and the natural world. We underscore the ecological, environmental, and cultural consequences of uncontrolled artificial light.

Overview of the Document's Structure

This part offers a brief overview of the document's structure, detailing what each section will cover. It acts as a roadmap for readers, allowing them to navigate through the comprehensive analysis.

Causes of Light Pollution

Urbanization and Population Growth

Urbanization and population growth are significant drivers of the increase in artificial light sources and, consequently, light pollution. Here's how these factors contribute to the problem:

1. **Expansion of Urban Areas**: As urban populations grow, cities expand both horizontally and vertically. New buildings, roads, and infrastructure require outdoor lighting for safety and functionality. This expansion leads to the installation of more streetlights, commercial lighting, and residential lighting, increasing the overall intensity of artificial light in urban environments.

2. **Increased Energy Consumption**: Urbanization often corresponds with higher energy consumption. As more people move into urban areas, there is a greater demand for energy, which can lead to the increased use of lighting. This not only contributes to light pollution but also places a strain on energy resources and increases greenhouse gas emissions.

3. **Commercial and Industrial Zones**: Urbanization typically concentrates commercial and industrial activities in specific zones. These areas are illuminated with powerful lighting to operate efficiently, including factories, warehouses, and commercial centers. The concentration of these zones exacerbates light pollution.

4. **Residential Lighting**: The growth of urban and suburban populations results in more residential areas requiring outdoor lighting for safety and security. Homeowners and businesses often install bright and poorly shielded fixtures, which can contribute to light pollution by directing light upward and outward.

5. **Advertising and Signage**: Urbanization and population growth lead to increased advertising and signage in commercial areas. Bright, large, and unregulated signs can emit excessive light that contributes to clutter and glare, two forms of light pollution.

6. **Transportation Networks**: Expanding urban areas often require more extensive transportation networks, including highways, airports, and public transit systems. These infrastructures require extensive lighting for safety, navigation, and visibility, increasing the presence of artificial light in the night environment.

7. **High-Rise Buildings**: The construction of high-rise buildings in urban areas often involves extensive architectural lighting for aesthetic purposes. These tall structures can cast light over a wide area, contributing to skyglow and light trespass.

8. **Recreational and Entertainment Venues**: Growing urban populations often result in more recreational and entertainment venues such as stadiums, arenas, and amusement parks. These venues require substantial lighting for nighttime events, contributing to localized light pollution.

9. **Outdoor Advertising**: Billboard advertising is prevalent in urban areas, and these signs are often illuminated with bright and uncontrolled lighting. The proliferation of advertising contributes to clutter and glare, particularly in commercial districts.

10. **Technological Advancements**: As cities modernize, they often adopt newer lighting technologies, such as LED lighting. While LEDs are more energy-efficient, they can produce harsh, cool-toned light, which may increase light pollution if not properly designed and controlled.

To mitigate the contribution of urbanization and population growth to light pollution, urban planners and policymakers must consider responsible outdoor lighting practices, such as using shielded fixtures, implementing lighting ordinances, and raising public awareness. Balancing the need for outdoor lighting with efforts to minimize light pollution is essential to preserving the natural nighttime environment and mitigating the adverse effects on ecosystems and human health.

Effects on Wildlife

Impact on Birds

Light pollution has a significant impact on birds, disrupting their natural behaviors, migration patterns, and overall well-being. The effects of light pollution on birds can be broadly categorized as follows:

1. **Disruption of Nocturnal Behavior**:
    - **Altered Foraging**: Nocturnal light pollution can disrupt a bird's feeding behavior. Many species of birds, especially insectivorous ones, rely on darkness to hunt for prey. Excessive artificial light can interfere with their ability to find food, affecting their feeding success.
    - **Disrupted Sleep Patterns**: Birds, like many other animals, have circadian rhythms regulated by light and darkness. Light pollution can disrupt these rhythms, leading to altered sleep patterns and reduced rest time. This can have adverse effects on their overall health and fitness.
2. **Altered Migration Patterns**:
    - **Attraction to Light Sources**: Artificial light can attract migrating birds, causing them to become disoriented and circling around lit structures like tall buildings and communication towers. This disorientation can lead to exhaustion and collisions, resulting in bird fatalities.
    - **Delayed Migration**: Light pollution can delay or disrupt the timing of migration, potentially affecting breeding and nesting patterns. For example, birds that rely on specific environmental cues, such as the lunar cycle or star patterns, may become confused by artificial light.
3. **Increased Vulnerability to Predation**:
    - **Increased Visibility to Predators**: The excess light can make birds more visible to predators, both on the ground and in the air, increasing the risk of predation.

Predators can spot prey more easily under artificial light, leading to higher mortality rates.

4. **Impact on Breeding and Nesting**:
    - **Disrupted Courtship and Nesting Behavior**: Light pollution can disrupt courtship displays and interfere with breeding and nesting activities. This can reduce the reproductive success of bird species that breed in urban or well-lit areas.
5. **Shifts in Habitat Use**:
    - **Avoidance of Well-Lit Areas**: Some bird species may avoid well-lit areas altogether, leading to changes in their habitat use. This can result in a reduction in available foraging and nesting locations, impacting population distributions.
6. **Attraction to Anthropogenic Light Sources**:
    - **Collisions with Buildings**: Birds are often attracted to illuminated buildings during migration, which can lead to collisions with windows and structures, causing injury or mortality. These collisions are a significant concern in urban areas.
7. **Disruption of Ecosystems**:
    - **Impact on Food Chains**: Light pollution can disrupt nocturnal ecosystems by altering the behavior of prey species, which can, in turn, affect the species that prey on them, including birds. These disruptions can ripple through food chains and impact entire ecosystems.

Efforts to mitigate the impact of light pollution on birds include:

- **Shielded Lighting**: Using properly shielded outdoor lighting fixtures that direct light downward and minimize upward and outward light spillage.
- **Lighting Curfews**: Implementing lighting curfews during critical bird migration periods to reduce the likelihood of disorientation.
- **Educational Campaigns**: Raising public awareness about the importance of reducing light pollution and adopting bird-friendly lighting practices.
- **Conservation of Dark Sky Areas**: Establishing and protecting dark sky areas, such as International Dark-Sky Parks, where lighting is minimized to preserve natural darkness.

Addressing light pollution is crucial for the well-being and conservation of bird species, as well as the overall health of ecosystems. It requires a combination of responsible lighting practices, policy measures and public awareness.

Effects on Insects

Light pollution has significant and often adverse effects on insects, disrupting their natural behaviors, life cycles, and ecological roles. Here are some of the key impacts of light pollution on insects:

1. **Attraction to Light Sources**:
    - **Disorientation**: Many nocturnal insects, including moths and beetles, are attracted to artificial light sources. They can become disoriented and spend excessive amounts of time circling artificial lights, which can lead to exhaustion and predation.
    - **Altered Flight Paths**: Insects that are drawn to artificial light may deviate from their natural flight paths. This can disrupt their ability to locate suitable habitats, food sources, and mating partners.
2. **Disruption of Reproductive Behaviors**:
    - **Mating Behavior**: Light pollution can interfere with the mating behaviors of nocturnal insects. Male moths, for example, may be drawn away from females due to artificial lights, reducing their chances of reproduction.
    - **Egg-Laying**: Light pollution can affect the timing and location of egg-laying for insects. Some species lay eggs on plants, and the disruption of natural light cues can lead to suboptimal choices of oviposition sites.
3. **Reduced Foraging Efficiency**:
    - **Predation Risk**: Insects attracted to artificial lights are at an increased risk of predation by nocturnal predators, such as bats and birds. This can lead to a decline in insect populations, which can have cascading effects on ecosystems.
    - **Interference with Pollination**: Nocturnal pollinators, such as moths and certain beetles, may be less effective in their role due to the distraction of artificial lights, which can impact the reproductive success of flowering plants.
4. **Disruption of Circadian Rhythms**:
    - **Altered Activity Patterns**: Light pollution can disrupt the circadian rhythms of insects, affecting their activity patterns and daily cycles. This can lead to changes in feeding, mating, and rest times.
5. **Shifts in Habitat Use**:

- **Avoidance of Lit Areas**: Some insects may avoid well-lit areas altogether, altering their habitat use and potentially leading to population shifts.

6. **Ecological Consequences**:
    - **Impact on Food Chains**: Changes in insect behavior and abundance due to light pollution can disrupt food chains and affect predators that rely on insects as a primary food source.
7. **Impact on Insect Biodiversity**:
    - **Reduced Diversity**: Light pollution can lead to a decrease in insect species diversity in urban and suburban areas, as some species are more sensitive to artificial light than others.

Efforts to mitigate the impact of light pollution on insects include:

- **Reducing Light Intensity**: Using lower-intensity outdoor lighting or installing motion-activated lights that only activate when needed can help minimize light pollution.
- **Shielded Lighting**: Employing properly shielded lighting fixtures that direct light downward and reduce light spillage into the surrounding environment.
- **Selective Lighting**: Using lighting with specific spectral characteristics (e.g., warmer color temperatures) that are less attractive to insects can reduce their attraction to artificial lights.
- **Curfews and Dimming**: Implementing lighting curfews or dimming measures during key insect activity periods, such as during migration or mating seasons.
- **Educational Initiatives**: Raising public awareness about the negative effects of light pollution on insects and the importance of responsible outdoor lighting practices.

Addressing light pollution is essential not only for the well-being of insects but also for maintaining the ecological balance and functioning of ecosystems, as insects play critical roles in pollination, decomposition, and food webs.

Aquatic Life

Light pollution can have significant impacts on aquatic life, particularly in freshwater and marine ecosystems. Artificial light can disrupt natural light cycles in aquatic environments, affecting a wide range of organisms, from phytoplankton to fish and even marine mammals. Here are some of the key effects of light pollution on aquatic life:

1. **Disruption of Natural Behavior**:
    - **Nocturnal Behavior**: Many aquatic organisms, such as fish and crustaceans, have evolved to rely on natural light cues to regulate their daily activities, including feeding, mating, and avoiding predators. Light pollution can disrupt these behaviors by altering their perception of day and night.
2. **Ecological Consequences**:
    - **Predation**: Predators that rely on low-light conditions to hunt may become less effective under artificial light, allowing prey species to thrive. Conversely, prey species may become more vulnerable to predation under artificial light.
    - **Changes in Reproductive Patterns**: Some aquatic organisms, like sea turtles, rely on natural darkness to nest. Light pollution can deter females from coming ashore to lay their eggs or disorient hatchlings, leading to reduced reproductive success.
3. **Shifts in Habitat Use**:
    - **Avoidance of Well-Lit Areas**: Some aquatic species may avoid well-lit areas, resulting in shifts in habitat use. This avoidance can limit available habitat and alter ecosystem dynamics.
4. **Disruption of Planktonic Organisms**:
    - **Phytoplankton and Zooplankton**: Phytoplankton, the foundation of marine food chains, relies on natural light patterns for photosynthesis. Light pollution can disrupt their growth and distribution, impacting zooplankton and other species higher up the food chain.
5. **Changes in Migration and Navigation**:
    - **Marine Migrations**: Some marine species undertake long-distance migrations, guided by natural light cues, such as the moon and stars. Light pollution can disorient these animals, leading to navigation errors.
6. **Impact on Coral Reefs**:
    - **Coral Health**: Coral reefs are vulnerable to light pollution, which can disrupt their natural light cycles and the behaviors of reef-dwelling organisms. This can have cascading effects on the health and survival of coral ecosystems.
7. **Altered Spawning Behavior**:

- **Fish Spawning**: Some fish species rely on specific light conditions for successful spawning. Light pollution can interfere with these behaviors, potentially reducing recruitment and population sizes.

8. **Impact on Bioluminescent Organisms**:
    - **Bioluminescent Species**: Bioluminescent organisms, such as certain species of jellyfish and fish, use their natural light emissions for communication, camouflage, and predation. Artificial light can interfere with these behaviors.

Efforts to mitigate the impact of light pollution on aquatic life include:

- **Proper Lighting Design**: Using well-designed and shielded lighting fixtures near bodies of water to minimize light spillage.
- **Lights-Out Programs**: Implementing lights-out programs in coastal areas during sea turtle nesting seasons to reduce hatchling disorientation.
- **Reducing Coastal Development**: Limiting excessive coastal development and the installation of bright artificial lights near sensitive aquatic habitats.
- **Educational Campaigns**: Raising awareness about the negative effects of light pollution on aquatic ecosystems and encouraging responsible lighting practices near water bodies.
- **Research and Monitoring**: Conducting research to better understand the specific impacts of light pollution on aquatic life and monitoring changes in ecosystems to assess the effectiveness of mitigation efforts.

Addressing light pollution in aquatic environments is crucial for maintaining the health and balance of these ecosystems, which provide habitat for a wide variety of species and support fisheries and tourism industries.

Case Studies Illustrating Ecological Consequences

here are five case studies that highlight the impact of light pollution on wildlife:

Case Study: Sea Turtle Hatchlings Disorientation

- **Location**: Coastal regions around the world.
- **Description**: Sea turtle hatchlings are known to be particularly vulnerable to light pollution. Bright artificial lights near nesting beaches can disorient hatchlings, leading them away from the ocean and towards danger, such as roads and predators. Many conservation efforts have focused on reducing light pollution in sea turtle nesting areas to improve hatchling survival rates.

- **Impact**: Light pollution has led to a decline in sea turtle populations in some areas, as fewer hatchlings make it to the ocean safely.

Case Study: Decline in Nocturnal Insect Populations

- **Location**: Various urban and suburban environments.
- **Description**: Researchers have conducted extensive studies on the effects of light pollution on nocturnal insects, such as moths and fireflies. These studies have shown that artificial light attracts and disorients these insects, leading to reduced populations. Declines in insect populations can have cascading effects on ecosystems, affecting insect-eating birds and bats.

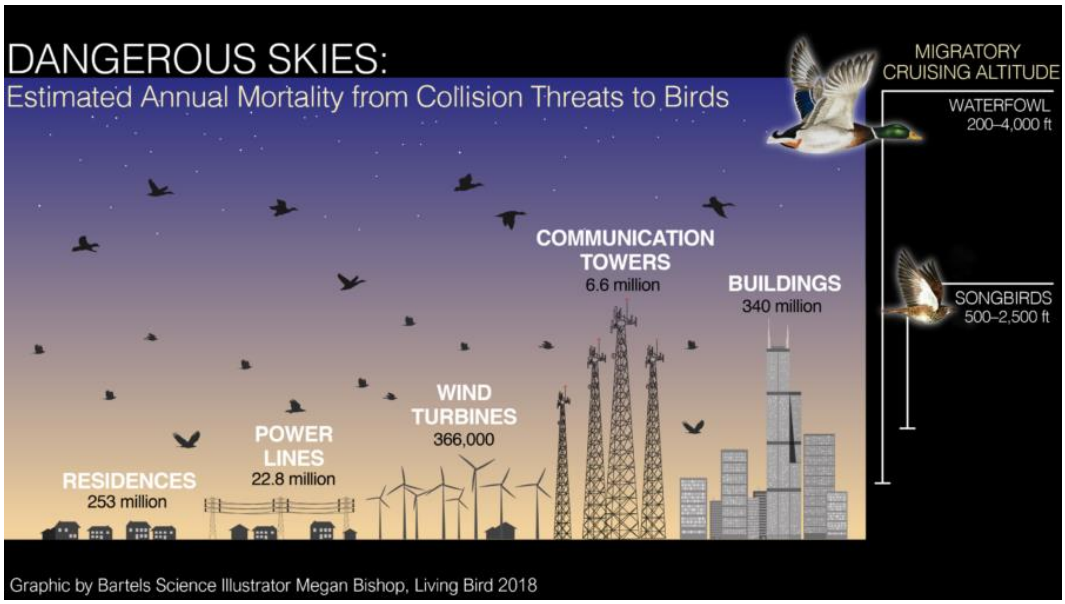
Fireflies swarming in the Bükk National Park (Bükk Dark Sky Park)

- **Impact**: Light pollution contributes to declines in insect biodiversity and can disrupt ecological interactions in affected areas.

