Light Pollution and its Impact on Astronomy – Awareness and Action

Duration	45 minutes
Age group	15-19 yo.
Aim and objectives	**Aim:** To raise awareness of the problem of light pollution, its impact on astronomical observations, and to present possible solutions to reduce it. **Objectives**: • Understand what light pollution is and how it affects astronomy. • Learn about the Dark Sky Movement and other initiatives fighting light pollution. • Recognize the differences in night sky quality using the Bortle Scale. • Interpret global light pollution maps. • Compare natural and artificial light spectra and understand their evolution.

	• Identify practical actions to reduce light pollution.
Learning Outcomes in Line with Curriculum	**Natural Sciences / Physics / Astronomy:** • Explain how artificial light affects the observation of celestial bodies. • Understand the physical properties of light and its sources, both natural and artificial. • Recognise the role of technology and human activity in altering environmental conditions. **Geography / Environmental Studies:** • Analyse spatial distribution of light pollution using maps and atlases (*The New World Atlas of Artificial Night Sky Brightness*). • Identify environmental challenges on local, national, and global scales. • Use observational methods to collect and interpret environmental data (Bortle Scale exercise). **Civic Education / Sustainable Development:** • Propose actions to mitigate light pollution at individual, community, and policy levels. • Recognise the importance of international cooperation in environmental protection (e.g., Dark Sky Parks network, EU environmental policies). **Cross-Curricular Skills (Key Competences for Lifelong Learning – European Reference Framework):** • **Scientific literacy:** Apply scientific reasoning to environmental issues.

	• **Digital competence:** Interpret and use digital maps and data visualisation tools. • **Cultural awareness:** Appreciate the value of the natural night sky as cultural and scientific heritage.
Teaching Methods	• **Expository:** Presentation, storytelling. • **Problem-solving:** Questions prompting reflection. • **Practical:** Observation tasks, map analysis. • **Interactive:** Brainstorming, group discussion.

Materials Needed

☐ Photos of night skies: pristine vs. light-polluted (attachment 1)

☐ Song "Turn off the Lights" (attachment 2) with lyrics (attachment 3)

☐ The Bortle Scale animation (attachment 4)

☐ Maps from *The New World Atlas of Artificial Night Sky Brightness* (attachment 5)

☐ Maps of the Ursa Major (the Great Bear) constellation (attachment 6)

☐ Laptop/projector or interactive whiteboard

☐ printed worksheet: *Light Pollution Observation Sheet* (attachment 7)

☐ Maps of the Orion constellation imaged at left from dark skies and in a city (attachment 8)

Workshop/Lesson Plan

Duration	Description	Notes
10 minutes	**Introduction: The Problem of Light Pollution** • Teacher greets students, shows pictures (attachment 1) and asks: *"Can you spot anything unusual in this picture?".* Possible answers: *The Milky Way is visible above a brightly lit city, which is unrealistic because light pollution would usually block the view of so many stars.* *The sky is too bright for a rural-quality view, yet the scene shows an urban environment.* *The picture might be AI-generated or heavily edited, combining incompatible elements.* • Short video showing the light pollution problem ("Losing the Dark"). Teacher ask: *What is light pollution? Have you ever noticed the Milky Way?*	
10 minutes	**Impact on Astronomy & The Dark Sky**	

	Movement
	
	• Discuss how light pollution hinders astronomical research.
	• Show photos of the same constellation taken in a Dark Sky Park vs. a city.
	• Present the Dark Sky Movement, Globe At Night Campaign and examples of Dark Sky Parks.
	• Play the song “Turn off the lights” (attachment 2) and distribute the lyrics (attachment 3). Students listen to the song and follow the lyrics. Afterward, they discuss the meaning:
	  ◦ What is the main message of the song?
	  ◦ What emotions or images does it create?
	  ◦ Who might be asking to “turn off the lights”?
	
	Together, they conclude that the song is a call for balance between progress and nature, and for protecting the beauty and peace of the night.	

10 minutes	**Measuring Light Pollution** • Explain the Bortle Scale using the animation (attachment 4) • Practical task: Students imagine from recent memory and try to determine the Bortle class of their location by identifying visible stars/objects (attachment 7).	**Homework note:** Students will observe the night sky in the evening/at night, locate the constellation *Ursa Major* (the Great Bear), and compare the visible sky with the maps (attachment 6) to estimate their local light-pollution level using the Bortle Scale.

10 minutes	**Analyzing Light Pollution Maps** • Show *The New World Atlas of Artificial Night Sky Brightness* (attachment 5). • Students locate their region on the atlas and on **lightpollutionmap.info**, compare the two sources, and discuss the observed patterns in light pollution.	
5 minutes	**Summary** • Strategies: Shielded lighting, warm-colour LEDs, turning off unnecessary lights, motion sensors. • Recap key points. • Students suggest at least one action they can take in their own neighbourhood.	

Reflection Questions

Bortle Scale Assessment

- Which Bortle class did you assign to your observation site?
- What features of the night sky helped you make this decision?

Map Comparison

- How does your observation match the data from *The New World Atlas of Artificial Night Sky Brightness*?
- Were there any differences between what the map suggested and what you actually observed? Why might that be?

Astronomical Impact

- Which celestial objects were easy to see, and which were difficult or impossible due to light pollution?
- How would your results differ if you observed from a Dark Sky Park?

Environmental Awareness

- What are the main sources of artificial light in your observation area?
- How does light pollution in your area affect not only astronomy but also wildlife and human health?

Solutions and Action

- What practical steps could be taken locally to improve night sky visibility?
- Which of these actions could you personally take part in or promote within your community?

