Engaging Citizens in the Study of Light Emissions in Berlin, Germany

Website: https://sites.google.com/view/be21-lght/home

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Abstract

The GeoForschungsZentrum, a German research center, developed the app *Nachtlichter* for people to count and classify lights to better understand light pollution. The app needed a tutorial to ensure understanding of the classifications to collect accurate data. By investigating difficulties in classifying, creating a framework and undergoing a cycle of testing, feedback and revisions we produced a tutorial. This tutorial was tested and proven effective at teaching citizen scientists by reducing confusion as well as increasing confidence and classification accuracy.

Executive Summary

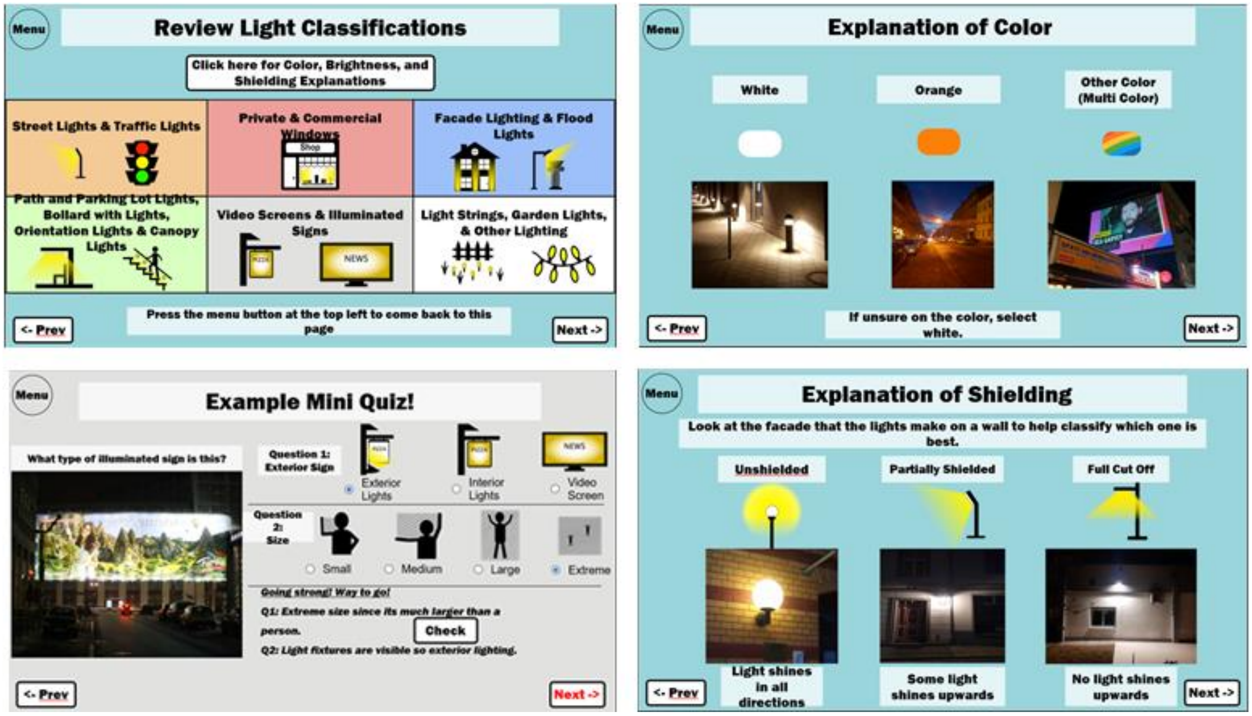
Research institutions around the world actively collect data on night-time artificial light emissions in order to understand the scope of light pollution, such as Germany's GeoForschungsZentrum (GFZ). These institutions adopt satellite imaging as a primary method of data collection. However, in order to further understand the details of an area's light emission, such as the specific types of light fixtures contributing to a bright spot, satellite images often present limitations in resolution and consistency. To overcome these limitations, researchers often need to conduct street level surveys manually to verify the remote measurements, or ground truthing. Because of the vast manpower needed in this effort, researchers often employ voluntary members of the public. These volunteers, or citizen scientists, often need to be trained in the subjects of research in order to produce valid data collection.

GFZ's public campaign *Nachtlicht BüHNE* aims to gather groups of citizen scientists to help collect light emission data. Its goal is also to educate them in the process. As GFZ intends to categorize all lights in its predefined classifications, it launched a classification survey first in paper, and currently as an upcoming mobile app called *Nachtlichter*. To help ensure the data collection quality by the citizen scientists, this IQP group aims to develop a light classification tutorial that will be integrated into *Nachtlichter*.

This project team aims to **teach** citizen scientists how to **classify** lights on an existing application created by GFZ to accurately **correlate** the amount of lighting on the ground with the light detected from satellite imaging. This mission was accomplished through three objectives. The first objective was to **determine the challenges that citizen scientists faced** while categorizing lights on a paper version of the app the preceding year. This information was collected through a Google form survey. The second objective was to **create the framework of the tutorial** using the information from objective one. The framework was a basic outline of what the tutorial would look like. The third objective was to **produce the tutorial**. This included sending our tutorial out to citizen scientists provided by GFZ, who were working on the app, in order to get feedback and make revisions to the tutorial. Upon making these revisions we had transformed the framework into a fully functioning interactive tutorial through multiple iterations. The last step of the objective was to return the tutorial to GFZ, allowing them to make edits of their own and implement it into their app.