Case Study: Disruption of Bird Migration

- **Location**: Urban and suburban areas along migratory bird routes.

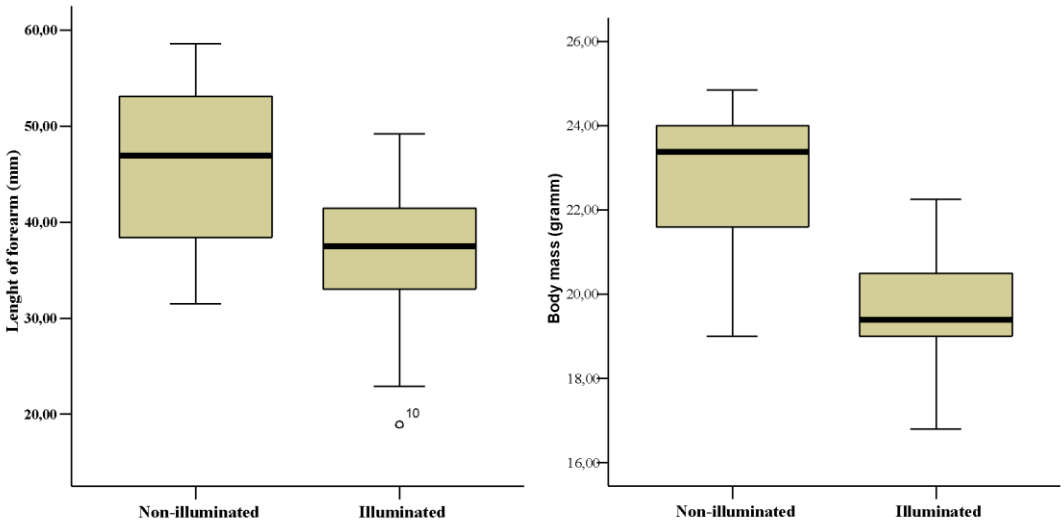
- **Description**: Migratory birds often rely on natural light cues, including the moon and stars, for navigation during their long journeys. Light pollution can disorient these birds, causing them to collide with buildings, towers, and other structures. Studies have shown that light pollution can result in increased mortality rates among migratory birds.
- **Impact**: Light pollution poses a significant threat to migratory bird populations, particularly in urbanized regions.



Harmful lights for birds
source: https://birdcast.info/science-to-action/lights-out/

Case Study: Impact on Bats and Their Prey

- **Location**: Areas with high levels of light pollution near bat habitats.
- **Description**: Bats are nocturnal creatures that rely on darkness for hunting insects. Artificial light can disrupt their foraging behavior, reducing their feeding efficiency. Additionally, the insects that bats prey upon may be drawn to artificial lights, making them more vulnerable to predation by bats and other predators.
- **Impact**: Light pollution can disrupt the delicate balance of bat-insect interactions, potentially leading to changes in bat populations and insect pest dynamics.



Bat body mass indexes at illuminated and non illuminated environments (Source: Aggteleki National Park Directorate, Boldogh et al.)

Case Study: Impact on Marine Ecosystems

- **Location**: Coastal and marine environments with high levels of light pollution.
- **Description**: Coral reefs and other marine ecosystems can be affected by light pollution, which can disrupt the behaviors of nocturnal marine species. For example, some fish and coral species rely on natural light cues to coordinate their activities. Light pollution can interfere with these behaviors and disrupt the health and ecology of these ecosystems.
- **Impact**: Light pollution can contribute to the decline of coral reefs and the disruption of marine food chains and ecological processes.

These case studies illustrate the diverse and far-reaching impacts of light pollution on wildlife across various ecosystems. Efforts to mitigate these impacts often involve reducing artificial light levels, implementing lighting regulations, and raising public awareness about the importance of minimizing light pollution.

Effects on Natural Systems

Light Pollution's Effect on Plant Life

Light pollution can also have notable effects on plant life, although these impacts are often less studied and understood compared to its effects on animals and ecosystems. Here are some of the ways light pollution can affect plant life:

1. **Altered Growth Patterns**:
    - **Extended Photoperiods**: Artificial light at night can create extended photoperiods (daylight hours) for plants. Some plants may respond to this prolonged light exposure by altering their growth patterns. For example, certain species may continue to photosynthesize during the night, potentially affecting their development and reproduction.
    - **Flowering and Fruiting**: Light pollution can disrupt the natural timing of flowering and fruiting in some plant species. Changes in the length of night periods can lead to irregular flowering and fruiting cycles.
2. **Impact on Pollination**:
    - **Disrupted Pollinator Behavior**: Many plants rely on nocturnal pollinators, such as moths and bats, for successful reproduction. Light pollution can disrupt the behavior of these pollinators, affecting the pollination of plant species that depend on them.
3. **Altered Plant-Insect Interactions**:
    - **Herbivore Behavior**: Insects that are attracted to artificial light may inadvertently damage nearby plants through herbivory. This can affect plant health and alter the dynamics of plant-insect interactions.
4. **Impacts on Seed Dispersal**:
    - **Changes in Seed Dispersal**: Nocturnal animals, including bats and some rodents, play important roles in seed dispersal. Light pollution can disrupt their natural behaviors, potentially affecting the dispersal of seeds and the distribution of plant species.
5. **Influence on Plant Biodiversity**:
    - **Altered Competitive Relationships**: Changes in growth patterns, flowering times, and pollination dynamics can lead to altered competitive relationships among plant species. Some species may gain a competitive advantage under light-polluted conditions, while others may decline.
6. **Indirect Effects on Ecosystems**:
    - **Changes in Food Availability**: Light pollution can affect the abundance and behavior of insects, which are a crucial food source for many animals. These

changes in insect populations can have cascading effects on ecosystems, potentially impacting plant-pollinator interactions and food web dynamics.

It's important to note that the effects of light pollution on plant life can vary depending on the plant species, the intensity and duration of artificial light exposure, and the specific ecological context. While some studies have highlighted these potential impacts, further research is needed to fully understand the extent and nuances of light pollution's effects on plant communities and ecosystems.

Astronomical and Human Health Effects

Challenges Faced by Astronomers

Astronomers are the first party when it comes to noticing the real effects of light pollution. Since they conduct direct observations, they are subject to its most visual effects.

This whole new set of challenges affect several regular lines of work that astronomers face on a daily basis:

1. **Difficulty on faint object observations**:

Intense sky brightness might produce some loss of detail when observing through a telescope. The lack of a good amount of contrast between the “dark” parts of an image and its details worsen the quality of the assessments made on such observations.

This phenomenon can be quantified via the limiting magnitude concept: the faintest object that a given instrument can observe. All telescopes have a theoretical limit that only depends on their aperture, and can be computed via:

$$m_{lim} = 2 + 5\,log(D_0)$$

Where *m* represents the limiting magnitude and D the diameter of the telescope’s aperture.

It is hardly ever possible to be able to get to such values due to external factors, such as light pollution. We can say we are in a heavily polluted environment when the difference between the theoretical and the actual limiting magnitude is large.

2. **Limited access to observation sites and tough observation conditions**:

The existence of heavily polluted environments near the most populated nuclei of our society makes the factual practice of astronomical technique an impossibility for such places. In that scenario, those people who want to pursue these observations feel forced to move to remote places that have a reasonable dark sky quality to perform their work.

In most cases this involves transportation to sites hours away from the cities, and the construction of observatories in less resourceful environments, which also increments the cost of the activity. Finding a dark place nowadays is a very demanding challenge, but some organisations such as the International Dark Sky Association (IDA) or the Starlight Foundation provide some help when it comes to it.

3. **Disruption of Observing Schedules**:

Most of the astronomical observations are time dependent. This means that observing them is only feasible during a given window of time (that can either refer to optimal observation conditions or physical events happening at given points of time).

Such times can be heavily interrupted or disrupted by light pollution, preventing the astronomers from performing the observations at the right time.

4. **Impact on Public Outreach and Education**:

The impact created by the first sight of a *real* dark sky is something that leaves a mark upon the observer. That feeling is something astronomy communicators use as a tool to generate emotion in their audience and generate a feeling of responsibility and protection towards it.

It is everyday more difficult to find skies that live up to these expectations, so the job of communicator becomes harder. Light pollution diminishes the effect of the message that communicators try to develop.

5. **Scientific Impact**:

Both earth-based and space-based observations are heavily affected by light pollution. The abusive usage of lights in population nuclei is something harmful that has affected beyond earth. Even telescopes such as the Hubble feel the disruption caused by these lights.

Scientific impact is something difficult to measure, but it can ultimately be related to the publications produced by a given team and their impact on society. If a telescope has their output reduced by some extrinsic cause, that can already tell us that such an effect plays a key role on the scientific impact of the instrument.

6. **Energy Consumption and Environmental Impact**:

Even though it might make no direct impact on astronomical observations, the excessive usage of misdirected light becomes a problem for energy usage, since the profit taken out of such energy is reduced by misuse. This has an economical impact on society as well as it becomes a natural problem.

Addressing these challenges requires concerted efforts to reduce light pollution through responsible outdoor lighting practices, the adoption of lighting ordinances and regulations, public education and awareness campaigns, and the preservation of dark sky areas. These efforts are essential to ensure that astronomers can continue to make significant contributions to our understanding of the universe.

Human Health Concerns

Light pollution can have several human health concerns, primarily related to disruptions in sleep patterns, circadian rhythms, and overall well-being. Here are some of the key health concerns associated with light pollution:

1. **Sleep Disturbances**:

The amount and temperature of the light perceived by the human eye plays a crucial role in the sleep cycle. When intensity and light temperature decrease, our bodies are able to generate melatonin, a hormone related to sleepiness.

That can lead to sleeping disorders related to falling asleep, staying asleep or the “night shift effect”, that causes general tiredness and sleepiness due to bad quality sleeping.

2. **Circadian Rhythm Disruption**:

Human bodies rely heavily on cyclic patterns to regulate their processes, and light is something crucial in that aspect. In the absence of change on the light perceived there are circadian alterations, where metabolism and general health feel the effects of disorder on the natural hormonal patterns.

These changes have been proven to be very detrimental for human beings leading ultimately to mood swings and personality changes, weight gain and cardiovascular problems.

3. **Impaired Cognitive Function**:

Sleep deprivation and circadian disruption caused by light pollution can impair cognitive functions such as attention, memory, and decision-making. This can have implications for productivity and safety in social environments.

4. **Disruption of Hormonal Regulation**:

Light pollution can disrupt the regulation of hormones such as cortisol, insulin, and thyroid hormones, potentially contributing to metabolic and endocrine disorders.

5. **Increased Risk of Certain Cancers**:

Some studies have suggested a link between exposure to light at night and an increased risk of breast cancer. The disruption of melatonin production, which has anti-cancer properties, may play a role in this association.

Light pollution has also been associated with an increased risk of prostate cancer in some research, particularly among shift workers.

6. **Eye Health Concerns**:

Excessive exposure to artificial light, especially from digital screens and bright indoor lighting, can lead to eye strain, discomfort, and visual disturbances.

Efforts to mitigate the human health concerns associated with light pollution include using warm-colored, low-intensity lighting at night, adopting responsible lighting practices, reducing light emissions from electronic devices before bedtime, and promoting awareness about the importance of natural darkness for sleep and well-being. Public education and policy measures can play significant roles in addressing these health concerns.

Societal and Cultural Implications

Light pollution has a range of societal and cultural implications that extend beyond its direct environmental and health effects. These implications touch upon various aspects of society, culture, and human behavior:

1. **Disconnection from the Night Sky**:

The history of mankind has been tightly related to its relation with the night sky. In fact, the interest for cosmology and cosmogony has a close relation with stargazing. The effects of light pollution are directly translated into a loss of connection and understanding for something we can no longer enjoy at its fullest.

2. **Impact on Outdoor Recreation**:

Excessive artificial light at night can discourage outdoor activities such as camping, hiking, and nighttime sports. People may miss out on the recreational and educational benefits of experiencing natural darkness.

A heavier control towards light pollution may necessitate restrictions on nighttime events, such as music festivals or outdoor performances, affecting cultural and social gatherings. Nevertheless, this impact will surely be smaller than the one caused by the lack of awareness.

3. **Energy Waste and Environmental Impact**:

Light pollution represents an inefficient use of energy and resources, leading to higher energy bills, increased greenhouse gas emissions, and contributing to climate change. Overall, a luxury that Earth can not afford and against which we must fight thoroughly.

Excessive artificial lighting can disrupt local ecosystems, affecting wildlife behavior, migration, and reproduction. This environmental impact can have long-term consequences for biodiversity and ecological balance. It adds up to many other effects that already make the coexistence of man and environment difficult.

4. **Health and Well-Being**:

Sleep disruption due to light pollution is a health concern that can affect many aspects of human health, both mental and physical. Such concerns should become a priority when fighting light pollution because they affect individuals whose behavior is directly related to the security and productivity of their environments.

5. **Urban Planning and Aesthetics**:

Light pollution management may change our way of understanding urban aesthetics. The fact that we can obscure natural environments can lead us to see diminished beauty in urban environments. A new way of understanding design and architecture might have to be introduced to better cope with such events.

6. **Economic Implications**:

Light pollution imposes economic costs on communities through increased energy consumption, healthcare expenses related to sleep disorders, and decreased property values in areas affected by excessive lighting.

On the other hand, areas with minimal light pollution can attract tourists and amateur astronomers, contributing to local economies through tourism and stargazing events. Also, this whole new branch called Astro Tourism can be the settlement of new economical activities based around the darkness of the sky.

7. **Public Awareness and Education**:

Raising public awareness about the negative effects of light pollution can lead to a cultural shift toward more responsible lighting practices and appreciation for natural darkness. This can give society a leading role towards the needed change.

Educational initiatives that promote the value of dark skies and the importance of preserving them can have far-reaching cultural implications by fostering a greater appreciation for the night

environment, especially among those young publics that will have to take care of it in the near future.

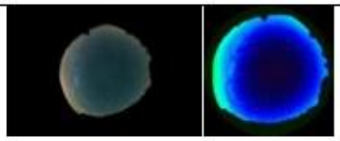
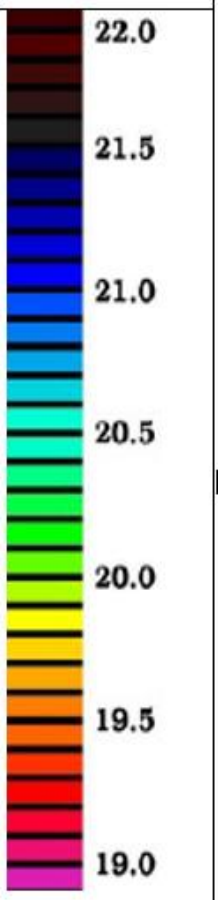
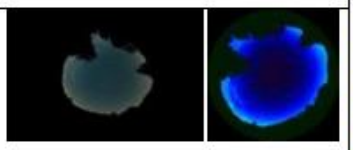
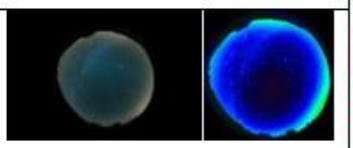
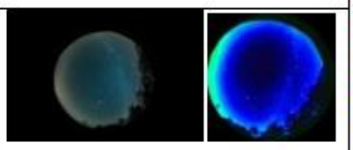
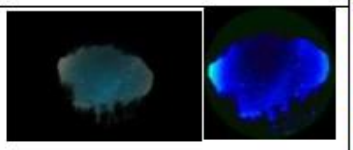
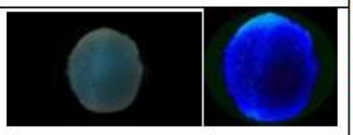
Addressing light pollution requires a multi-faceted approach that involves changes in lighting technologies, urban planning, public policy, and individual behavior. Culturally, it involves fostering an appreciation for the natural night sky and recognizing its significance in various cultural and scientific contexts.