Kahoot Quiz

1. What exactly is light pollution?

A. When lights make the night sky too bright to see stars
B. When light bulbs stop working
C. When streetlights use too much electricity
D. When sunlight reflects off buildings

☐ **Correct:** A

2. Why can't we see many stars from big cities?

A. There are fewer stars above cities
B. Clouds stay longer over urban areas
C. City lights make the night sky glow and hide stars
D. Buildings block our view of space

☐ **Correct:** C

3. What does the Bortle Scale help you describe?

A. How dark or bright the night sky is
B. How hot the Sun is
C. How big stars appear
D. How old a galaxy is

☐ **Correct:** A

4. If your sky is Bortle Class 8 or 9, what would you probably see?

A. The Milky Way clearly visible
B. Only a few of the brightest stars
C. Thousands of stars and dark clouds
D. Aurora borealis

☐ **Correct:** B

5. What is the main reason astronomers prefer *Dark Sky Parks*?

A. They are close to big cities
B. They have no artificial light nearby
C. They have free Wi-Fi
D. They are warmer at night

 Correct: B

6. When you look at the World Atlas of Artificial Night Sky Brightness, what do you notice?

A. Europe and large cities shine the brightest
B. Africa glows the most
C. The oceans are full of lights
D. Antarctica is covered in light

 Correct: A

7. When the teacher played the song *"Turn off the Lights"*, what message could you hear?

A. We should stop using all light
B. We need to protect nature and the night sky
C. We should buy better LEDs
D. It's about city nightlife

 Correct: B

8. What changes in light technology make skyglow worse?

A. Lights becoming more energy-efficient
B. Lights using shorter, bluer wavelengths
C. Using yellow and orange streetlights
D. Turning lights off earlier

 Correct: B

9. When you compared spectra of different lights, what did you notice?

A. Natural sunlight has a smooth spectrum; artificial lights have spikes
B. All lights look the same
C. Artificial lights have no color
D. The Sun emits only red light

□ **Correct:** A

10. Imagine your town wants to become a Dark Sky Community. What's one thing you could suggest?

A. Turn off unnecessary lights after midnight
B. Replace all lamps with blue LEDs
C. Painting lamps white
D. Build a big observatory downtown

□ **Correct:** A

Additional materials

https://darksky.org

https://youtu.be/dd82jaztFlo?si=9kO8LIm4TgBaAwWo

https://globeatnight.org/

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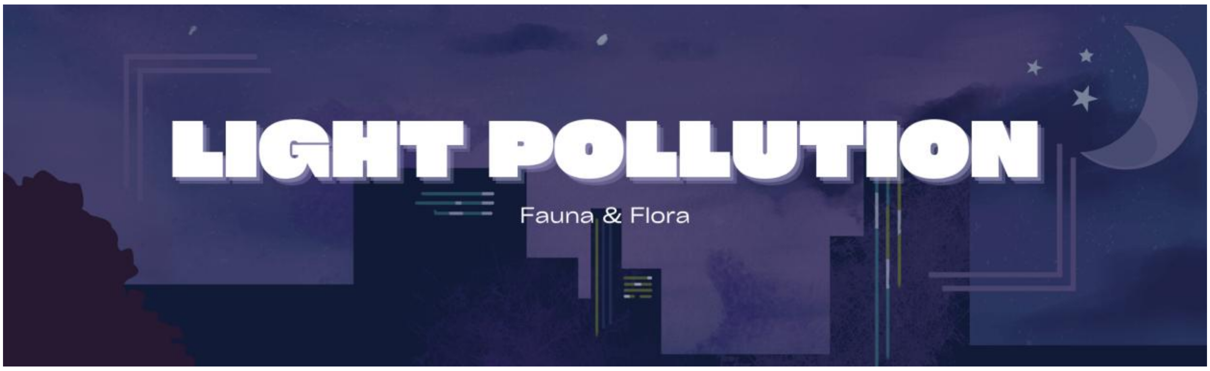

Light Pollution and its Impact on Astronomy – Awareness and Action

Duration	45 minutes
Age group	15-19 yo.
Aim and objectives	**Aim:** To help Learners understand how artificial light at night (ALAN) affects ecosystems and the behaviour of living organisms, and to introduce responsible lighting as a way to restore natural balance. **Objectives**: Learners will: • Recognise the difference between natural day-night cycles and artificial light at night (ALAN). • Identify at least three ecological consequences of light pollution for animals, plants and whole ecosystems. • Describe how different species (e.g. bats, moths, frogs, trees, humans) change their behaviour under increasing artificial light.

	• Explain that responsible lighting choices can reduce negative impacts on biodiversity, human health and energy use.
Learning Outcomes in Line with Curriculum	**Natural Sciences / Biology / Environmental Science:** Learners will be able to: • Describe examples of nocturnal and crepuscular species and their ecological roles (e.g. pollination, seed dispersal, predation). • Explain how changes in light conditions can affect feeding, migration, pollination, communication, reproduction and sleep. • Recognise human activity and artificial light at night as factors that alter habitats and ecological balance. **Geography / Environmental Studies:** Learners will be able to: • Relate light pollution to patterns of land use (urban, suburban, rural) and to local environments (streets, parks, school grounds). • Identify and describe local sources of artificial light at night and their potential influence on wildlife. **Civic Education / Sustainable Development:** Learners will be able to: • Propose realistic actions to reduce light pollution at individual, school and community level. • Recognise that responsible use of technology (lighting design, timing, colour and intensity) can protect

	biodiversity, human health and energy resources.
Teaching Methods	• Brainstorming and guided discussion • Role-play / simulation (Option A – indoor) • Simple field observation and comparison (Option B – outdoor) • Group work and short presentations • Reflective questioning

Materials Needed

Common to both options:

☐ Two contrasting images: a dark sky reserve or very starry rural sky (e.g. attachment 1); a bright urban skyline at night (attachment 9)

☐ Whiteboard or flipchart and markers

☐ Sticky notes or small pieces of paper

☐ Printed worksheet (attachment 10): Ecosystem in the Dark – Observation Sheet (one per Learner or pair)

Option A – Indoor visualisation (role-play)

☐ Species role cards written on folded post-its (attachment 11)

☐ 2–3 torches or headlamps (ideally at least one "cold/blueish" and one "warm/yellowish")

☐ Possibility to dim or switch lights on and off in the classroom

☐ Clear floor space for safe movement

Option B – Outdoor mini-experiment

☐ Access to three contrasting zones (or portable lamps to create them):
one cold, bright LED light;
one warmer, dimmer bulb;
one relatively dark zone for comparison

☐ Clipboards or something firm to write on

☐ Pens/pencils

☐ Stopwatches or phones to time short observation periods

☐ Optional: simple insect pots or magnifying glasses (only if ethical and safe handling of animals is ensured).

Workshop/Lesson Plan

Duration	Description	Notes
10 minutes	**Introduction – What happens at night in nature?** • Educator greets Learners and asks: "What happens outside when it gets dark?" Learners brainstorm examples of night-time activity (animals, plants, people, lights). Educator writes key words on the board (e.g. bats, insects, stars, streetlights, sleep). • Educator shows two images: a dark sky reserve vs. a brightly lit city at night. Short guided discussion: Which place looks better for animals? For astronomers? For sleeping? Why? • Educator introduces the term Artificial Light at Night (ALAN): human-made light that shines during the night, often where or when it is not needed. Four impact areas are mentioned briefly: human health (sleep and hormones),	Keep vocabulary simple. For less advanced groups, focus on "day-night rhythm" and "body clock" rather than technical terms.

	biodiversity (animals and plants), energy use and climate, visibility and safety (seeing vs glare).	
25 minutes	**Main Activity – Ecosystem in the Dark** <u>Option A – Indoor role-play (simulation)</u> • Educator explains that the class will create a "living ecosystem" in the room. Learners receive species role cards (bats, moths, frogs, night-flowering plants/trees, humans). In species groups they answer: "What do we normally do at night in natural darkness? What do we need from our habitat? • **Round 1** – Natural darkness: lights are dimmed as much as safely possible. Each species acts out what they do in a naturally dark night (bats "flying" and hunting insects, moths visiting flowers, frogs calling near an imaginary pond, plants "opening" flowers or simply standing, humans walking carefully or resting). After 2–3 minutes, short pause: how easy was it to move, feed, communicate, rest? Learners record brief notes on the worksheet. • **Round 2** – Some artificial light: one or two warm, low-level lights or torches are switched on to represent well-designed, limited lighting. Ecosystem runs again for 2–3 minutes. Learners notice what has changed (e.g. some insects move towards light; some animals avoid bright patches). Short debrief, notes on worksheet. • **Round 3** – A lot of artificial light: more lights are turned on, including	Educator chooses one option in advance. For Option A, ensure safe movement (no running in the dark). For Option B, choose locations in the school grounds or very nearby, ideally where existing lights already provide cold/warm contrast; otherwise use portable lamps. If insects are scarce (season or weather), focus on how it feels in each light: comfort, glare, ability to see stars, etc.

	cold/blueish light. The room now represents a brightly lit town or car park. Ecosystem runs again for 2–3 minutes. Then each species reports how their behaviour changed compared with natural darkness: Did they avoid lit areas? Lose food sources? Become more visible to predators? Did "night" feel shorter or disappear? Learners summarise in the worksheet, listing at least one consequence per species. <u>Option B – Outdoor mini-experiment (observation)</u> • Educator explains safety rules: staying with the group, watching footing, staying away from roads. Class is split into three groups: A – cold LED, B – warm bulb, C – darker zone. • Each group spends around 5 minutes at its assigned location counting or estimating the number of insects (and any other animals) and noting their behaviour (circling lights, resting on surfaces, avoiding area). They also note nearby plants (flowers, trees) and how bright it feels. • Groups rotate so each visits all three zones (LED, warm bulb, dark). They fill in the observation table on the worksheet for each zone. Back together, they quickly compare: Where were most insects? Did cold or warm light attract more? What about the dark area?	
10 minut	**Debrief – Ecological consequences and solutions** • Whole-class discussion: "What did you notice when light increased?" "Which species seemed most sensitive to light?"	You can display the five principles as a simple slide or

	"What might happen to this ecosystem if it was bright every night for years?" Educator supports Learners to name ecological consequences, e.g. disrupted pollination (moths at lights instead of flowers), predators losing dark hunting areas, prey more visible, habitat fragmentation when animals avoid bright zones. • Educator links back to four impact areas of ALAN: biodiversity, human health, energy/climate, visibility and safety. Short mention of human circadian rhythms: bright, especially blue, light at night can confuse the body clock and disturb sleep. • Educator introduces or recalls five principles of responsible lighting (when, where, how much, colour, shielding) and asks Learners to suggest at least one realistic change at home, school or in their town (e.g. turning off outdoor lights after a certain hour, using motion sensors, choosing warm, shielded lamps). Learners write one personal action idea on their worksheet.	poster. For groups that already did the "Understanding the Night" activity, explicitly connect to skyglow, glare, light trespass and clutter. Encourage Learners to link ecological impacts to places they know (local car park, playground, street).

Reflection Questions

These can be used as written questions on the worksheet, for homework, or as discussion starters.

Ecosystem and Behaviour

- Which species in our activity seemed to suffer most when light levels increased? Why?

- How did artificial light change interactions between species (for example, between pollinators and plants, predators and prey)?
- If this ecosystem remained brightly lit every night, what might happen to its biodiversity after several years?

Understanding ALAN

- In your own words, what is artificial light at night (ALAN)?
- How is ALAN different from natural light from the Moon and stars?
- Which of the four impact areas (biodiversity, human health, energy, visibility/safety) do you think is most important in your community? Explain your choice

Human Health and Circadian Rhythms

- How might bright or very blue light in the evening affect a person's sleep and daily rhythm?
- Where in your home or school do you think people are most exposed to bright light at night (screens, streetlights through windows, indoor lighting)?

Solutions and Action

- Choose one place you know well (your street, the school entrance, a sports field). What is currently good about the lighting there, and what could be improved?
- Which of the five responsible lighting principles (only when needed, only where needed, minimum brightness, warm colour, good shielding) is easiest to apply in your life right now? How could you do it?
- What small action could you personally take, or propose to others, to reduce unnecessary light at night while still keeping people safe?