1.2. Measuring and Assessing Light Pollution

Instruments like Sky Quality Meters

Sky quality meters (SQMs) are specialized instruments used to measure and quantify light pollution and the quality of the night sky. These devices provide objective measurements of sky brightness, which is essential for assessing the impact of artificial light on the night environment. Here are the key features and functions of sky quality meters:

1. **Photodetector**: The heart of a sky quality meter is a highly sensitive photodetector, typically a photodiode or photomultiplier tube. This component measures the amount of light falling on its surface.
2. **Spectral Sensitivity**: Sky quality meters are often designed to have a sensitivity that closely matches the human eye's response to light across different wavelengths. This makes their measurements more relevant to human perceptions of brightness.
3. **Field of View**: SQMs have a specific field of view that determines the area of sky from which they collect light. The field of view can vary depending on the model, but it's usually around 20-30 degrees, allowing them to capture a wide portion of the sky.
4. **Data Logging**: Many modern sky quality meters are equipped with data logging capabilities. They record measurements over time, enabling the assessment of how light pollution changes throughout the night or across seasons.
5. **Unit of Measurement**: Sky quality meters typically report measurements in units like magnitudes per square arcsecond (mag/arcsec^2), which quantifies the brightness of the sky in astronomical terms. Lower values indicate darker skies, while higher values signify more light pollution.

Coordinates and collected SQM-L data	Image (orginal/false colour)	mag/as^2
48° 4'35.69N; 20°27'5.98E SQM-L: 21.3		
48°04.558'N ; 20°24.726' E SQM-L: 21.4		
48° 4'38.11"N; 20°29'40.48"E SQM-L: 21.2		
48° 3'25.17N ; 20°31'12.22E SQM-L: 21.3		
48° 3'21.22"N ; 20°29'55.19"E SQM-L: 21.1		
48° 2'43.40"N; 20°28'48.47"E SQM-L: 21.2		

Coordinates with measurements in the Bükk Dark Sky Park (mag/arc2)
Pictures were taken with fish eye lenses and control with SQM-L

6. **Integrated Measurements**: Some SQMs provide integrated measurements over a specified period (e.g., one minute). This can help to average out short-term fluctuations in light levels.

7. **Directional Sensitivity**: Some models can measure the brightness of the sky in different directions, allowing for the assessment of light pollution from specific sources or in specific regions of the sky.

8. **Portable and Mountable**: SQMs are designed to be portable, allowing users to take them to different locations for measurements. They can also be mounted on telescopes or other instruments for specialized applications.

9. **Data Output**: SQMs often have data output options, such as USB or serial ports, to transfer measurement data to a computer for analysis. Some models also have wireless connectivity for remote data access.

10. **Calibration**: Regular calibration is essential to ensure the accuracy of sky quality meters. Calibration typically involves comparing the meter's readings to known standard values under controlled conditions.

11. **Dark-Sky Certification**: Some sky quality meters are used by organizations to assess and certify dark sky areas. These meters help determine if a location meets the criteria for designation as a dark sky park or reserve.

Sky quality meters are valuable tools for astronomers, environmentalists, and researchers studying the effects of light pollution. They provide objective data that can be used to advocate for better lighting practices, raise public awareness, and assess the impact of light pollution mitigation efforts.

Remote Sensing Techniques

Remote sensing techniques can be used to measure and monitor light pollution from space or aircraft, providing a broader perspective on the extent and distribution of artificial light. These methods are valuable for assessing light pollution at regional and global scales. Here are some remote sensing techniques for measuring light pollution:

1. **Radiance and Reflectance Measurements**:
    - **Satellite Imagery**: Satellites equipped with radiometric sensors, such as radiometers or multispectral cameras, can capture images of the Earth's surface at night. These images reveal the radiance or reflectance of artificial light sources and the terrain below.
    - **Data from Low-Earth Orbit Satellites**: Several Earth-observing satellites, such as the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (NPP) satellite and the Day/Night Band (DNB) on the Joint Polar Satellite System (JPSS) series, provide nighttime light data.
2. **Light Pollution Indices**:
    - **Normalized Difference Vegetation Index (NDVI)**: NDVI is a commonly used index that measures the difference between visible and near-infrared light. It can indirectly provide information about urbanization and the extent of artificial lighting in an area.

- **Light Pollution Indices**: Researchers have developed various light pollution indices that quantify the intensity and spatial distribution of artificial light. These indices use data from remote sensing instruments to assess light pollution's impact on the night sky.

3. **Radiative Transfer Models**:
    - **Light Propagation Models**: Radiative transfer models simulate the propagation of artificial light through the atmosphere and its interaction with the Earth's surface. These models can be used to estimate skyglow and ground-level light pollution based on remote sensing data.
4. **Time-Series Analysis**:
    - **Change Detection**: Time-series analysis of remote sensing data can reveal changes in the extent and intensity of artificial lighting over time. Researchers can identify trends and evaluate the effectiveness of light pollution mitigation efforts.
5. **Thermal Infrared Imagery**:
    - **Thermal Infrared Sensors**: Some remote sensing satellites are equipped with thermal infrared sensors that can detect the heat generated by artificial lighting, such as streetlights and buildings. This information can be used to estimate the distribution of light sources.
6. **Urban Growth Assessment**:
    - **Land Use and Land Cover Change Analysis**: Remote sensing data can be used to assess changes in land use and land cover, including urban expansion. These changes are often associated with increased light pollution.
7. **Mapping and Spatial Analysis**:
    - **Geographic Information Systems (GIS)**: Combining remote sensing data with GIS allows for the creation of detailed maps and spatial analyses of light pollution. GIS can help identify areas with high light pollution levels and their proximity to sensitive ecosystems.
8. **Cloud Detection and Filtering**:
    - **Cloud Masking**: Remote sensing data processing includes cloud detection and masking techniques to ensure accurate measurements of artificial light. Cloud cover can obscure the view of city lights.

Remote sensing techniques provide a valuable tool for monitoring and assessing light pollution on regional and global scales. They enable researchers and policymakers to track changes in light pollution over time, identify areas of concern, and develop targeted strategies for mitigating its impact on the environment and human health.

The Role of Citizen Science

Citizen science initiatives play a crucial role in monitoring light pollution and contributing to our understanding of its extent and impact. Here are several key reasons why citizen science is important in this context:

1. **Extensive Geographic Coverage**: Citizen scientists are distributed across diverse geographical regions, including urban, suburban, and rural areas. Their participation enables the collection of data from a wide range of locations, providing a more comprehensive view of light pollution's spatial distribution.
2. **Data Quantity and Frequency**: Citizen scientists can contribute a large volume of data on a regular basis. This high-frequency monitoring helps capture temporal variations in light pollution, such as changes due to seasonal factors or specific events like holidays.
3. **Cost-Effective Data Collection**: Citizen science projects can leverage the power of volunteers to collect data, reducing the costs associated with monitoring light pollution compared to traditional research methods. This cost-effectiveness allows for larger-scale initiatives.
4. **Public Engagement and Education**: Citizen science projects engage the public in meaningful scientific activities. Participants learn about the effects of light pollution on the environment and human health, fostering awareness and understanding of the issue.
5. **Community Involvement**: Citizen science empowers communities to take an active role in monitoring and addressing local light pollution. This involvement can lead to collaborative efforts to reduce light pollution and promote responsible lighting practices.
6. **Quality Control and Validation**: Many citizen science projects incorporate quality control measures to ensure the reliability of data. This often includes data validation through comparison with professional measurements, ensuring the accuracy of collected information.
7. **Early Detection of Problems**: Citizen science initiatives can serve as early warning systems, detecting and documenting instances of excessive or poorly designed lighting. This early detection can prompt local authorities to take corrective actions.

8. **Policy Advocacy**: Data collected by citizen scientists can be used to advocate for policy changes and the implementation of outdoor lighting regulations at the local, regional, or national levels. The evidence provided by citizen scientists strengthens the case for light pollution mitigation.
9. **Research and Scientific Insights**: Citizen-generated data can complement and enhance scientific research on light pollution. Researchers can use this data to validate models, assess the effectiveness of mitigation efforts, and gain insights into the ecological and health impacts of artificial light.
10. **Long-Term Monitoring**: Citizen science projects can be sustained over the long term, providing continuous data collection. Longitudinal data sets are valuable for tracking trends and evaluating the success of mitigation strategies over time.
11. **Collaborative Networks**: Citizen science initiatives often foster collaboration between researchers, citizen scientists, environmental organizations, and policymakers. These networks can lead to interdisciplinary research and a more holistic approach to addressing light pollution.

Overall, citizen science initiatives make it possible to monitor light pollution on a scale that would be challenging for researchers alone. They harness the collective power of individuals who are passionate about protecting the night sky and preserving natural darkness, making citizen science an essential component of ongoing efforts to combat light pollution.

1.3. Mitigating Light Pollution

Shielding and Proper Fixture Design

a) Shielding as a Solution

1. **Directing Light Where Needed**: Shielding involves designing fixtures in a way that directs light downward, onto the intended target area. This reduces light spillage and glare, preserving natural darkness while ensuring adequate illumination for safety and visibility.
2. **Types of Shields**: Full cutoff, cutoff, and semi-cutoff fixtures are designed to limit light emission above the horizontal plane. Full cutoff fixtures are especially effective in reducing upward-directed light.
3. **Dark-Sky Communities**: Many communities and organizations have adopted dark-sky-friendly lighting ordinances that require the use of properly shielded fixtures. These efforts help combat light pollution on a local level.

b) Proper Fixture Design

1. **Choosing the Right Fixtures**: Fixture design plays a vital role in minimizing light pollution. By selecting fixtures designed for specific purposes and locations, we can reduce over-illumination and light trespass.
2. **Low-Intensity Lighting**: Proper fixture design includes using lower-intensity lighting when possible. This approach not only reduces light pollution but also conserves energy.
3. **Efficient Light Sources**: Embracing energy-efficient light sources, such as LEDs, allows for precise control of light output, reducing unnecessary brightness.

The Potential of LED Lighting

LED lighting has great potential for reducing light pollution due to its directional and controllable lighting features. Compared to traditional lighting sources, such as high-pressure sodium lamps, LED lighting emits less scattered light. Additionally, LED lighting is adaptable and can be used in a variety of applications, including outdoor lighting, street lighting, and decorative lighting. LED lighting is also programmable which allows for the precision control of light levels and patterns, helping to reduce light pollution from urban areas. They can be scheduled to dim during off-peak hours or when there are no pedestrians or vehicles in the vicinity. Furthermore, LED lights can be installed with dimming sensors that react automatically to external light conditions. Overall, LED lighting has great potential for reducing light pollution by providing precise and directional lighting that minimizes energy waste. It is an energy-efficient, cost-effective, and eco-friendly lighting solution for addressing the growing concern of light pollution.

However, LEDs by themselves do not provide the solutions that light pollution management requires. The default installation from most companies consists of high-power white LEDs that go directly against the issue.

This is why it is important to be aware that the most complete solution should always be some LEDs between 2000K and 2700K of effective temperature and programmable dimmers. Like that we maximize both the positive impact to the environment and the energy consumption reduction

The Importance of Legislation and Public Awareness

Legislation and public awareness are crucial in reducing light pollution as they can help to promote responsible lighting practices and ensure that effective strategies are implemented to reduce light pollution. From a legislative standpoint, policies and regulations can be put in place to limit the use of artificial lighting or promote the use of energy-efficient lighting systems. This can include stricter regulations on outdoor lighting, mandates for the use of dark sky-compliant

lighting, or a ban on the use of certain types of lighting that contribute to light pollution. Public awareness campaigns can also be highly effective in reducing light pollution by educating individuals on the negative impacts of excessive artificial lighting on the environment, wildlife, and human health. These campaigns can encourage people to reduce their reliance on outdoor lighting, turn off lights when they are not needed, use energy-efficient lighting solutions, and promote the importance of dark sky preservation. Both legislative and public awareness efforts can play a critical role in reducing light pollution and helping to protect the environment and our health. By working together and taking action, we can help to reduce the effects of light pollution and create a more sustainable and efficient society.

International Dark-Sky Parks

Dark Sky Parks are protected areas where artificial lighting is kept at a minimum to preserve the natural darkness of the sky. These parks offer a unique opportunity to observe the night skies in their full glory, without the interference of excessive artificial lighting or light pollution. Dark Sky Parks have become increasingly popular in recent years, as people have become more aware of the negative impacts of light pollution on the environment, wildlife, and human health. These parks help to raise awareness about the importance of preserving dark skies, and the need for responsible lighting practices. There are now Dark Sky Parks all over the world, including in the US, Europe, and Asia. Some of the most famous Dark Sky Parks include Big Bend National Park in Texas, Grand Canyon-Parashant National Monument in Arizona, and Brecon Beacons National Park in Wales. These parks offer a variety of educational programs and events to promote awareness about light pollution and its impacts. Visitors to these parks can witness the beauty and wonder of the night sky in its natural state, and learn about the importance of reducing light pollution in their everyday lives. Overall, Dark Sky Parks are important in raising awareness about light pollution and promoting responsible lighting practices. They offer a unique opportunity to experience the natural beauty of the night sky, and inspire people to take action to reduce light pollution in their communities.

In the case of this project, 3 IDSPs have been involved:

- IDSP in Bukki mountains (Hungary) that already hosts an observatory with a full program for visitors to better understand the world of astronomy but also to spread the conservation message needed for light pollution management.
- IDSP in Daruvar (Croatia), which as of now is developing to become a future observatory. At this point, activities are conducted for stargazing and dark sky preservation.
- IDSP in Albanyà (Spain) which also hosts an observatory, with the same goals of the aforementioned parks.

Exemplary Cases of Responsible Lighting

For reference, we include 15 exemplary cases of responsible lighting all over the world. These belong to places that have done a remarkable job at implementing juridic tools or have introduced technical improvements to their lighting systems:

1. Sydney, Australia - A lighting plan for the city has been developed to reduce light pollution, increase energy efficiency, and protect the night sky.

2. Reykjavik, Iceland - The city has implemented a policy to dim street lights during non-peak hours, reducing energy usage and light pollution.

3. Flagstaff, Arizona, USA - The city has been designated as the world's first "International Dark Sky City," with initiatives in place to reduce light pollution.

4. Venice, Italy - The city has implemented a "Lights OFF" program, turning off unnecessary lights in public areas at night.

5. San Francisco, California, USA - The city has installed LED lighting in public areas to reduce energy usage and light pollution.

6. Singapore - The city has implemented a lighting master plan that uses low-glare streetlights and LED lighting in public spaces to reduce light pollution.

7. Osaka, Japan - The city has implemented an eco-friendly lighting plan that uses LED streetlights and smart lighting systems to reduce energy usage and light pollution.

8. Copenhagen, Denmark - The city has implemented a lighting plan that uses energy-efficient streetlights and lighting controls to reduce energy usage and light pollution.

9. Rotterdam, Netherlands - The city has implemented a lighting master plan that uses energy-efficient LED lighting, lighting controls, and light sensors in public areas to reduce energy usage and light pollution.

10. Glasgow, Scotland - The city has implemented a "Night Time Economy Strategy," which includes a plan to reduce light pollution in public areas during nighttime hours.

11. Ahmedabad, India - The city has installed LED streetlights and developed a smart lighting system to reduce energy usage and light pollution.

12. Helsinki, Finland - The city has implemented a lighting plan that uses low-glare streetlights, lighting controls, and LED lighting in public areas to reduce energy usage and light pollution.

13. Valencia, Spain - The city has implemented a "smart lighting" system, using LED lighting and lighting controls to reduce light pollution and energy usage.

14. Toronto, Ontario, Canada - The city has implemented a lighting strategy that uses energy-efficient streetlights and lighting controls to reduce energy usage and light pollution.

15. Munich, Germany - The city has implemented an eco-friendly lighting plan that uses energy-efficient LED lighting, streetlight sensors, and lighting controls to reduce energy usage and light pollution.

1.4. Conservation Efforts

Strategies for Minimizing Light Pollution's Impact

For concrete action, there are several strategies that can be employed to minimize the impact of light pollution. Most of them can only be performed by the political sector, but it is important that they are aware of what improvements must be done. Those include:

1. Installing efficient lighting fixtures - Using energy-efficient lighting fixtures such as LED lights reduces the amount of energy used, minimizes the need for additional light sources, and minimizes the amount of light pollution created.