Kahoot Quiz

1. What does ALAN stand for?

A. Artificial Light Around Nature
B. Artificial Light At Night
C. Astronomical Light And Nature
D. Added Light At Night

- [ ] **Correct:** B

2. Which ecological process can be disrupted by light pollution?

A. Photosynthesis
B. Pollination
C. Evaporation
D. Erosion

- [ ] **Correct:** B

3. What happens to predators when areas are too bright?

A. They hunt better
B. They lose dark hunting spaces
C. They disappear instantly
D. They become herbivores

- [ ] **Correct:** B

4. Why do insects gather around artificial lights?

A. They confuse light with natural navigation cues
B. They are attracted to heat only
C. They use lights as food sources
D. They avoid predators there

- [ ] **Correct:** A

5. Which best describes ecological fragmentation caused by light?

A. Loss of vegetation cover
B. Division of habitats into light and dark “islands”
C. Increase in urban green spaces
D. Soil degradation due to heat

 Correct: B

6. In the classroom experiment, why did insects gather near LED light?

A. LEDs emit ultraviolet food signals
B. Short-wavelength light disrupts insect orientation systems
C. Insects prefer artificial surfaces
D. LEDs simulate moonlight

 Correct: B

7. W What is the MOST likely long-term ecosystem effect of increasing ALAN?

A. Higher biodiversity in cities
B. Stabilization of nocturnal ecosystems
C. Decline of nocturnal species and ecosystem imbalance
D. No significant change

 Correct: C

8. Which chain of events is MOST scientifically accurate?

A. Light → predators disappear → insects increase → plants decline
B. Light → insect attraction → reduced pollination → plant decline → herbivore decline
C. Light → more oxygen → biodiversity increase
D. Light → climate cooling → ecosystem stabilization

 Correct: B

9. Increased urban lighting leads to fewer nocturnal predators. What is a likely secondary effect?

A. Increase in prey species followed by resource depletion
B. Immediate ecosystem stabilization
C. Reduction in all species equally
D. No ecological response

- **Correct:** A

10. Which factor MOST strongly links astronomy and ecology in light pollution studies?

A. Telescope technology
B. Shared dependence on absence or presence of light as an environmental signal
C. Planetary motion
D. Weather forecasting

- **Correct:** B

Additional materials

Additional activities (attachement 12)

Author: Associazione Kora

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Impact of Light Pollution on Mental health

Duration	45 minutes
Age group	15-19 yo.
Objectives	• To understand better the impact of light pollution on human health • To know how to protect our health from light pollution • To develop coping strategies
Learning Outcomes in Line with Curriculum	• Advocate for responsible lighting practices • Formulate personal behavioral changes • Articulate an argument for the importance of natural darkness to both human health and the broader ecosystem
Teaching Methods	• Theoretical presentation • Practical Exercises

Materials Needed

☐ Materials on Impact on light pollution on mental health (attachment 13)

☐ Whiteboard or flipchart and markers

☐ Sticky notes or small pieces of paper

☐ Printed worksheet (attachment 14): Tracking Your Circadian Rhythm and Light Exposure

Workshop/Lesson Plan

Duration	Description	Notes
5 minutes	**Introductory part** Introduction to the topic and its meaning for the young people and the planet.	
10 minutes	**Foundation of light and health** <u>Objectives</u> • To establish a fundamental understanding of light as an environmental factor and its natural and artificial forms. • To introduce the concept of light pollution and its primary sources. • To explain the basic biological mechanisms through which light affects human physiology. <u>Learning outcomes</u> • Define light pollution and identify its main types and sources. • Explain the pathway through which non-visual light information travels from the eye	Materials – attachment 13

	to the brain's clock. • Distinguish between natural light exposure and disruptive artificial light exposure. 1.1. Introduction to Light Pollution 1.2. Researches on the Impact of Artificial Light on Human Health 1.3. Human Circadian Rhythm, Sleep, and Melatonin Production <u>Methods used:</u> - Theoretical presentation of the content to the students - Discussion	
15 minutes	**The Circadian Rhythm and Mental Health** <u>Objectives</u> • To detail the central role of the circadian rhythm in regulating human physiological processes. • To analyze the specific negative impacts of light pollution on sleep, mood, and cognitive function. • To connect circadian disruption directly to various mental and physical health issues .<u>Learning outcomes</u> • Describe the function of the SCN and how light timing entrains the human body clock. • Articulate how nocturnal light exposure negatively affects sleep quality and quantity. • Summarize the evidence linking circadian rhythm disruption from light pollution to common mental health conditions.	

	2.1. Researches on Circadian Rhythm – Nobel Prize in Medicine 2017 2.2. Impact of Circadian Rhythm Disorder on Insomnia and Mental Health Methods used: - Theoretical presentation of the content to the students - Discussion	
10 minutes	**Impact and mitigation strategies** Objectives • To explore the broader public health and environmental consequences of light pollution. • To examine practical, interdisciplinary solutions to mitigate light pollution and its health effects. • To review current research trends and areas for future study in chronobiology and environmental health. Learning outcomes • Propose and justify effective lighting design principles (The 4 principles: Fully Shielded, Correct Spectrum, Appropriate Intensity, Only When Needed) for reducing light pollution. • Identify at least three personal and three policy-level actions that can mitigate the negative health effects of artificial light at night. • Connect the impact of light pollution on human health to its broader environmental and public health context.	

	3.1. Wider impacts 3.2. Mitigation strategies: Design and solutions <u>Methods used:</u> - Theoretical presentation - Discussion - Practical exercises	
5 minutes	**Final review and learning outcomes check** The session concludes by reinforcing the final message: Darkness is a critical resource for health. We must commit to using the right light, at the right time, in the right place. Ask the learners: 1. Name two forms of light pollution. (Answer: Skyglow, Light Trespass) 2. Which color of light is most effective at suppressing melatonin? (Answer: Blue-rich light) 3. Name one of the Four Principles of dark-sky lighting. (Answer: Fully Shielded, Correct Spectrum, Appropriate Intensity, or Only When Needed)	

Reflection Questions

Module 1: Foundations of Light and Health

- How has artificial light changed the role of light as an environmental factor?
- Are all types of light pollution equally harmful? Explain using biological mechanisms.

- What is the role of ipRGCs in non-visual light perception, and why is it important?
- How does light spectrum (not just intensity) affect human health?
- To what extent can links between ALAN and diseases be considered causal rather than correlational?

Module 2: Circadian Rhythm and Mental Health

- Why is the SCN considered the "master clock" of the body?
- How do PER and TIM gene mechanisms explain the stability of circadian rhythms?
- Why can even low levels of light at night disrupt sleep?
- How does circadian disruption affect neurotransmitters like serotonin?
- Are sleep disturbances a cause or a consequence of mental health disorders?
- How does circadian misalignment impact cognitive functions such as memory and attention?

Module 3: Impact and Mitigation Strategies

- Why should light pollution be treated as both a public health and environmental issue?
- What are the strengths and limitations of current legal approaches to light pollution?
- Which of the four lighting principles is most important for human health, and why?
- What barriers exist to reducing light pollution at societal and individual levels?
- Can individual behavior effectively reduce the impact of urban light pollution?

Kahoot Quiz

1. Which type of light pollution creates a bright glow over cities?

A. Glare
B. Light trespass
C. Skyglow
D. Clutter

- **Correct:** C

2. Which hormone is most affected by light at night?

A. Cortisol
B. Melatonin
C. Dopamine
D. Insulin

- **Correct:** B

3. What is the main function of melatonin?

A. Regulates digestion
B. Controls movement
C. Signals sleep and darkness
D. Increases heart rate

- **Correct:** C

4. Where is the "master clock" (SCN) located?

A. Retina
B. Pineal gland
C. Hypothalamus
D. Brainstem

- **Correct:** C

5. Which type of light most strongly suppresses melatonin?

A. Red light
B. Blue light
C. Yellow light
D. Infrared light

 Correct: B

6. What is “circadian rhythm”?

A. A sleep disorder
B. A 24-hour biological cycle
C. A type of hormone
D. A brain disease

 Correct: B

7. Which condition is linked to circadian disruption?

A. Depression
B. Broken bones
C. Allergies
D. Hearing loss

 Correct: A

8. What does Social Jet Lag measure?

A. Travel fatigue
B. Sleep quality
C. Difference between weekday and weekend rhythms
D. Screen time

 Correct: C

9. Which strategy helps reduce blue light exposure at night?

A. Using bright LEDs
B. Screen filters or night mode
C. Turning on more lights
D. Watching TV in the dark

- **Correct:** B

10. What is the best time to reduce light exposure?

A. Morning
B. Midday
C. Afternoon
D. Evening

- **Correct:** D

Additional materials

Social jet lag: https://pubmed.ncbi.nlm.nih.gov/16687322

Author: Law and Psychology team

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Programming a Cloud Light Detection system

Duration	90 minutes
Age group	15-19 yo.
Objectives	**Aim:** Creating a project using a microcontroller and a light sensor to measure the light level and store data on the cloud. **Objectives:** • Understand how IoT devices communicate and send data to the cloud. • Interface a light sensor (e.g., LDR or BH1750) with the ESP8266 microcontroller. • Connect the ESP8266 to Wi-Fi and transmit data to a cloud service. • Visualize collected data via a dashboard or online platform.
Learning Outcomes	**Computer Science / Programming** • Students will write Arduino/ESP8266 programs to read sensor input.

in Line with Curriculum	• Students will debug and troubleshoot hardware–software communication errors. • Students will understand the use of APIs and how data is transmitted over Wi-Fi. • Students will apply coding logic for conditional actions based on sensor values. Math: • Students will analyze numerical light-intensity values. • Students will observe trends and interpret graphed data over time. • Students will utilize measurement, comparison, and threshold calculations to make decisions. Science / Physics: • Students will understand the concept of photons, luminosity, and light measurement. • Students will relate sensor physics to real-world phenomena (day vs night, room lighting, shadows). • Students will use hypothesis-based observations and experimental verification. Cross-Curricular Skills (Key Competences for Lifelong Learning – European Reference Framework): 1. Problem Solving • Students diagnose wiring, coding, or connection issues. • They experiment with different light conditions to refine results. • They iterate the design based on testing outcomes

	2. Critical Thinking • Students evaluate sensor readings for reliability. • They reason about data interpretation (e.g., why readings change). • They consider environmental factors affecting measurements. 3. Creativity & Innovation • Designing an original IoT solution. • Proposing new features (alarms, notifications, automation). • Thinking beyond the classroom—smart homes, agriculture, smart cities. 4. Collaboration & Teamwork • Students work in pairs or groups to assemble the circuit. • They divide roles: programmer, hardware technician, data analyst. • They communicate findings and provide peer feedback.
Teaching Methods	• **Expository:** Presentation, storytelling. • **Problem-solving:** Questions prompting reflection. • **Practical:** Manual, light detector construction. • **Interactive:** Brainstorming, group discussion.

Materials Needed

- ☐ ESP8266 (NodeMCU)
- ☐ Traffic Light Module
- ☐ Female-female Jumper Cables (ab. 10 pc) and USB-microUSB cables
- ☐ Light sensor (Digital light sensor such as BH1750)
- ☐ Laptop with Arduino IDE installed
- ☐ Internet access / Wi-Fi

☐ Cloud platform (e.g., ThingSpeak, Adafruit IO, MQTT broker)

☐ TUNIOT FOR ESP8266 (attachment 15)

☐ Teacher Guide (attachment 16)

Workshop/Lesson Plan

Duration	Description	Notes
10 minutes	**Introduction to Embedded systems and with real world applications** Asking the students about their prior knowledge about Embedded systems. Showing a short video about Embedded system.	Resource 1: What is an Embedded system (attachment 17)

20 minutes	**The LED programming**
	○ Blinking the Internal LED
	    ○ Create the blink program with TUNIOT
	    ○ Upload the program
	
	<u>Challenge 1</u> : Make a change to the program using TUNOT and blink the LED faster.
	
	<u>Challenge 2:</u> Make a change to program using the ARDUINO IDE and blink the LED slower.
	