2. Proper lighting placement - Proper placement of lighting fixtures can prevent excessive light from escaping into the atmosphere and neighbourhoods. It is best to place lights in a way that directs the light where it is needed, without creating unnecessary light pollution in nearby areas.

3. Use of timers and motion sensors - The use of timers and motion sensors for outdoor lighting can help ensure that lights are only on when necessary and adjust according to movement and daylight availability.

4. Use of shields or covers - Using shields or covers on lighting fixtures can reduce light pollution by reflecting light back into the appropriate space and minimizing the amount of light that escapes into the environment.

5. Dark sky friendly lighting - Dark sky-friendly lighting fixtures are specifically designed and placed to minimize light pollution, focus light where it is needed, and prevent glare to neighbouring areas.

6. Education and awareness - Educating the public on the impacts of light pollution and encouraging responsible lighting habits is crucial to minimizing its impact. This can include promoting the use of energy-efficient lighting, encouraging individuals to only install needed fixtures, and using them appropriately.

7. Regulations - Enactment of light pollution legislation can enforce appropriate usage of light fixtures and minimize the amount of excess light pollution created. By implementing these strategies, communities and individuals can play a role in minimizing light pollution's impact and preserving the natural beauty of the night sky.

Education

There are several reasons why it is important to educate students about light pollution:

1. Environmental concerns - Light pollution affects the environment by disrupting animal's natural behaviours and interfering with ecosystems and migration patterns. Educating students about the negative effects of light pollution on wildlife and ecosystem health can instil a sense of responsibility and help create a future generation of eco-friendly illumination.

2. Astronomical knowledge - Light pollution drowns out the beauty of the night sky, making it difficult to observe planets, stars, and galaxies. Educating students about light pollution can increase their appreciation and understanding of astronomy while sparking curiosity and inspire astronomical exploration.

3. Resource conservation - Light pollution leads to unnecessary spending on excess energy use, which contributes to climate change through the release of greenhouse gasses. Educating students on energy conservation strategies and appropriate lighting usage can help conserve resources and reduce light pollution.

4. Responsibility for our surroundings - Educating students about light pollution encourages them to take responsibility for their actions in their local community by ensuring proper lighting designs and usage that is friendly to the environment and humans.

5. Social benefit - Light pollution can cause light trespass, lighting glare and hinder our sleep patterns. Educating students on how to prevent light pollution and promote responsible lighting can positively impact quality of life for people and their neighbourhoods. Overall, educating students about light pollution can help create a citizenry concerned about environmental sustainability and informed about appropriate lighting behaviours, overtime making it more sustainable to live in an urban environment.

Conservation Programs

Emerging Technologies and Innovations

Innovative solutions can help significantly in reducing light pollution. Here are some examples:

1. Smart Lighting: The use of intelligent systems that rely on sensors, timers, and other digital technology to adjust illumination levels automatically. For example, IoT-enabled smart street lighting systems can adjust light levels according to specific parameters like time of day, traffic flow, and weather. Such systems increase energy efficiency while reducing the unnecessary light disperses in the air.

2. Light Emitting Diodes (LEDs): LED technology is more energy-efficient, longer lasting than traditional lighting sources, and the colour temperature could be adjusted to reduce an area affected by light pollution. Remote sensors can be installed for automatic dimming to improve energy efficiency.

3. Yellow/Amber Colour Lighting: One of the leading causes of light pollution is the usage of excessive blue and white wavelength emissions commonly used in Electronic displays and LED lights. Switching to yellowish or amber colour LEDs may reduce light pollution.

4. Optics Design: Lighting fixtures with well-designed shields and optics emit less light pollution into the sky while providing the necessary illumination. New developments in lighting technology reduce the light escape around the fixtures while retaining its useful illumination.

5. Astronomical tourism: Innovative lighting design in the tourism industry can help save dark sky areas and promote sustainable tourism for an enjoyable stargazing experience. These innovative solutions have the potential to reduce the amount of light emitted, reduce energy consumption, and minimize the impacts associated with light pollution. As the technology continues to develop and the benefits of responsible lighting continue to be appreciated, it is expected that new solutions will emerge, creating a more balanced and ecologically sensible scenario.

1.5. Conclusion

The Urgency of Addressing Light Pollution

At this point, we hope that the reader can already see the transversality of the issue and the fact that it needs an addressing that starts on individual action and ultimately leads to political intervention.

For clarity, we find it natural to sum up and sectorize the different areas where light pollution becomes a problem.

1. Negative Environmental Impact: Light pollution has negative impacts on wildlife, ecosystems, and human health, making it essential to address this issue urgently. Light pollution disrupts

animal behaviours such as bird migration and the hunting patterns of nocturnal species. Artificial lighting alters breeding and feeding habitats, ultimately altering the ecosystem as a whole. Reducing light pollution is crucial for restoring balance to disrupted natural habitats and allowing wildlife to thrive.

2. Efficient Energy Usage: Waste of energy is another major concern associated with light pollution. An excessive use of lighting results in unnecessary energy consumption and carbon footprint. As the climate change crisis worsens daily, it is essential for individuals and organizations to act responsibly, ensuring that the appropriate amount of lighting is used, and energy is not wasted to reduce carbon footprint.

3. Astronomy and Space Exploration: Light pollution drowns out the natural beauty of the night sky, blocking astronomical views and creating an obstacle for space exploration and research. Lack of a natural night sky can reduce interest in astronomy, and limit people's knowledge of the universe. Also, the fact that astronomy is heavily disrupted may result in significant delays to the future plans of mankind for space exploration.

4. Artificial Lighting and Quality of Life: Light pollution can have adverse effects on human health and well-being. Overuse of lighting can cause glare, discomfort and affect natural sleep patterns, leading to health problems. Resolving light pollution issues can improve human mental and physical health and foster a sense of wellbeing. In conclusion, addressing light pollution is an urgent global issue that affects various aspects of human life, including healthy ecosystems, wildlife welfare, energy conservation, and astronomical research. Individuals, governments, and organizations alike must take responsibility and prioritize reducing light pollution to ensure that all generations can enjoy a naturally lit sky and to minimize the impact of light pollution on human health, energy consumption and sensitive ecosystems.

Call to Action

Finally, after having exposed the issue and the general concerns, we must acknowledge that change is not only necessary but also possible. Starting such a change can become a huge challenge for those who try, but we believe that a few small actions combined can cause the necessary impact. Here, we express a few:

1. Raise Awareness: Significant changes can start with education, so it is essential to raise awareness by informing members of your community, family, and friends about the impacts of light pollution. With broader awareness, more people will feel the urgency to take sustainable actions.

2. Use Dark Skies Lighting: The use of fully shielded lighting fixtures that prevent light from being emitted upwards, directing illumination downwards and softening the surrounding light. Also,

switching to lower intensity lighting during non-peak hours can save energy and reduce unnecessary light pollution.

3. Turn off lights when Not Needed: Reducing unneeded light helps to reduce energy consumption during off-peak times, lowering carbon emissions and saves money on energy bills.

4. Changes in Public Policy: Encourage the local government to promote environmentally responsible outdoor lighting codes as part of their comprehensive planning, zoning, and public safety policies. Many countries have begun regulating outdoor lighting to reduce its negative impact.

5. Support the International Dark-Sky Association: Support organizations such as the International Dark-Sky Association who work towards promoting responsible lighting practices, protecting natural night skies, and preserving astronomical research facilities.

Taking these steps to reduce the adverse effects of light pollution would pave the way for more efficient energy consumption, improved environmental conditions, and better quality of life. It's up to individuals and the community to be proactive in promoting responsible lighting practices to preserve the night skies and to improve the overall environment.

2. GUIDANCE FOR SCHOOL TEACHERS TO WORK ON LIGHT POLLUTION

2.1. Light pollution exercises for students in open air

Activity for forest school students aged 8-14 years. Astronomy and light pollution in environmental education (open air school).

Getting familiar with astronomy (stargazing)

For which season: Spring to autumn
For what age: 10-14 years
Capacity: 30 students
Length: 3-4 hours.

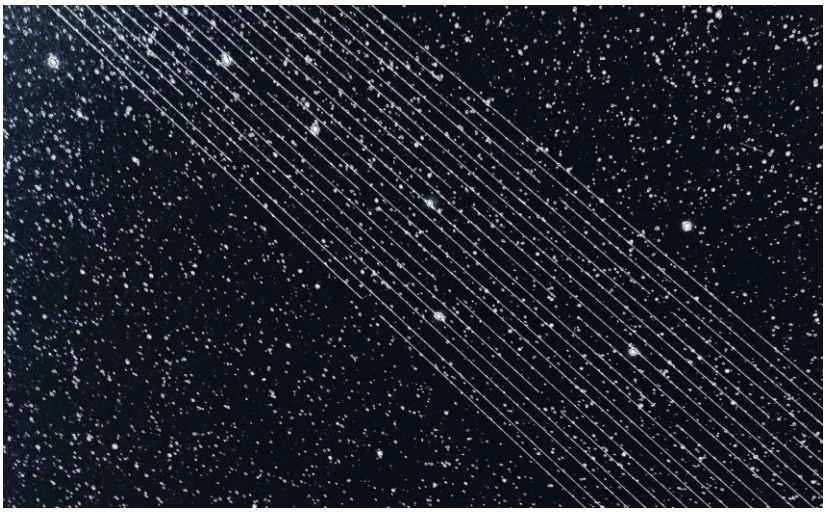
Nowadays, children grow up not knowing the starry sky, nor can they enjoy the view of the Milky Way. Recently, the size of the areas from which the starry sky can be seen without disturbing lights has decreased rapidly. With the drastic increase in the number of human facilities and settlements, the light emission also increases. Several groups of animals (such as bats, insects, migratory birds) are also active at night and are disturbed by man-made artificial lights.

Light pollution is a form of environmental pollution that must be combated and we must protect the starry sky as our cultural heritage so that those who come after us can see it in the same beauty as our predecessors. This idea fits well into the system of sustainable development: "We did not inherit the Earth from our grandfathers, but borrowed it from our grandchildren." The activity draws attention to the problem of light pollution and also builds on the expansion of astronomical knowledge. It awakens children's curiosity to learn about celestial objects and brings to the surface that ancient, deep-seated wonder that fills us when we spy the infinite on a dark night.

Some sessions of the activity are organically built on each other and include an element that is not just related to astronomy, which is the nighttime nature trail walk. Experiencing the silence and darkness of the night forest is a very unique experience, which, based on my experience so far, I must say is a very successful occupation of the module. The nature trail is first covered with a light, and then a part of it is completely without light. At that time, we would think that we will not see anything, but within a few minutes the miracle will happen: Our eyes will get used to the dark and we will be able to see.

This activity can be connected and supplemented by netting and studying night-flying bats, and a non-frontal presentation about them based on questions and answers, which can faithfully crown a stay at a forest school.

Supplemental night time activities as a „warm up" of the night time hike and stargazing: Observing nocturnal flying mammals: bats



During the activity, several artificial satellites can be observed. The starlink satellites are making the astronomer's work very difficult. The undisturbed natural night sky is our cultural heritage and must be preserved.

Curriculum sheet:

Purpose of the activity and brief content:

- Preparation for active work, the child should actively participate in observations, playful sessions, community strengthening in a room (presentations, videos, pictures as warm-ups)
- A narrower and broader understanding of our cosmic environment
- Getting to know the sights of the starry sky, orientation in the night sky
- Practicing and developing the conscious use of the senses.

Tasks of the activity:

- Informative presentation, questions-answers. Solving a simple astronomy-type exercise
- Orientation practices: Orientation in the sky based on constellations, recognition of more spectacular constellations, definition of astronomical units, familiarization with the laws of the movement of the stars and the "fixed stars".
- Stargazing with a telescope: Identifying the most attractive objects in the actual nocturnal sky.
- Required personnel: 1 person (amateur astronomer, teacher, etc.)

Location: Where the horizon is well visible, light pollution free zone.

The presentation about astronomy can be held in the conference room of the forest school, and the nocturnal guided walk can be more exciting as thought: Fireflies during night time hiking make this activity even more interesting and promising in june.

Name of activity: **Stargazing**

Name of sub-activity	Pedagogical goals	Methods, work orders	Name of field, test, illustrative and presentation tools, educational aids, literature, other material tools	Method of control, evaluation and feedback per module	Time needed (hour)
Playful question-and-answer, projected image presentation. Motivation by flashing interesting, spectacular images. General overview of the work of astronomers, more interesting aspects of science, Lecture, question and answer session about the problem of light pollution. Projected picture presentation in the conference room of the forest school. Solving a simple astronomy-type test.	Motivation by flashing interesting, spectacular images. General overview of the work of astronomers, more interesting aspects of science, Lecture, question and answer session about the problem of light pollution. Projected picture presentation in the conference room of the forest school. Solving a simple astronomy-type problem.	Frontal work, independent task solving. Use of mathematical knowledge. The group all together with little stops	Projector,computer	Solving a worksheet as a summary of the module	1
Nocturnal hike: Knowing nocturnal animals, their lifes, using no flashlight during the tour	Using all senses ,except eyes, making the students more sensitive to the forest night life.		Warm clothes, boots, flashlight for the leader		1
Orientation in the night sky and stargazing with telescope	Orientation in the sky based on constellations, recognition of more spectacular constellations, definition of astronomical units, familiarization with the laws of the movement of the stars and the "fixed stars".Grouping and identification of more spectacular objects in the sky.	In a small group, with frontal processing, individual observation	Telescope, laser, Compass, binoculars, binoculars, laser		2

Stargazing activities can amaze young students, and for most of them, the undisturbed nocturnal sky has a lot of hidden objects that they could not see so far. Even the Milky Way can be observable what is not any more visible from cities.

The fancy stargazing events can be made not only for students , but also for grown ups. This case the pedagogical goals are almost the same , but the methods are slightly different and the in-depth knowledge is on an elevated level, hence the average knowledge of astronomy,physics is equal to a 13 year-old student.

2.2. Light pollution in environmental education – comparing light traps

Background of the activity*:*

Light fixtures are attracting millions of invertebrates. By statistically analyzing large amounts of data, it is possible to estimate the amount of biomass removed by different types of lamps from their habitat, to monitor daily and longer-term activity changes, and to analyze the attractiveness of LEDs of different color temperatures.

Photosensitivity is essential for a wide range of animals, especially flying insects. Insects are sensitive to a wide spectrum of light, from ultraviolet (UV) invisible to humans to red. Their orientation, daily activity, and annual rhythm are highly dependent on lights and natural light patterns. Increasing outdoor lighting today poses a significant conservation problem due to its impact on insects. Luminaires used in public lighting practically act as light traps. In dark areas, a light source can attract up to 2,000 to 11,000 insect specimens overnight.

The amount of insects removed from their habitat by artificial lights - and mostly killed - is enormous: in a study in the US, a single light trap caught 36.8 kg (about 85 million individuals) of mud mosquitoes in one night (Rich and Longcore, 2006)

Therefore blue or cool white light-emitting metal halide lamps or LEDs have a 6-10 times higher attractive effect for moths than sodium lamps with longer wavelength (warm white or yellow) light. (Novák R. et al 2021 in ACTA Universitatis, Sectio Biologiae, Tom. XLVI.)

The most important in this activity is to raise attention for night time animals and their relation to light pollution. The leader (teacher) gives all the information and help in order to solve the tasks. Student groups are collecting the samples from the traps and analyzing their content. They not only try and measure the samples, but try to identify the animals with the help of the identifier book. After weighting and identifying, they draw conclusions from the data gathered at the end of the activity. Finally, they compare their findings and results with the assist of the activity leader (teacher).

Curriculum sheet:

Purpose of the activity and brief content:

- The aim of this activity is to raise attention to nocturnal lights and light pollution and its effect on wildlife. Students can conduct scientifically important measurements and methods in order to get an idea what are the harmful color temperatures for nocturnal insects. Preparation of samples, making measurements and working as a team.
- Understanding the effects of light pollution and why animals are attracted to some different kind of lighting fixtures.

- Field work, collecting samples, preparing samples, measuring and collecting data makes students more open to scientific work
- Practicing and developing the conscious use of the senses.