	○ The Traffic light Module
	    ○ Connect the traffic light module to the NODEMCU. Use the resource 5
	    ○ Test your module by turning on all
		Resource 2: Blink the Internal LED (attachment 18)
		
		<u>Challenge 1 answer key:</u> Resource 3 (attachment 19)
		
		Challenge 2 answer key: Resource 4 (attachment 20)

	the LEDs. Use the resource 6	**Resource 5:** Traffic light wiring (attachment 21) **Resource 6:** The traffic light Module (attachment 22)

10 minutes	**The Light Sensor programming**
	○ Hardware setup
	  ○ Connecting the light sensor to the NODEMCU
	○ Software setup
	  ○ Displaying the value of the light sensor on the serial Monitor
		Resource 7: BH1750 wiring (attachment 23)
		
		Resource 8: The light Sensor Module (attachment 24)

5 minutes	**Quiz 1: Embedded systems** (attachment 25)	
5 minutes	**Introduction to IOT** What is IoT? What is an object? How objects are connected together?	**Resource 9:** What is IOT? (attachment 26)
15 minutes	**Connecting the ESP8266 to WIFI** Challenge 3: Make some modification to the program: when the board is not connected to a wifi network, the Red LED is turned ON. When the board is connected the Green LED is ON**.**	**Resource 10:** Connecting to Networks (attachment 27) Challenge 3 answer key:

		Resource 11: Connecting to networks with LED (attachment 28)
20 minutes	**Sending data to the cloud** ○ Creating an account with Thingspeak ○ Sending random data to ThingSpeak ○ Sending sensor's data to the cloud ○ Take readings in different lighting environments	**Resource 12:** Sending data to Thingspeak (attachment 29)
5 minutes	**Quiz 2: IOT** (attachment 30)	

Reflection Questions

Embedded Systems & IoT

- What makes an embedded system different from a general-purpose computer?
- Why is a microcontroller suitable for specific tasks in everyday devices?
- How does the ESP8266 support Internet of Things (IoT) applications?
- Why is built-in Wi-Fi an advantage in smart device design?
- What information does the BH1750 sensor provide?
- How does the sensor's light measurement relate to real-life environments (e.g. classroom, sunlight, dark room)?
- What did you learn from programming the traffic light module?
- What challenges did you face during wiring or programming?
- How could this project be expanded into a real smart-city or environmental monitoring system?

Higher-order Reflection

- How can embedded systems help solve environmental problems such as light pollution?
- In what ways does this activity connect programming with real-life problem solving?
- How might IoT technology be used to improve energy efficiency in cities or schools?

Additional materials

http://easycoding.tn/index.php/nodemcu/video-tutorials/

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Project "Turn off the light" (2024-2-PL01-KA220-YOU-000278243): 01.06.2025 – 31.07.2027

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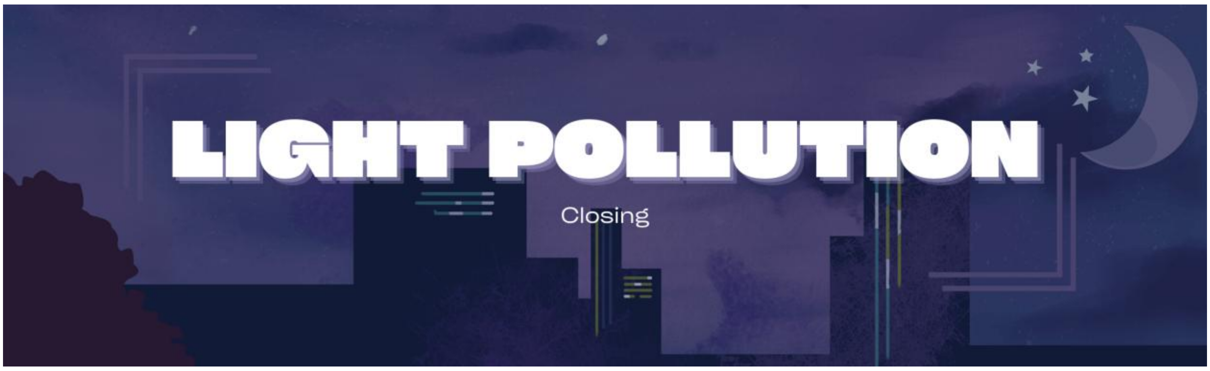

Collection and Analysis of Observational Data

Duration	45-90 minutes
Age group	15-19 yo.
Aim and objectives	**Aim:** To help students understand how observational data are collected, processed, analysed, and presented using appropriate scientific methods and visualization tools. **Objectives**: Students will: • understand the three types of twilight (civil, nautical, astronomical) and recognise them in observational data, • learn what airglow is and how solar radiation and solar activity influence it, • plan and conduct systematic brightness measurements, • reduce, clean, and analyse datasets to identify natural and artificial sources of sky brightness changes, • detect clouds, artificial lights, Moon influence, and airglow using graphs, • compare night-sky brightness between nights, weekdays, and seasons, • investigate whether solar activity correlates with night-sky brightness,

	• classify the local night sky according to the Bortle Scale, • summarize results critically and understand uncertainties.
Learning Outcomes in Line with Curriculum	**Natural Sciences / Physics / Astronomy:** • Explain natural factors affecting night-sky brightness (twilight, airglow, Moon, atmosphere). • Identify civil, nautical and astronomical twilight phases based on Sun altitude ($h_{\odot} = -6^\circ, -12^\circ, -18^\circ$). • Collect and structure quantitative observational data. • Recognize patterns and correlations in brightness curves (e.g., clouds, city glow, airglow). **Mathematics / ICT:** • Use spreadsheets for calculations (average, min, max, trend lines, correlation). • Create scatter plots, line graphs, and comparative charts. • Interpret Pearson correlation coefficient values to evaluate correlations (brightness vs sunspot number). **Civic Education / Sustainable Development:** • Understand the environmental importance of protecting natural darkness. • Recognize the importance of transparency and objectivity in reporting results. **Cross-Curricular Skills (Key Competences for Lifelong Learning – European Reference Framework):** • **Scientific literacy:** Applying scientific reasoning to real-world data.

	• **Digital competence:** Using online and software-based tools for data presentation. • **Cultural awareness:** Evaluating the reliability and limits of conclusions.
Teaching Methods	• **Expository:** Short theoretical introductions, guided presentation. • **Problem-solving:** Group analysis of sample datasets, interpretation tasks. • **Practical:** Data collection, spreadsheet exercises, visualization creation. • **Interactive:** Reflection, discussion, peer feedback.