Tasks of the activity:

- Preparation: Students are getting familiar with the field, instruments, tasks to do
- Sample collection: After having all the most important information, they collect samples from the light traps
- Weighting: Drying and weighing samples

Location: Project area

Required personnel: 1 person (project leader)

Jermy-type traps with different lighting fixtures. Light is emitted in a different color temperatures, different spectra and different type of lamps

Jermy trap, equipped with amber LED

Name of activity: **Light Colours**

Name of sub-activity	Pedagogical goals	Methods, work orders	Name of field, test, illustrative and presentation tools, educational aids, literature, other material tools	Time needed
Preparation	Getting familiar with the project area, instruments, light traps, working methods	The students are divided into 3 groups. They go and visit each traps (different colur temperatures)	Flashlight, map, light trap instrumental assembly plan	1 hour
Sample collection	Working together as a team. Observing the trapped animals,and trying to identify them with the help of insect identifier	Each groups has their own lighting fixture, and they need to collect the samples, trapped the night before	Collecting boxes, insect identifier book	30 minutes
Weighting	Working with analytical instruments, working together as a team	Because we need the dry weight, a drying furnace is used in order to dry the samples	Pencil, exercise sheet, balance, drying furnace	1 hour

Amounts of animal collected by the traps (from left to right):
LED 4000 K, MVL 4000 K, LED 2700 K, CFL 4000 K

2.3. Star counter as a sky quality meter - the stars we see.

Background of the activity:

A good measure of the light pollution on some sites can be assessed by the estimate of the total number of stars one could get to see.

Counting them should, by no means, be hard. Using the power of statistics, we can get a good estimate on the total amount of stars visible in the sky.

Curriculum sheet:

This activity consists of two parts: one dedicated to crafting a useful apparatus for the measuring, and the other one for the measuring itself.

Necessary material to carry out the crafting part:

- Scissors
- 25x25cm cardboard
- 30 cm long thread
- Adhesive tape
- Compass (to draw circumferences)
- Ruler

Tasks to carry out when observing:

1. We should take our cardboard and mark its center. Right after, we will take the ruler and open the compass to a 6 cm aperture, to draw a 12 cm diameter circumference centered on the midpoint of the cardboard.
2. After having drawn the circumference, we must remove the inner part, so that we are left with a square cardboard piece with a circular hole on it.
3. On one of the sides of the square, centered, and below the hole, we will make a little hole so that we can introduce our thread. We will make a knot on its tip so that it doesn't slip. It might be convenient to take a thread longer than 30cm so that we can ensure that the usable part of the thread does have this length.

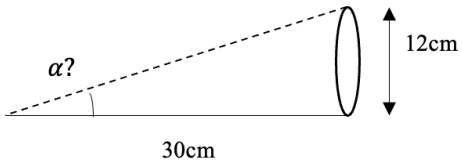
After this crafting, we should be left with something like this, that students may decorate as they see fit:

The second part consists of the usage of this instrument. It must be used on a clear night, without clouds or fog. We must choose 5 different directions in the sky, take one tip of the thread, and extend our other arm holding the cardboard perpendicular to the thread. Right after doing so we must count how many stars we can see and take notes in a table such as the one that follows:

	# of visible stars
Direction 1	
Direction 2	
Direction 3	
Direction 4	
Direction 5	
Averaged value of the 5 directions	

After having computed our averaged value (summing all 5 numbers and dividing by 5), we must compute what is the contribution of the 12cm diameter hole at 30cm from our eye to the total of the sky. We will assume the sky is homogeneous to compute the total number.

For that, we first apply Pythagoras' theorem to compute the angle covered by the circle. That is:



In order to derive alpha, we compute the following:

$$\tan(\alpha) = \frac{length\ of\ the\ opposed\ side}{length\ of\ the\ adjacent\ side} \rightarrow \alpha = \tan^{-1}\frac{opposed\ side}{adjacent\ side}$$

In our case, that leads to 21,8º. Now, we must take into account that the visible sky has 180 degrees in the vertical direction and 360 degrees in the horizontal direction. Hence, the fractional contribution of our circle to the total sky is:

$$\frac{21.8}{180} vertically, \frac{21.8}{360} horizontally$$

That means that if we multiply these numbers and invert them, we will get a number (136,35) that corresponds to the correction we must make to our averaged number of stars that will give us the total number of visible stars in the sky.

$$total\ \#\ of\ stars = averaged\ number\ of\ stars\ \times\ 136.35$$

Doing this measurement on different environments (city, outskirts, backcountry, …) might yield different results that can be used as a light pollution meter.

A nice addenda to this exercise, would be to put actual numerical limits to the already existing Bortle scale, whose definition for values is based on the sky brightness measurement.

2.4. Using the small bear (or dipper) as a light pollution meter.

Background:

For at least 2500 years, stargazers have been able to easily identify both the shapes of the big and the small bear (also called dipper). Nevertheless, in latter times, the smallest of them both, has become less obvious and even challenging to observe, since most of their stars are very faint and come across as invisible to the naked eye in a light polluted environment.

This limitation opens up an interesting opportunity, since the amount of visible stars can tell us the limiting magnitude in a given observation site. Since the brightness of the stars is quite well known, we can put an upper bound on the magnitude of the stars we are able to see.

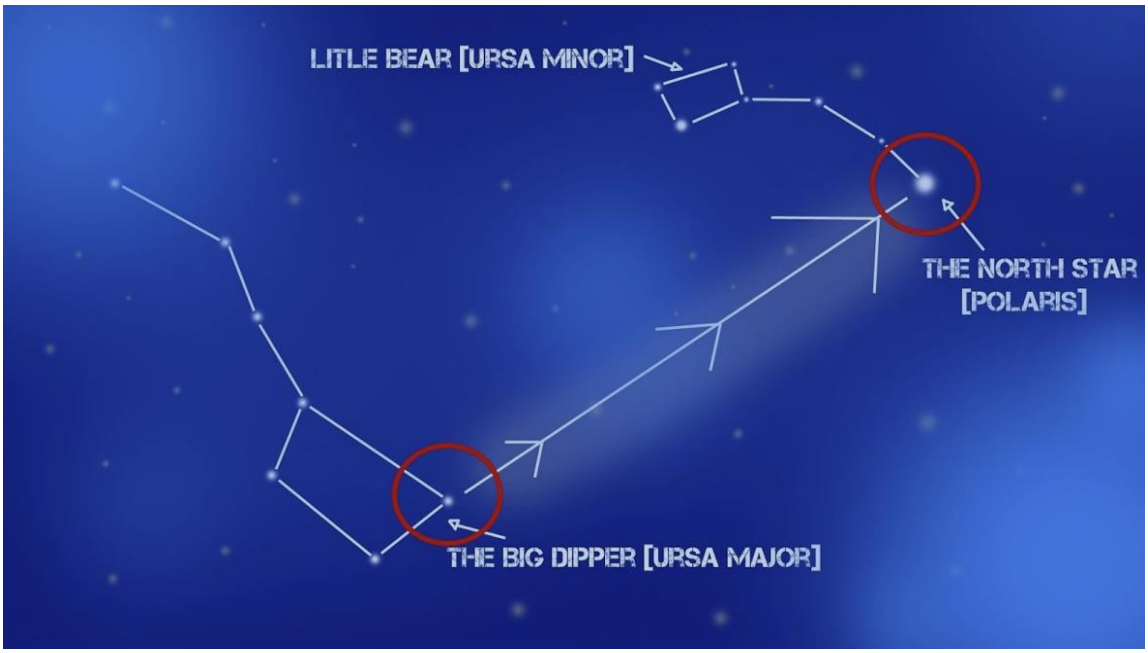
Curriculum sheet:

This activity is designed to be carried out with groups of minimum 4 people to work as expected.

In this case, we will be using the small bear (or dipper) constellation to check the sky quality for different environments.

The first challenge for this exercise will be to find the Ursa Minor constellation. Something that might be challenging for people unused to sky observation.

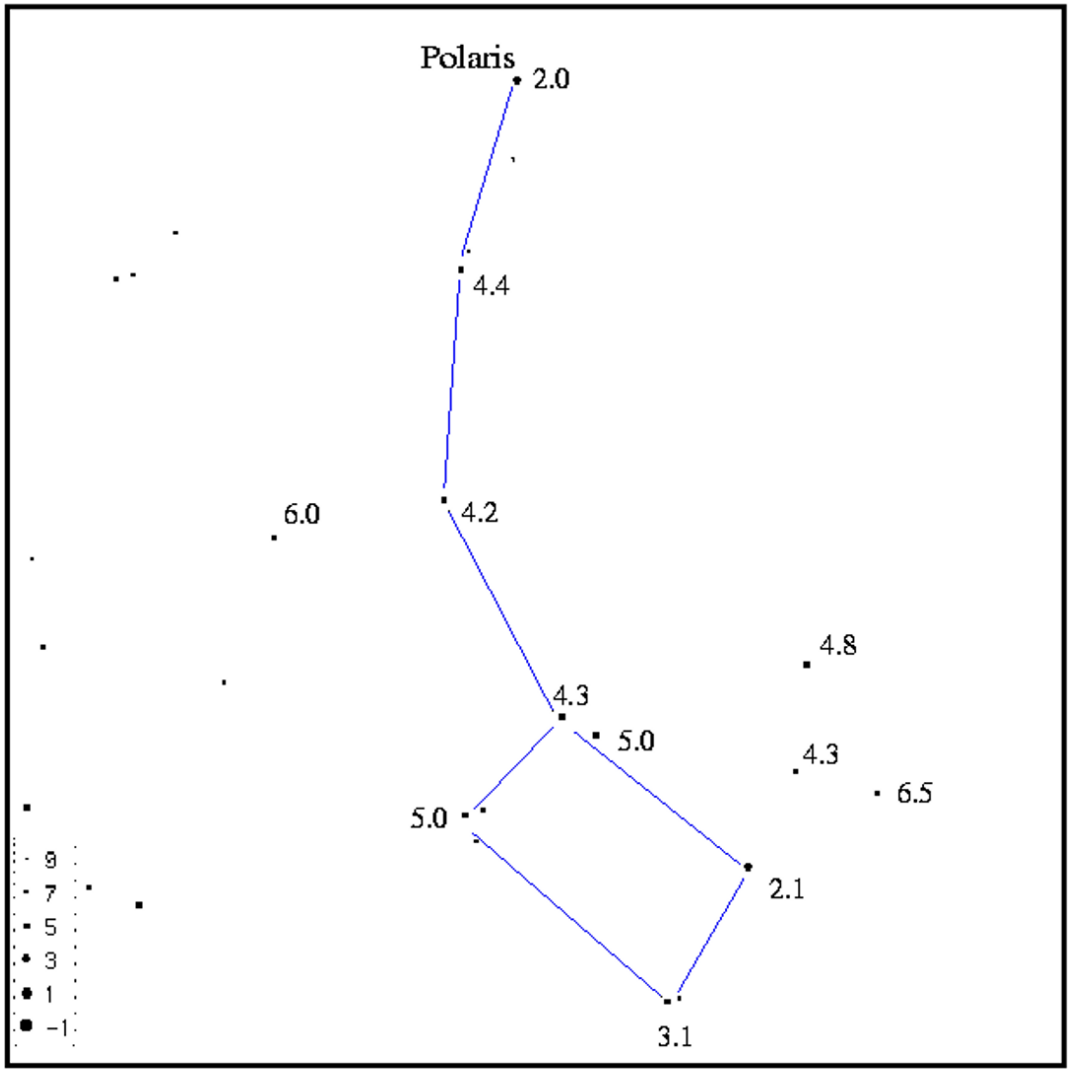
Ursa Minor is the constellation that includes the polar star, the true revolving center of the sky. Finding it is easily done by first locating a much bigger and brighter constellation, called Ursa Maior, and doing what follows:



Once Polaris has been located, finding the rest of the stars belonging to Ursa Minor, is much more challenging. For this reason, each group of students must be given a chart like the one that follows, and they have to mark the stars that **all of them** can see at plain sight.

Once they have, they must observe the numbers that lie beside the stars of the diagram. They are called magnitudes, and they are used to measure the brightness of the stars. The greater the magnitude, the fainter the star.

Ask your students to take notes of the biggest magnitude of the stars they can observe, since that might be the visual limiting magnitude of the spot, which may vary from protected environments to highly polluted environments.



2.5. Blue lights, red lights.

Background:

The amount of chemical reactions happening on our body in the presence of different lighting options, dictates the final outcome of some very basic functions like resting or feeling energized during the day.

This natural experience can be replicated in a much simpler fashion by exposing ourselves directly to red and blue lights. This is just an exaggeration of the daily cycles we go through, that might give some distress to our chemical side. This time, the experimenting field will be our own body.

Curriculum sheet:

To do this activity, you will need very little material, but it would be ideal to connect it with the Ursa Minor observation one.

Right after your students have gotten used to the darkness and started observing the different constellations of the sky (approximately 10 min of observing), it's the right time to start this activity.

Necessary material:

- Flashlight with white/blue light.
- Flashlight with red light.

Proceed by handing your students the red light and a white sheet of paper with something written on it. Ask them to read it under this light, and right after going back to observing the sky.

After having done so, repeat the procedure with blue light and ask your students the following questions.

1. Did you see more stars after using the red light or after using the blue light?
2. Did you have any feeling of distress after having used the blue light?
3. Did you feel some dizziness when it was first turned on?

Most students will feel minor distress with the blue lights, and that is just a small effect that we can see on humans. The presence of blue lights blocks the segregation of melatonin and interferes with the activation of the pineal gland, an essential part of the human circadian cycle, that allows us to sleep and carry out resting functions during the night.

2.6. Implementation of lighting fixtures at a class level

Background:

Street lighting serves a very specific purpose in communities — to light the street for automobile and pedestrian safety. Sometimes, however, streetlights are poorly designed or installed incorrectly and end up shining light onto your property or through a window of your home. This is known as light trespass — light that falls where it's not intended, wanted, or needed.

If you are experiencing light trespass that's keeping you up at night or seems to be wasting energy or polluting the sky, first take a look and see where the light is coming from. If the offensive lighting is from a neighbor's light fixture, see our My neighbor's lighting page. If it's from street lighting, read on.

Once installed, streetlights are rarely, if ever, taken out. Polite yet firm action may be your best course to help you regain your peace of mind and dark skies.

First, do your homework. Learn about the adverse effects of light pollution and light trespass, and the Five Principles for Responsible Outdoor Lighting.

Next, determine which local governmental agency is responsible for the light fixtures (usually your local municipal public works or utility department). Write to the agency to explain how your quality of life has been diminished by the streetlight(s) and request a "fully shielded" replacement or a "house-side shield" for the most offending lights.

Shields for streetlights are available from most streetlight manufacturers, although your local utility may tell you otherwise. Be persistent in your requests, and let them know you simply request that the light shining in your direction be redirected toward the ground where it belongs.

If this approach fails or your written requests go unanswered, contact your local municipal politician and request action and support for your position. But be diplomatic. Many politicians might feel proud about lighting the streets and making people feel safe, even though the evidence linking brighter lighting to less crime is inconclusive.

Light fixture replacements in Hungary (left: a forest school external lights; right: complete change of fixtures with well visible results)

Finally, you could even offer to pay for the shields, but only do this as a last resort.

By tactfully and persistently making your case about the effects of light trespass on you and your property, eventually you should prevail.

The International Dark Sky Association recommends several approaches in choosing and installing LED lighting that enhances public safety, reduces light pollution and creates a healthier environment for urban wildlife. They include:

1. Limiting the color temperature of LED lighting to no more than 3000 Kelvins
2. Fully shielding all new fixtures and ensuring they're installed correctly, so the light is on the ground where it is needed
3. Installing dimmers, timers and other adaptive controls that limit the intensity of the lighting and the number of hours it's on.

If your city has already retrofitted its lights, unfortunately, there's not a lot that can be done. Here are a couple of potential solutions:

- Retrofit the lights with shields to direct light downwards and reduce glare

- Install after-market dimmers and/or timers to lower the intensity of the light at appropriate hours
- Add filtering materials to screen out harmful blue light emissions
- Take action!
- If your city hasn't retrofitted its lights yet, now is the time to act!

Ask questions and do your research! DarkSky has many resources for city residents, including:

Printable LED Information Handout (PDF)
Seeing Blue (PDF)

Write or call your Mayor and City Council Members. Speak to their staffers and let them know your concerns about the quality and effects of new energy-efficient street lighting systems.

Contact your city Transportation or Streets Department and ask for details about any proposed or anticipated changes to city street lighting.

Work to get a lighting ordinance enacted in your city, if none currently exists.

Remember, change is still possible! If you feel strongly about your nighttime environment, make sure your voice is heard. If you don't act, things won't change. Together we can work to make our cities healthier, safer places to live by insisting on quality lighting and not just short-term cost savings.

DarkSky certification

Quality outdoor lighting protects and restores the natural night environment by controlling light pollution.

Three International Dark Sky Park was involved in this project. Vrani Kamen (HR), Albanyá (ES), Bükk (HU).

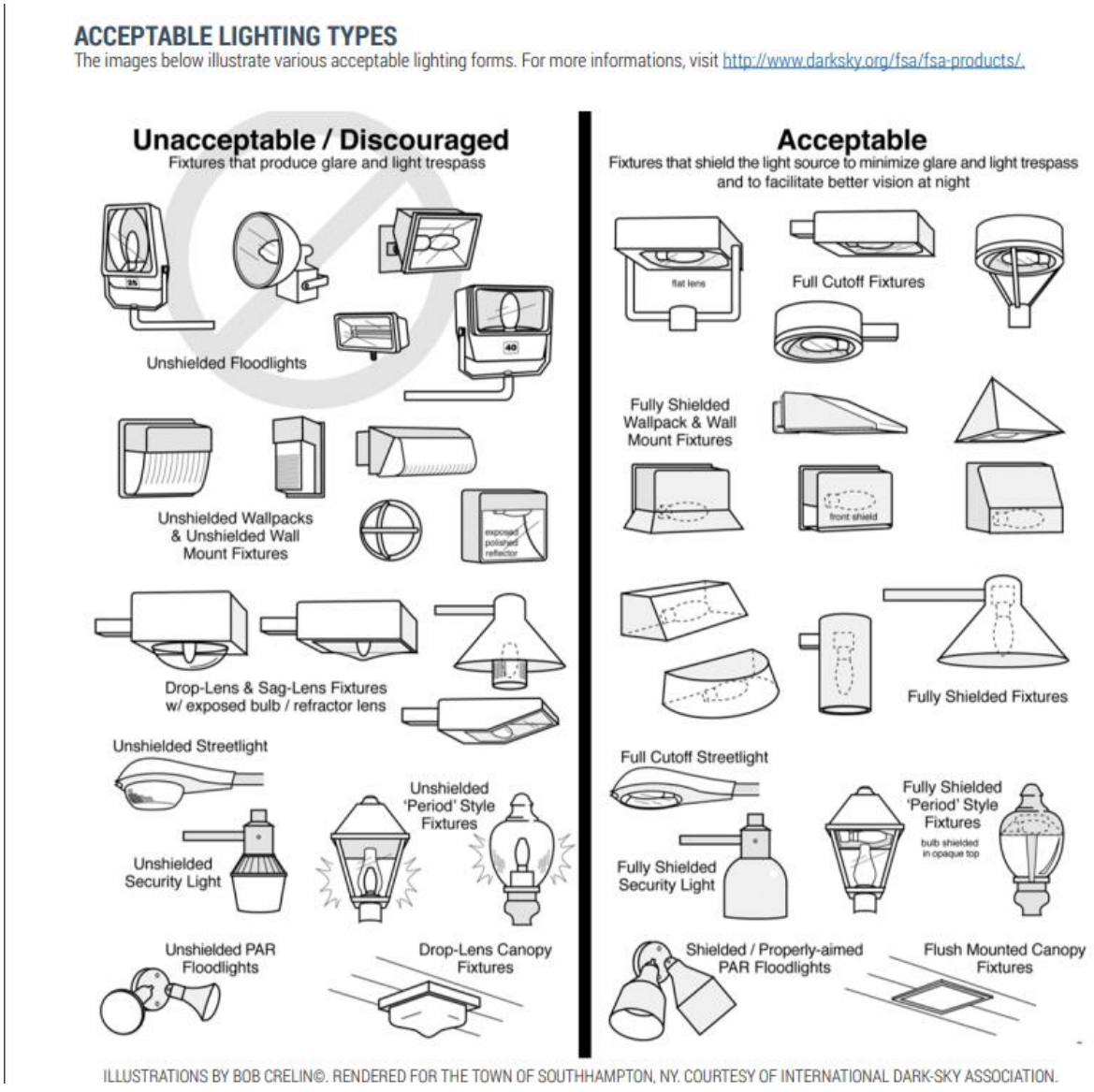
Bükki Csillagoségbolt -Park

VRANI KAMEN
PARK TAMNOG NEBA

The DarkSky Approved program provides objective, third-party certification for lighting products, lighting designs, and installed lighting projects that minimize glare, reduce light trespass, and reduce light pollution.

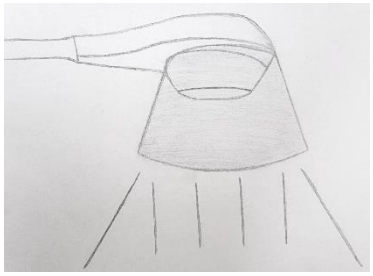
To be certified, they must:

- Restrict the amount of upward-directed light.
- Avoid glare.
- Avoid over-lighting.
- Utilize dimming and other appropriate lighting controls.
- Minimize short-wavelength (blueish) light in the nighttime environment.



2.7. TECHNICAL SCHOOL STUDENT ASSIGNMENT

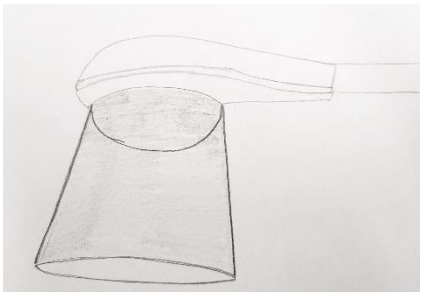
For this part, we include the results of a real exercise conducted at Daruvar's technical schools, where students were encouraged to come up with their own lighting fixtures.

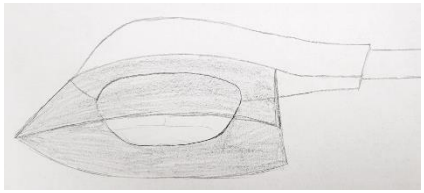
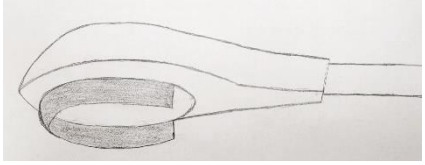


Suggestions for outdoor lighting protection made by students

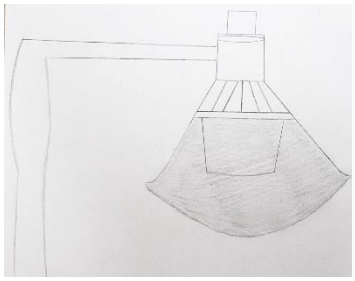
We suggest making additional shields against glare on existinglighting fixtures from various materials that can be recycled, such as:

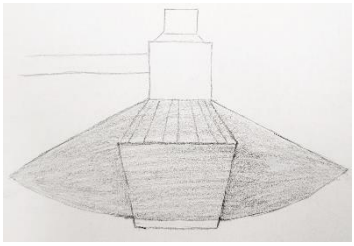
- Solid cardboard
- Various metals
- Wood
- Hard plastic
- 3D printed pieces



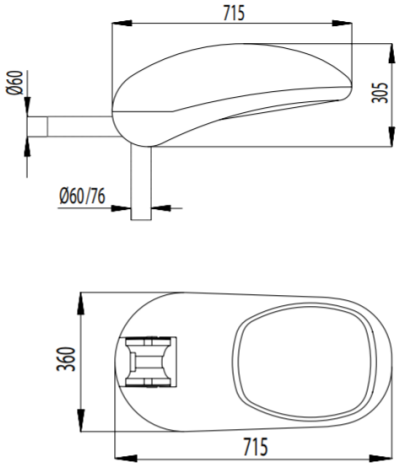



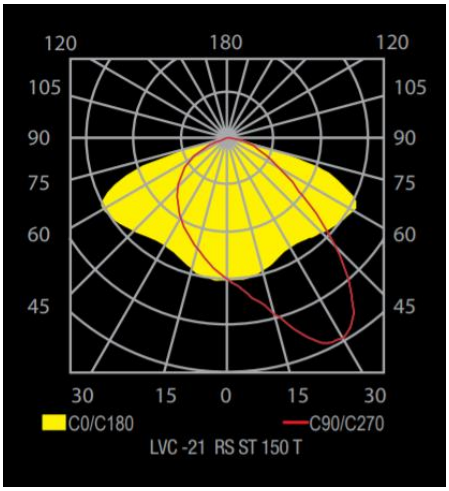
Shields can be placed on public lighting or on the one we have in our backyards





Suggestion for public lighting





- **Kapalux**
- USE: lighting for motorways, main roads and major city streets.
- STRUCTURE: lamp housing and lid, in the AP version, are made of pressurized aluminium alloy and painted by the electrostatic application of polyester powder.
- INSTALLATION: On a Ø60 console or Ø60 and Ø76 pole ends, under 0 ° to 20 ° in steps of 4.5 °. Rated voltage and frequency: 230 V, 50 Hz

With bulb:

- Type: Osram Bulb NAV-E 50W SUPER XT E27
- Power: 50W 4200 lm
- Power supply: 230V
- Bulb / Bulb holder: E27
- Dimensions: Diameter 71 mm; Length 156 mm
- Colour: dimmed (coated)
- Light colour: warm 2000K
- Lifetime: 36,000 hours
- Energy class: A
- Dimming capacity

2.8. Introducing light pollution in class

LIGHT POLLUTION DEFINITIONS

Teachers brainstorm the students' ideas on light pollution. Together, they have to come up with a definition that can be posted on posters or on an online platform.

REGULATIONS ON LIGHT POLLUTION

Teachers guided students on different regulations concerning light pollution.

UN Sustainable Development Goals by 2023

After searching and reading the UN Sustainable Development Goals by 2023, students analyzed specifically proposal 11, "Sustainable Cities and Communities". Teachers moderated a class discussion about proposal 11 and focused on the question: "what actions can be taken to achieve relevant goals?

Also, we discovered ODS 18, "Sky quality and access to starlight" and we supported the international campaign that is trying to establish ODS 18 by adding our signatures in the online form provided in https://ods18.org/en/

Catalan regulations: Decree 190/2015

We analyzed the Catalan regulations concerning light pollution and we checked the zone ratings (E1, E2, E3, E4) of the areas where students live. We suggest that each school analyzes the regulation of their government.

GLOSSARY OF TECHNICAL TERMS ON LIGHT POLLUTION

In teams, students created a glossary of technical terms on light pollution.

GLOSSARI CONTAMINACIÓ LUMÍNICA

Potència - Potencia - Power: És la quantitat de llum emesa per unitat de temps.

Luminància - Luminancia - Luminance: És la quantitat de flux lluminós que incideix, emergeix o travessa una superfície aparent d'una font de llum primària o secundària des-de un angle sòlid.

Àmbit supramunicipal - Ámbito supramunicipal - Supramunicipal scope: Infraestructura destinada a serveis de l'Estat, la qual s'obté per expropiació.

Llum artificial / Luz artificial / Artificial light: La llum artificial és la llum produïda per un aparell d'il·luminació elèctric, de gas, d'oli…

Llum natural / Luz natural / Natural light: La llum natural és aquella que prové de fonts naturals.

Sostenibilitat / Sostenibilidad / Sustainability:
Conjunt de polítiques destinades a fer compatible el creixement econòmic i la preservació de la biodiversitat i evitar la degradació de la biosfera provocada per l'acció humana.

Figure 1. Example of glossary on technical terms about light pollution

In our school, we decided to use Padlet as a way to put together the work we did on 1.1, 1.2 and 1.3

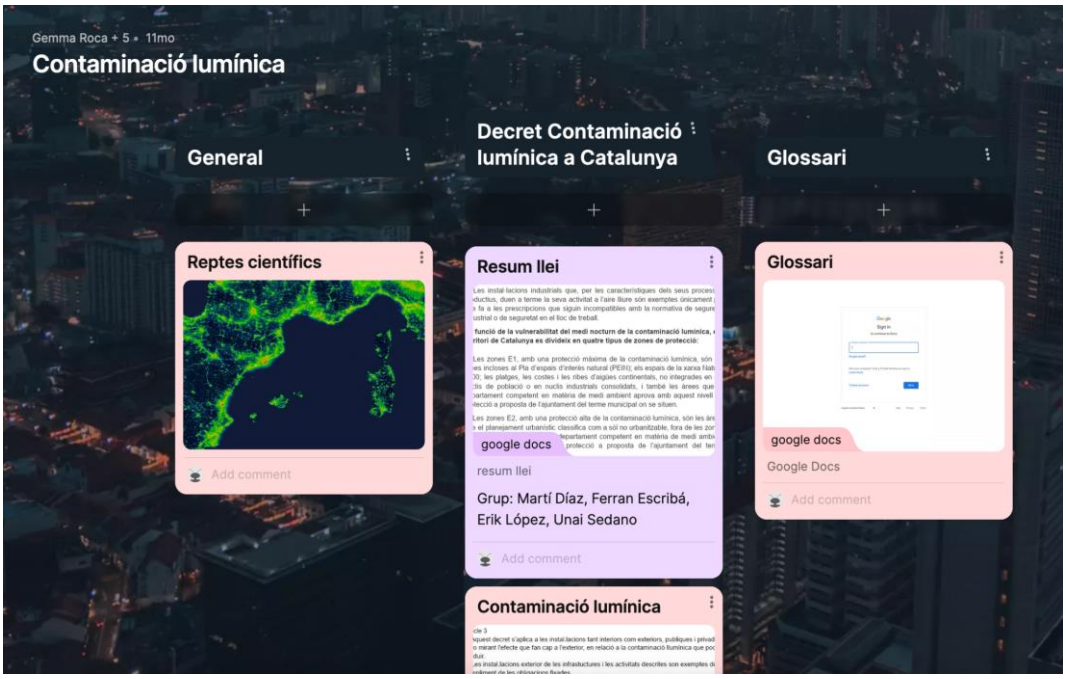


Figure 2. Padlet example on general information about light pollution

Apart from these three topics, teachers have given lectures on the best type of lamp post in public spaces according to the International Dark-Sky Association recommendations. Students have taken into consideration the type of lamp post, the type of bulb, the working hours and the consumption.

Additionally, under the teacher's guidance, students have been experimenting with light behavior in the laboratory.

2.9. Practical project: a spectrometer

In pairs or groups of three, students have created their own spectrometer. The materials they used were a kitchen roll cardboard, a CD, cardboard and tape.

With their spectrometer, students were able to observe the different wavelengths of different types of bulbs and they also examined and took pictures of the different light colour patterns.

We spent three sessions of 60 minutes each to make the spectrometer and experiment with it.

2.10. Students projects to improve light pollution in their area

In groups of four, students have analysed the light pollution of a specific area, have determined the main problems and suggested specific actions to improve light pollution in some areas in Figueres as well as in villages nearby.