Materials Needed

☐ Printed or digital Observation Sheet template (for recording measurements)

☐ SQM meter or light detector coded with TUNIOT (recommended)

☐ Computers/tablets with spreadsheet software (Excel, Google Sheets, LibreOffice Calc)

☐ Sunspot number data from SILSO

☐ Bortle Scale chart

☐ Observation Plan Sheet (attachment 31)

☐ Template of Thingspeak output: file example.csv (attachment 32)

☐ Data Analysis Worksheet (attachment 33)

Workshop/Lesson Plan

Duration	Description	Notes
10 minutes	**Introduction: Planning the Observation** Students begin by planning how their brightness measurements should be conducted. Working in small groups, they review the light detector they programmed in the previous lessons and discuss how often measurements should be taken (e.g. every 1–5 minutes) and for how long observations should last. The teacher explains the concept of sampling interval and why regular measurements are important for detecting patterns in environmental data. Students also decide which additional factors should be recorded during observations, such as Moon phase, clouds, or nearby artificial lights. Each group completes an **Observation Plan Sheet**, specifying the measurement interval, observation time, and observation location.	Observation Plan Sheet (attachment 31)
20 minutes	**Preparing and Cleaning the Dataset** Students access the ThingSpeak platform, where their light detector has been sending brightness measurements. They open their channel and download the dataset by selecting Export → CSV file. The teacher explains that a CSV file (Comma Separated Values) stores data as text, where values in each row are separated by commas. The dataset typically contains rows similar to the	Template: file example.csv (attachment 32) Data Analysis Worksheet (attachment 33)

	example below: created_at,entry_id,field1 2026-03-10T19:32:15Z,1,312 2026-03-10T19:37:15Z,2,298 2026-03-10T19:42:15Z,3,287 Students open the file in Excel or another spreadsheet program. They observe that the dataset contains columns such as *created_at*, *entry_id*, and the sensor measurement (*field1*). When opening the CSV file, students may see all values placed in a single column because the data are separated by commas. The teacher demonstrates how to fix this. Students select the column and use **Data** → **Text to Columns**, choose **Delimited**, and select **Comma** as the separator. The spreadsheet then splits the data into separate columns. Students keep only the relevant columns: the timestamp (*created_at*) and the brightness measurement (*field1*). They rename the columns to *Date & Time* and *Sky Brightness.* Students then check the dataset for obvious errors (e.g., unusually high values caused by shining a flashlight on the detector) and remove incorrect entries. To help students understand why unusual measurements should be removed, the teacher may show the video Outliers: What Are They? How To Spot Them? How Do They Affect The Three Measures Of Central Tendency?, which explains how extreme values can influence	Outliers: What Are They? How To Spot Them? How Do They Affect The Three Measures Of Central Tendency: http://youtube.com/watch?v=9m64Zi41rmw

	data analysis and statistical results. Students organise the dataset so that measurements are ordered chronologically. If necessary, they separate the timestamp into two columns (Date and Time) using the **Text to Columns** tool again. They verify that measurement intervals are consistent and check whether their detector recorded data at the expected frequency. Students discuss possible reasons for missing or irregular measurements.	
15 minutes	**Data Analysis** Students perform basic statistical calculations using spreadsheet functions. They calculate: average brightness, minimum value, maximum value, and optionally standard deviation. The teacher demonstrates functions such as =AVERAGE(), =MIN(), and =MAX(). Students interpret the results and discuss what these values say about the brightness of their sky during the observation period. Students create a line graph showing Sky Brightness vs Time in Excel or Google Sheets. They label axes and add a title. The teacher explains how line graphs help reveal temporal patterns. Students examine the brightness curve and identify periods of rapid or slow change in brightness.	
15 minutes	**Identifying Twilight Phases** Students use their brightness graph to estimate the transitions between civil, nautical, and astronomical twilight. The teacher explains that these twilight phases	timeanddate.com

correspond to specific Sun altitudes below the horizon:

- 6° – end of civil twilight
- 12° – end of nautical twilight
- 18° – end of astronomical twilight

Students analyse their graph to determine when these transitions likely occurred.

First, students examine the slope of the brightness curve, which shows how quickly the sky becomes darker after sunset. Twilight typically progresses in three stages. During civil twilight, brightness decreases very rapidly and the sky is still relatively bright, which appears on the graph as a steep downward slope. During nautical twilight, the sky continues to darken but at a slower rate, so the slope becomes less steep. During astronomical twilight, the brightness changes only slightly and the curve becomes almost flat. After this stage, the graph usually shows stable low brightness, indicating true night conditions.

Students mark three points on their graphs where the slope clearly changes:

- the transition from rapid darkening to slower darkening (approximate end of civil twilight),
- the transition from moderate darkening to very slow changes (approximate end of nautical twilight),
- the point where brightness becomes nearly constant (approximate end of astronomical twilight).

To verify their estimates, students compare their observations with astronomical data using **timeanddate.com**. They open the website and type the name of their city to

	access the location page. Then they navigate through the menu: Sun, Moon & Space → Night Sky → Sun & Moon Today → Night, Twilight, and Daylight Times. On this page, students find a table showing the times when the Sun reaches the key altitudes: civil twilight end, nautical twilight end, astronomical twilight end. They compare these calculated times with the points on their brightness graph where the slope changes. This comparison helps students understand how observational data corresponds to astronomical calculations. For more advanced students, the teacher may introduce a quantitative approach by calculating the brightness change between consecutive measurements in a spreadsheet: *brightness change = brightness(n) − brightness(n−1)* Large changes indicate rapid darkening (civil twilight), while very small changes indicate stable night conditions after astronomical twilight. Simple rule for interpreting the graph: Civil twilight → steep drop in brightness Nautical twilight → moderate drop Astronomical twilight → almost flat curve	
10 minutes	**Recognizing Patterns in Brightness Curves** Students analyse their graphs and identify patterns caused by environmental factors. The teacher presents typical examples: sudden spikes caused by artificial lights, gradual	

	increases caused by Moon rise, large fluctuations caused by clouds reflecting city lights, and small natural variations potentially related to airglow. Students annotate their graphs and explain the patterns they observe.	
20 minutes	**Influence of Solar activity** Students obtain daily Sunspot Numbers from the SILSO database and add them to their dataset: *Daily Estimated Sunspot Number -> CSV* Since sky brightness measurements are collected every 5 minutes (or similar) while sunspot numbers are reported once per day, students first need to aggregate the brightness measurements to daily averages to make a meaningful comparison. <u>Step 1 – Aggregate brightness</u> Ensure your dataset has at least two columns: Date & Time and Brightness. If your timestamp includes both date and time, create a Date column by extracting the date portion. For text timestamps like YYYY-MM-DD HH:MM, use the formula: =DATEVALUE(LEFT(A2,10)) This converts the first 10 characters of the timestamp into a proper Excel date. Select your data and go to Insert → Pivot Table.	https://www.sidc.be/SILSO/datafiles

Drag the Date column into Rows.