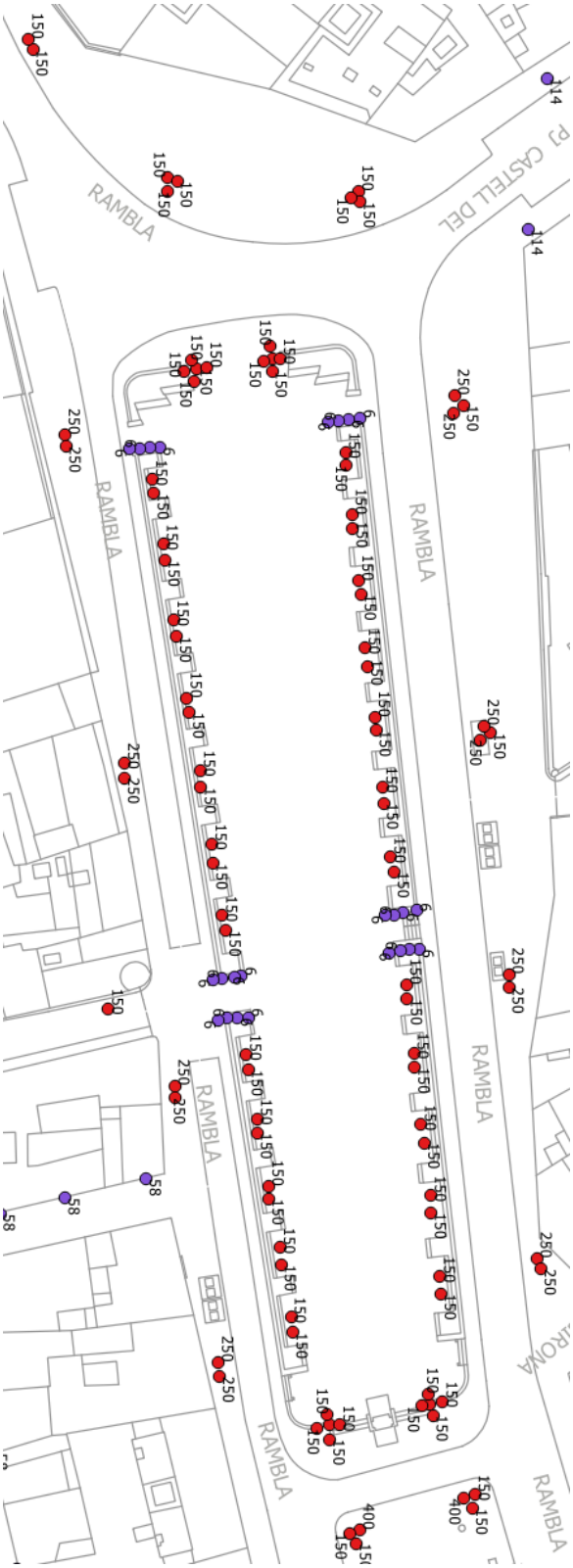
Measurements and analysis of a specific area
For the purpose of convenience, students chose an area that is close to the place where they live and they needed to analyse the lightest and darkest place of that area. Students measured SQM-L levels equipped with a Sky Quality Meter.

They took the following actions:
- They calculated how many lamp posts there were in the area and took pictures of them.
- They analysed the type of light, the power and colour of the light, efficiency and temperature.
- They analysed the quality of the night sky and took measurements by counting the number of stars.

Suggestions to improve light pollution

According to the area, students made different suggestions to improve light pollution, which included covering the bulbs to avoid light dispersion, using sensors, limiting the time when the lights should be on, reducing the number of light posts, changing the type of bulbs, particularly the white ones into orange ones.

This image represents the lamp posts that are installed in La Rambla in Figueres nowadays. The red dots represent the standing lamp posts and the purple dots the ones that are hanging from the walls. The numbers represent the power of each post in Watts (W).



Example of one of the projects from students: map of lamp posts in the Rambla, Figueres

2.11. Whole class project: interactive map

Using all the measurements students made in the area, they added the information into a Google Maps in groups. Afterwards, they put all the maps together in an interactive map using Genially.

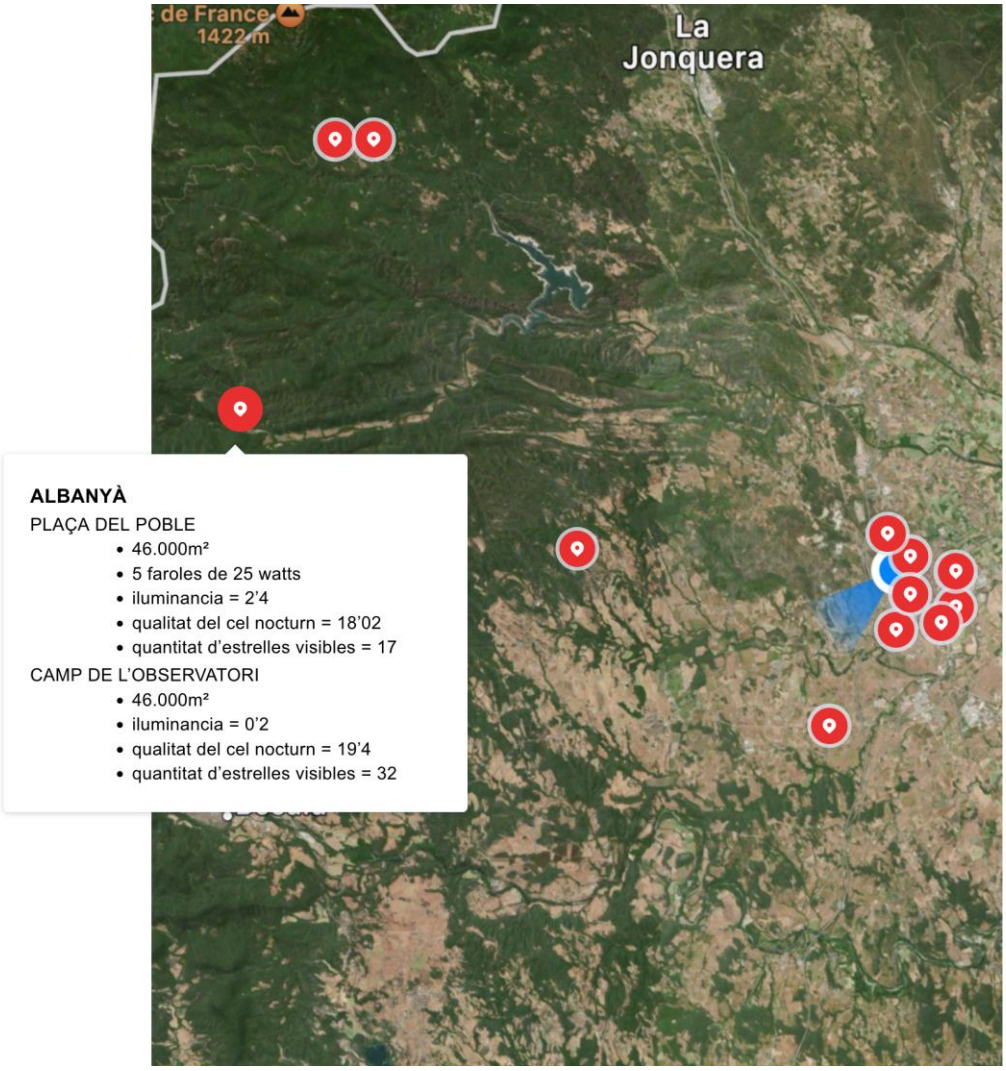


Figure 4. Interactive map with students measurements using Google maps and edited with Geinally.

2.12. Online accessible VR educational software in the everyday classes.

In our case, VR educational software has been unsuccessful. Unfortunately, even though teachers and students tried many times, we were unable to install the software that Lunar provided. Also, Lunar representatives tried to install it in our VR technology unsuccessfully.

As teachers, it was difficult for us to see the added value that VR technology provided in the analysis of light pollution.

Also, our school has adopted a 'no mobile phones' policy, and thus we were unable to use the VR technology that requires a mobile phone.

We wouldn't recommend the use of VR software for educational purposes for different reasons:
- the cost of the devices
- the need of a technician when it malfunctions
- the need of a place to store it and a supervisor that controls their use
- the difficulty to grant equal access to all students as our classes have more than thirty students and it is difficult to make half of them wait while the rest are using the technology.

2.13. Dissemination

Posters

Students designed posters about light pollution that we used to disseminate the project in our school, as we had the posters in the corridors.

Figure 4. Dissemination poster.

Figure 5. Dissemination poster.

Brochures

Students designed brochures on light pollution that we used to disseminate among the educational community and our local area.

Figure 6. Brochures on light pollution, its causes and how to improve it.

2.14. Final remarks

We felt that the students engaged very much in the project and they were able to learn about light pollution, the problems we face locally and globally related to it and to propose solutions for the future to come. They became honestly concerned about light pollution and ready to raise awareness among their communities about the seriousness of the issue. We also found VR technology unnecessary to successfully complete the project.

3. VR MODULE GUIDE AND INSTRUCTION MANUAL

OPERATIONAL MANUAL

FOR SCHOOL TEACHERS

3.1. Prepare your Oculus device

NOTE

From time to time (almost regularly) this process gets updated or modified by Meta (owner of Oculus brand). Some tools get updated, some apps or tools get visually different over time. These are guidelines, steps to installation and maintenance of Oculus VR headset at the time of writing.

Prepare e-mail address
(preferably dedicated for Oculus VR headsets)

1. Prepare an e-mail account (eg. gmail), remember / store the account information to safe place (so it could be found and used when needed)

Download

2. Look for and install "**oculus quest 2**" in **Google play store** to your **Android phone.**
(it will be used to initialize and configure VR headset)

3. Look for and install "**Oculus ADB driver for windows**" on computer.
(needed for SideQuest application)
https://developer.oculus.com/downloads/package/oculus-adb-drivers/

4. Install "**SideQuest Advanced Installer**" on your windows computer.
(used to install our VR APP to VR headset)
https://sidequestvr.com/setup-howto

Connect

5. Enable location, BT and WiFi on Android phone.

6. Connect headset and phone to internet.
(same WiFi network)

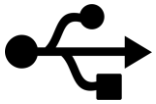
Sign in, verify account, activate developer mode

7. "**Sign in with e-mail**" to Oculus APP on Android phone.

8. sign in to your oculus/meta account on PC and create organization.
https://developer.oculus.com/documentation/native/android/mobile-device-setup/

9. when paired with VR headset, enable developer mode for each headset on your Android phone APP.

10. Reboot each VR headset.



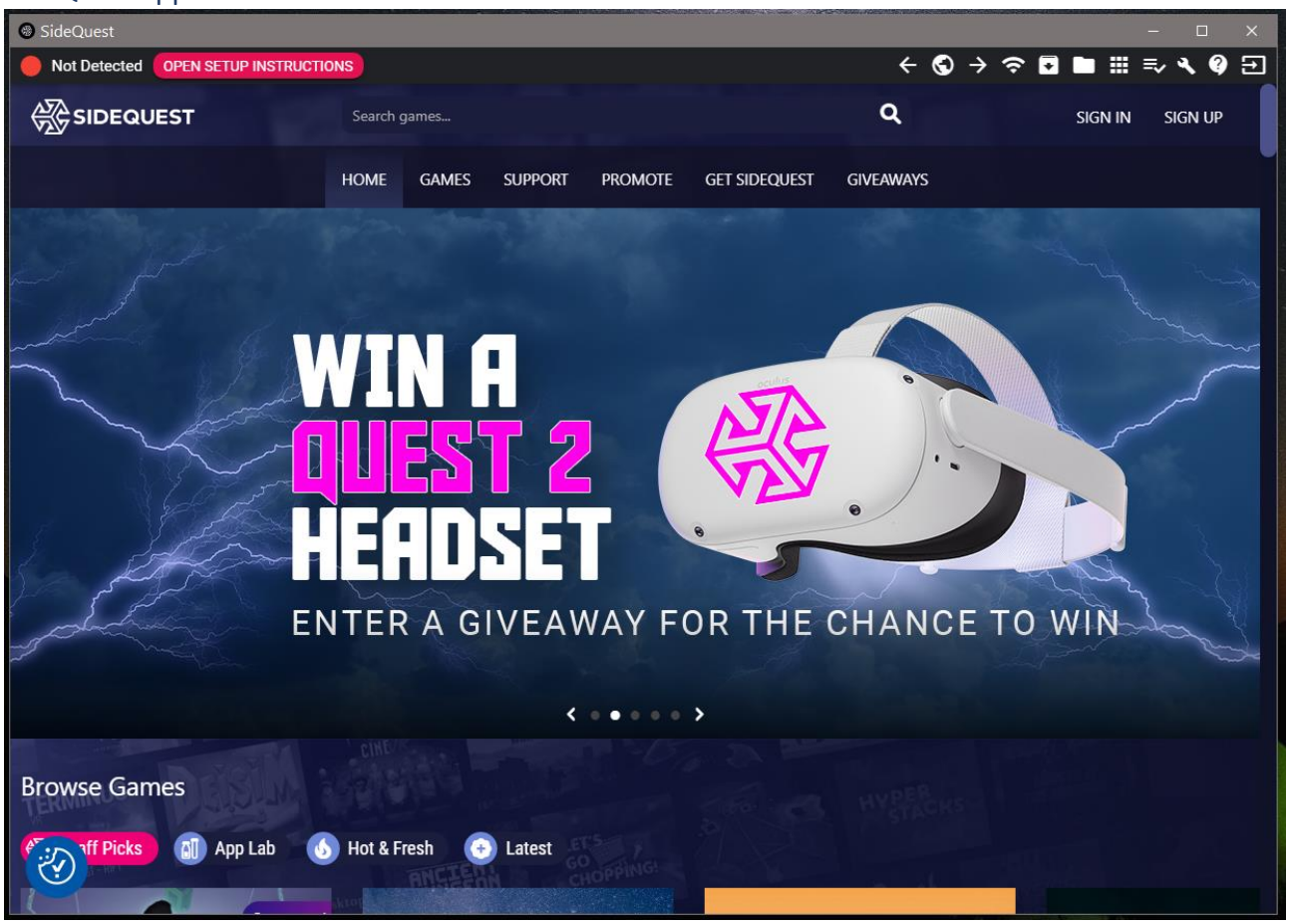
Connect with USB cable to install APP

11. Connect VR headset with your computer.
(using included “USB-C to USB-C” cable or “USB-A to USB-C”)

12. In the headset there will be a message to allow “**USB Debugging**”, choose “**Always allow for this computer**”.

3.2. Using SideQuest to install our application to the VR headset

SideQuest application view



NOTE:

Notice the Red dot and text "**Not Detected**" in the upper left corner!

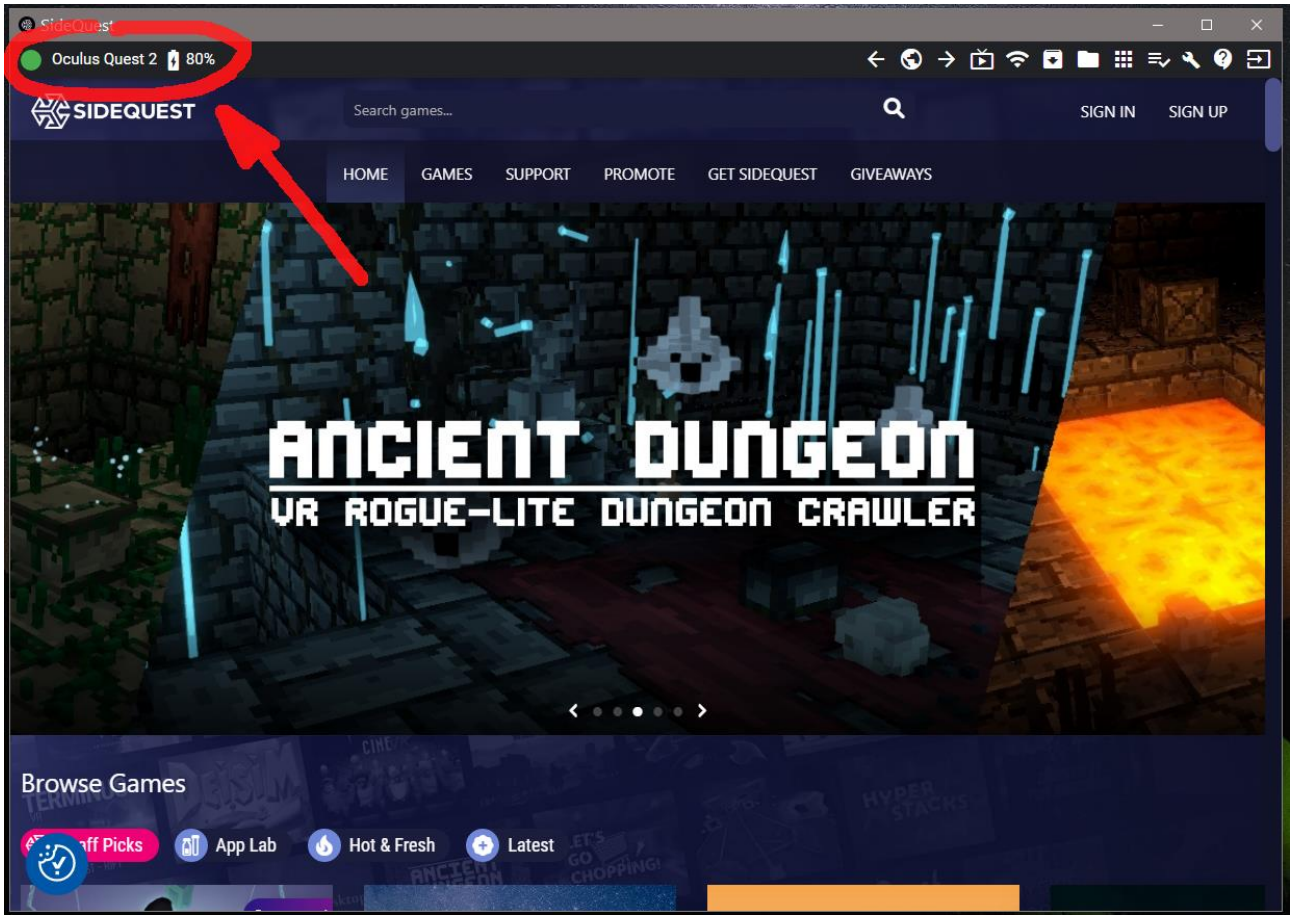
That means that VR headset is not detected:

- the cable is not connected
- the VR headset is not turned on or
- there is no driver installed

Sometimes (very rarely) you may need to reboot the VR headset and your computer and try again.

Also notice the **icon menu** on the top right side of the window.

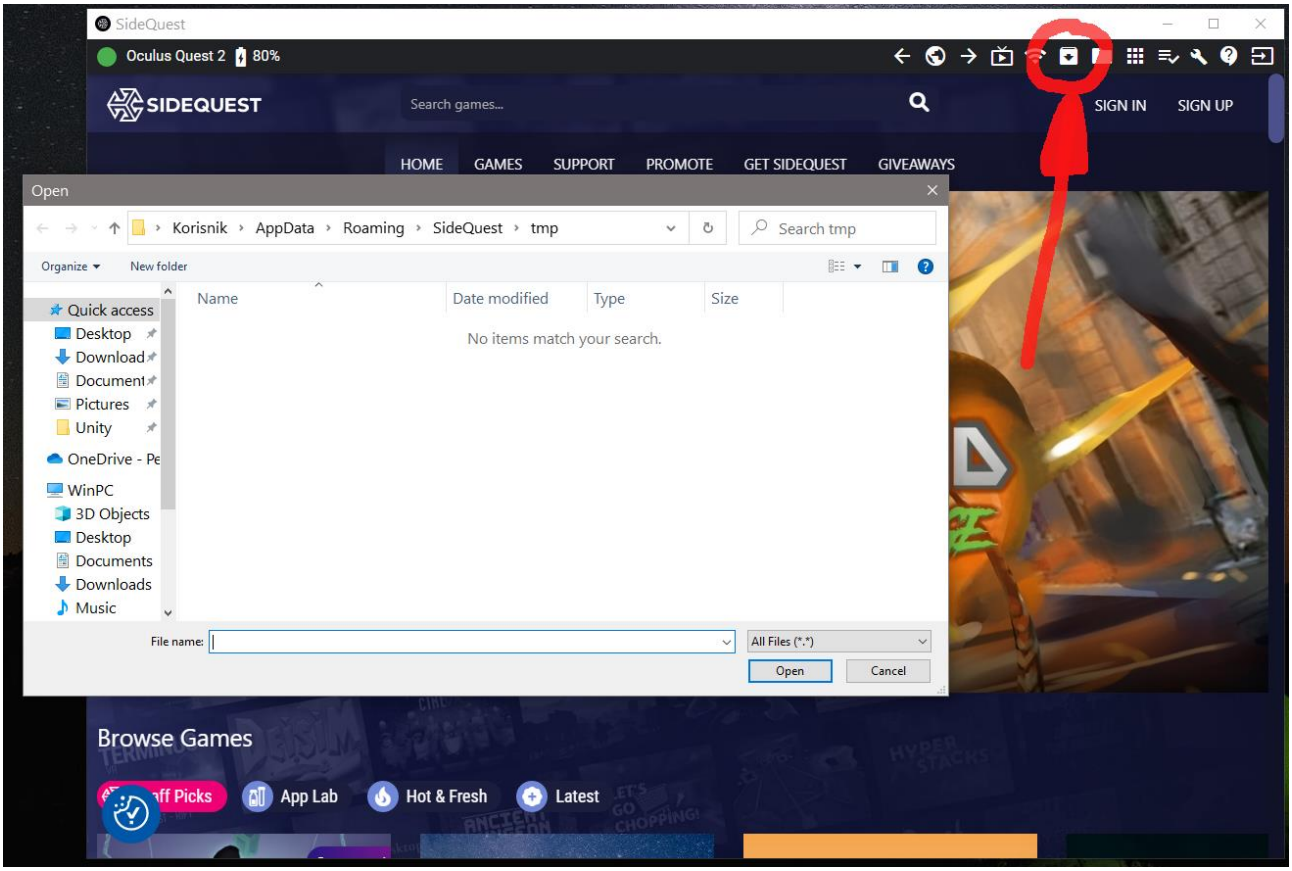
Side quest has detected your VR headset properly



NOTE:

Green dot meaning: headset is detected properly, the battery status is displayed, you are ready to install the application.

Install application to your headset



NOTE:

In the icon menu. The 6th icon from the left, similar to the “download” button is the one used to install apps to VR headsets.

When you click the icon, browse to your APK file and confirm by double-clicking the APK file or clicking the “Open” button.

Wait a while, in the bottom of the window there will be a message similar to:

“All tasks completed!”

At that point you may disconnect the headset and use it freely.

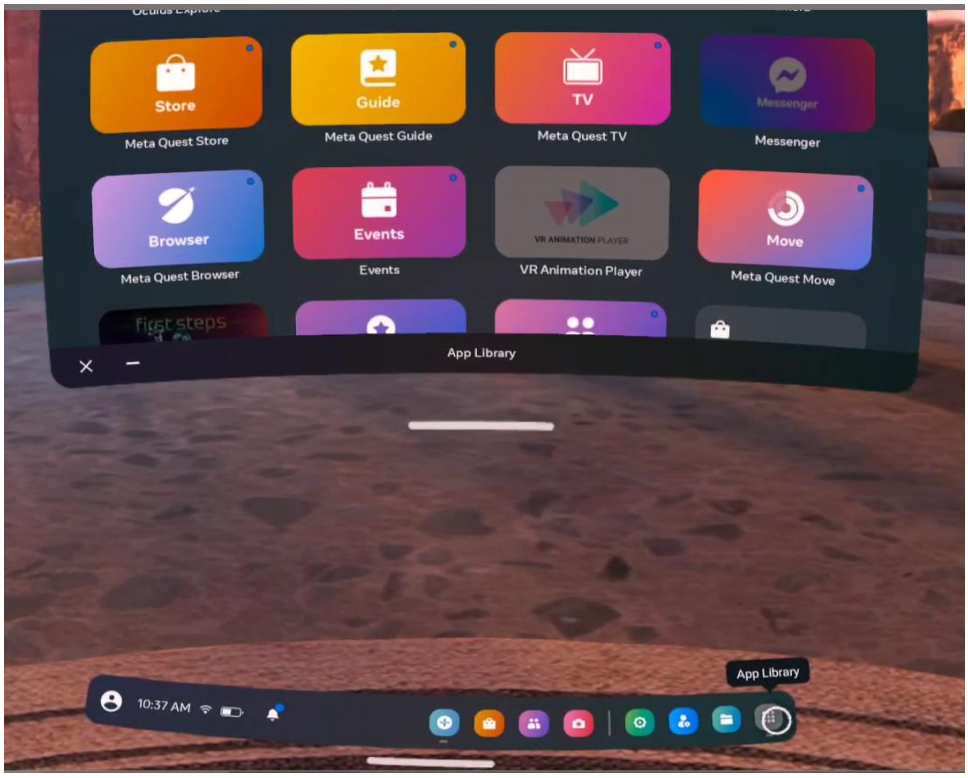
3.3. Starting the application after installation

In the lower part of the scene there will be a “main menu”. If you don’t see it, turn around and look for it. **Always remember: you’re in the virtual space.**

Alternatively: on the right controller there is an “O” = oculus button, press and hold this button for a second or two. In the lower part of the scene in front of you the “main menu” should appear.

On the far right (last item) is “applications”, point to it and “click”
(press the main fire button on the controller).

List of installed applications should appear similar to this, on the top there will be a “search” field, point and click on it.



Filter will appear on the top, in the middle section click and select “Unknown sources”, the application will be displayed in the list.

3.4. The game

The main problem that needs to be addressed is that pollution, climate change and our impact on the environment is abstract. Its meaning only unfolds in 10, 15, or 100 years. It is very hard for people to understand and plan and make decisions.
When dealing with light pollution even more so. Since we humans are day-active and we depend on daylight for most of our activities it may be hard for us to realize the situations where we have too much light, impact of color of the light or the importance of the construction of our light fixtures and light sources.
Main goal is to sensitize society, to acknowledge that the problem is real and exists. The other important aspect of this project is the night sky and stars, sensitizing the need to preserve the night sky and stars for us as well as for the environment (wild life).

Virtual reality may help in this process of bringing the subject closer to pupils, students and the general public through a simple, easy to understand application / game.
VR technology can also be used to promote best practices in lighting and energy efficiency. For example, VR simulations can be used to demonstrate the importance of lighting fixture designs, especially shaders and the direction of light, by choosing the color(temperature) of light that has less impact on the environment. By providing an immersive experience that enables people to see the impact of the choices they make, VR can help promote the adoption of optimal lighting fixture designs and light sources, and employ the best practices in order to minimize our impact on the environment by light. It is meant as a supplement for other intellectual outputs, workshops and classes on the subject of light pollution.

Another way VR can help mitigate the effects of light pollution is through the development of virtual simulations for light pollution and space/stars night sky and stargazing in general.

3.5. Astronomy game

The main aim is to produce an effective and attractive educational tool through which students will learn about the aspects of light pollution and our impact on the night sky and environment.

The game consists of three chapters, or segments:

- Light sources and light color temperature
- Sky puzzle
- Messier challenge

There is a competitive element in the game because at the end there is a score which could be compared with the results of other players.

Main targets are children of the age 14 – 18.

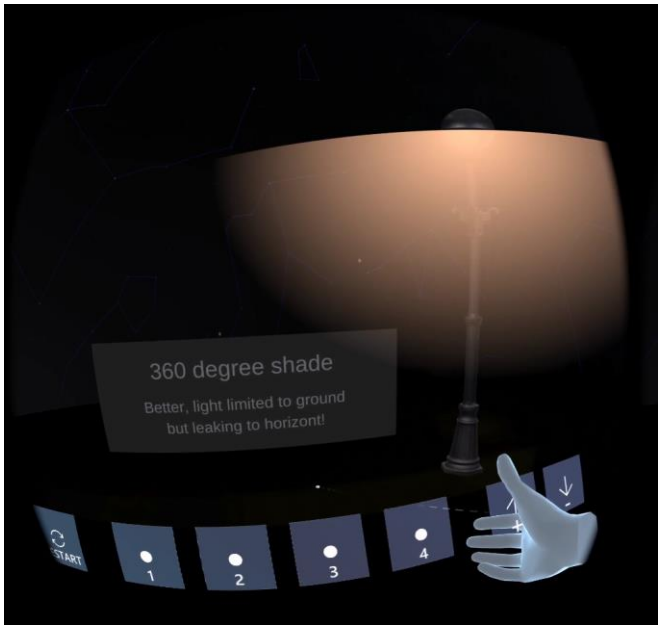
The scene of open educational resources for VR applications in the light pollution segment is limited. Therefore, the value of such applications developed under Erasmus programs is even greater.

3.6. Game play

1. Light sources and light color temperature

Simulates the night sky and impact to sky and stars visibility depending on the light fixture we choose and depending on the colour temperature of our light source. The point of this is to sensitize that the best light source is pointed to the area of interest in our example of typical street light -that's ground and that colour temperature of the light should be as low as possible around 2800 K.

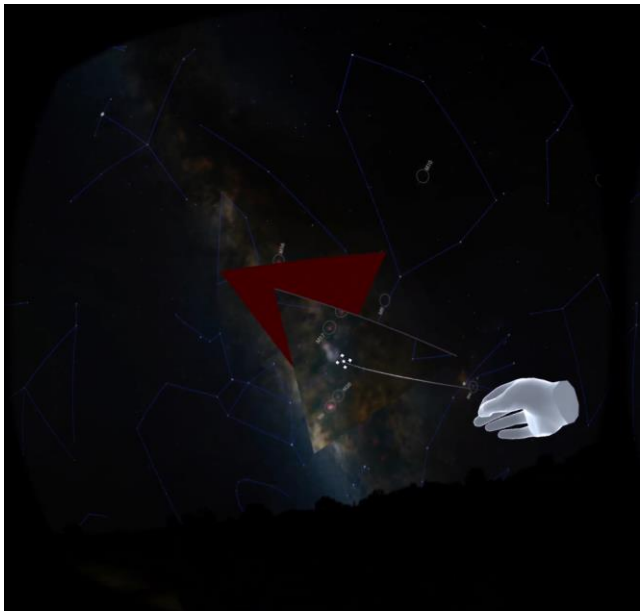
This part is completed when the player is explained the importance of light types and colour temperature of light, and when the player chooses the optimal parameters, the game continues to the second part.



2. Sky puzzle

In this part we introduce the importance of sky visibility, and general knowledge of the sky and stars arrangement. This is where basic arrangement of the stars, “the northern star” or general navigation by stars can be explained. The goal of this part is to complete the “puzzle”: three parts/triangles of the night sky will have to be placed and oriented correctly to complete the night sky.

Important sidenote: missing parts of the night sky dome are deep red -why red? Why are red light sources used in observatories and telescopes when working at night in the dark?



3. Messier challenge

After completing the puzzle part and raising awareness about the night sky and stars, about the importance of the night sky and importance of the ability to see the stars -we get to the third part of the game.

Charls Messier, the French astronomer, was interested in finding comets. While searching the night sky he found “annoyances” like star clusters and nebulae. With his assistant Pierre Mechain compiled a catalogue of about 110 such objects now known as the “Messier catalog”. This catalogue of objects is one of the most famous lists of astronomical objects today. This part introduces the Messier objects and Messier catalogue to the player. More knowledgeable players who are already familiar with Messier objects and catalogue will test their knowledge in this part.

Through the whole game messier objects are marked on the night sky. Right before the start of the messier challenge (before you click START) the player has time to look around, explore and examine the Messier object locations.

When the player is ready and presses the START button the task is to find and pinpoint five messier objects in the night sky. Identify the Messier objects by their catalog number and locate and place the marker on the night sky as close to its correct position as possible. Player picks the marker and pushes it away into the night sky. The marker will turn green when it’s pushed far enough in the sky.

Additional information about Messier objects is displayed: catalogue number, title/description and a well-known image of the object.

3.7. Results

The first part “Light sources and color temperatures” is an informational and introduction part and it is not timed. The “Sky puzzle” and “Messier challenge” are competitive parts, and are timed. The goal is to complete them in reasonable (least possible) time with as few errors as possible and as accurate as possible, errors are displayed and calculated as time penalty. By having a comparable numeric result (total time) you can organize a competition with your students, also, having a competitive element can get higher student involvement and better motivation and attention.