Drag the Brightness column into Values and set Value Field Settings → Average.

The pivot table now shows the daily average brightness for each day.

Step 2 – Processing SILSO CSV Data

The SILSO data file (EISN_current.csv) is provided in CSV format:

Column	Description
1	Gregorian Year
2	Gregorian Month
3	Gregorian Day
4	Decimal date
5	Estimated Sunspot Number
6	Estimated Standard Deviation
7	Number of Stations calculated
8	Number of Stations available

Instructions to prepare the sunspot dataset for comparison:

Open the CSV file in Excel.

If all the data appear in a single column, split them into separate columns using *Data → Text to Columns → Delimited → Comma*, as done previously for the brightness CSV.

Keep only the relevant columns.

Retain Year (1), Month (2), Day (3), and Estimated Sunspot Number (5). Delete other columns to simplify the dataset.

Convert Year, Month, Day into a single Excel date. In a new column, use the formula:

=DATE(A2,B2,C2)

A2 = Year, B2 = Month, C2 = Day.

Excel will create a date in its internal date number format (e.g., 45959).

Change the cell format to "General" to ensure the date is stored as a number, which matches the format of aggregated brightness dates.

Ensure alignment with brightness data.

The daily average brightness dates must also be in Excel date numbers.

<u>Step 3 – Combine Datasets</u>

Add the sunspot numbers.

Copy the daily sunspot numbers from the processed SILSO CSV next to the daily average brightness values in the Pivot Table.

Ensure correct date alignment.

Since both datasets now use Excel date numbers, each daily average brightness matches the correct sunspot number.

<u>Step 4 – Create Scatter Plot and Calculate Correlation</u>

Insert a scatter plot:
X-axis: Sunspot Number

Y-axis: Daily average Sky Brightness

Calculate the Pearson correlation coefficient:

Use the Excel formula:

=CORREL(range_sunspot_numbers, range_daily_brightness)

Interpret the correlation coefficient (r).

r value	Strength of relationship
0.0 – 0.2	Very weak / negligible
0.2 – 0.4	Weak
0.4 – 0.6	Moderate
0.6 – 0.8	Strong
0.8 – 1.0	Very strong
Negative values	Inverse relationship (higher X → lower Y)

Positive r means higher sunspot numbers are associated with higher brightness, while negative r indicates the opposite.

Step 5 – Analyze and Discuss

Students evaluate whether higher solar activity corresponds to higher or lower sky brightness.

Discuss potential sources of variability:

- Cloud cover or weather conditions
- Local light pollution
- Measurement errors or outliers in the data.

15 minutes	**Comparative Data Visualization** Students compare brightness measurements from different nights or groups. They create a comparative chart (for example a line graph showing two nights or two locations). Students discuss differences caused by clouds, Moon phase, or local artificial lights.	
10 minutes	**Reflection and Scientific Interpretation** Students summarize the results of their investigation. They discuss which factors most strongly influenced sky brightness and whether any correlation with solar activity was observed. The teacher highlights the importance of long-term measurements and careful interpretation of observational data.	

Reflection Questions

• What patterns or trends did you notice when analyzing your data in the spreadsheet?

• How did organizing the data into tables or charts help you understand the results?

• Were any of the results surprising or different from what you expected?

• How could similar measurements be used by scientists to monitor environmental changes?

• What skills did you develop during this activity (e.g., measurement, data analysis, visualization)?

• What additional questions or investigations could be explored based on your results?

Kahoot Quiz

1. Which unit is most commonly used to measure illuminance (light intensity reaching a surface)?

A. Lumen
B. Candela
C. Lux
D. Watt

 Correct: C.

2. What does a higher lux value indicate?

A. Lower light intensity
B. Higher light intensity on a surface
C. A higher temperature of the light source
D. A longer wavelength of light

 Correct: B

3. Which factor could most strongly distort outdoor light measurements at night?

A. The phase of the Moon
B. The number of nearby trees
C. The temperature of the air
D. The altitude of the observer

 Correct: A

4. 6. In data analysis, what is an outlier?

A. The average value of the dataset
B. A value significantly different from the others
C. The smallest measurement

D. The most frequently occurring value

 Correct: B

5. When analyzing a dataset, which statistical value represents the central value of an ordered dataset?

A. Range
B. Median
C. Maximum
D. Deviation

 Correct: B

6. At what Sun altitude does astronomical twilight end?

A. -6° below the horizon
B. -12° below the horizon
C. -18° below the horizon
D. -24° below the horizon

 Correct: C

7. What does a high sunspot number usually indicate?

A. Lower solar activity
B. Higher solar activity
C. Lower solar temperature
D. A smaller Sun diameter

 Correct: B

8. What is airglow?

A. Light reflected from the Moon
B. Faint natural emission of light from Earth's upper atmosphere
C. Light produced by satellites
D. Radiation from distant galaxies

 Correct: B

9. What does the Pearson correlation coefficient (r) measure in a correlation plot?

A. The number of measurements in a dataset
B. The strength and direction of a linear relationship between two variables
C. The average value of a dataset
D. The difference between two measurements

 Correct: B

10. What does a Pearson coefficient close to 0 suggest?

A. Perfect positive correlation
B. Strong negative correlation
C. No significant linear correlation
D. Identical values in the dataset

 Correct: C

Additional materials

- Data visualization examples: https://datavizcatalogue.com
- NASA educational materials about the Sun, solar activity, and Earth's atmosphere https://science.nasa.gov/sun
- Excel or Google Sheets tutorials: https://edu.gcfglobal.org/en/excel
- Stellarium - free planetarium software for exploring the night sky and astronomical conditions: https://stellarium.org

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