Figure 1

Screenshots of the Nachtlichter Tutorial



A few screenshots of the tutorial for Nachtlichter

A defined methodology resulted in feedback from 35 people and the creation of a tutorial. Feedback was critical in determining what was unclear and what changes needed to be made. We completed six cycles of testing, feedback, and revisions.

Prior to the creation of the tutorial a Google form was created and sent to citizen scientists who had tested GFZ's paper version of *Nachtlichter*. This was to discover the challenges people face while classifying. Results from the 12 responses indicated that there were seven light classifications causing confusion, and this was due to the classifications being similar to another. The feedback also indicated that most respondents did not have trouble determining brightness or color of lights. Those that did have trouble with brightness suggested a dim option be added and those that reported difficulty with color reported confusion classifying lights that were multicolored.

After our group had received feedback via the google forms survey our sponsors at GFZ arranged a meeting for us to receive direct feedback from the citizen scientists themselves. In this meeting our group had the opportunity to speak with about 10 citizen scientists that our sponsors had been meeting with every two weeks. In this first meeting our group got to show the citizen scientists the first iteration of our tutorial. The feedback we received was positive as the citizen scientists were surprised and pleased with the progress we had made since what they had heard two weeks prior. Our group did receive some suggestions from them, which we had worked to add in for the next version. After addressing the suggestions, the citizen scientists had for us such as the brightness of the lights, the addition of a motivational piece, and the background our group made arrangements to meet with the citizen scientists again. For the second meeting with the citizen scientist group, we discussed the interactive version of the tutorial in the ActivePresenter8 software.

To test the effectiveness of the tutorial, 14 participants were asked to count and classify the lights on a road. The same road was selected and all participants received the paper version of *Nachtlichter*. Half of the participants received the tutorial to view before classifying. After returning with data and being asked a few questions the results were analyzed. Participants without the tutorial report confusion and feeling overwhelmed, needing time before feeling confident. Participants with the tutorial reported feeling little confusion and being confident from the beginning. Participants who viewed the tutorial also classified lights more accurately. The accuracy was proven by participants who had viewed the tutorial reporting a greater number of the lights that were in the area being classified.

Researchers worldwide have been conducting studies to understand and mitigate the problem of light pollution. GFZ has been conducting research to connect ground truthing with satellite images. In order to achieve this, it devised an app to count and classify all the lights in a given area. This resulted in the need for a tutorial to ensure citizen scientists understood how to properly classify lights. The creation of the tutorial required a series of testing, feedback, and revisions, but a tutorial was created that proves to be effective at educating citizen scientists to classify lights. Citizen scientists who view the tutorial prior to classifying lights report less confusion, more confidence, and show greater accuracy at classifying lights. The results indicate the tutorial will have a positive effect and help increase the accuracy of data that GFZ collects through *Nachtlichter*.

With GFZ's release date of *Nachtlichter* placed after the IQP completion, this team recommends giving GFZ full access to the tutorial for further modifications and translational work for a German copy. The tutorial should be transferred to GFZ along with instructions of editing in ActivePresenter8, along with minor adjustments to address any later feedback.

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Authorship

For the most part, each section of this report had a primary Author. Editing responsibilities were left to the discretion of the rest of our group. Below is a chart identifying how the writing for each section was divided.

Section	Author(s)	Editor(s)
Abstract	Ben	All
Executive Summary	All	All
Introduction (1.0)	All	All
Background (2.0)	Aidan	Aidan, Nick
2.1	Aidan	Aidan
2.1.1	Aidan	Aidan
2.2	Nick	Nick
2.3	Ben	Ben
2.4	Jeffrey	Jeffrey, Ben
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Survey Questions for Tutorial Testing Volunteers	Ben	All
Framework of Tutorial	Nick	All

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1. INTRODUCTION

Exposure to artificial light has been proven to have negative effects on human health, such as impacting the sleep cycle among other serious conditions ("Human Health," n.d.). Detrimental effects can result from too much exposure to different light types, ranging from LEDs to fluorescents to incandescent light bulbs. The majority of these adverse health effects stem from the way that one's sleep is disrupted by light exposure. Artificial light has negative effects on many local ecosystems around the world. Nocturnal species have had their sleep cycles affected and their food webs disrupted. Many species of migratory birds, such as geese, and pelicans, have had their migration cycles thrown out of order by artificial light exposure among other effects ("Light Pollution Effects on Wildlife and Ecosystems," n.d.). Even aquatic life has been impacted with certain species that rely on natural light for direction being led astray by artificial light, such as sea turtles among others. With the increase in light emissions and our growing knowledge of environment and human health, organizations like the EU have suggested regulations to be put in place. Although regulations exist regarding the minimum amount of light required to keep citizens safe on roads and in parks, there are no binding laws that prevent too much lighting. In Europe, the EU has worked to create guidelines as an attempt to reduce light pollution, but not all of their countries or cities have adopted them.

Because of the complexity of reducing light pollution, those who dedicate themselves to developing solutions often first need a very large amount of data on urban artificial light for analysis. Such data would typically include the quantity and categorization of light fixtures visible along city streets. In past studies, methods for collecting large amounts of light data have been inefficient. Involving the general public in these efforts as citizen scientists might prove to be the most effective way to record the data scientists need to understand the sources of light pollution.

The German Research Center of Geosciences (GFZ) studies light pollution in Berlin and elsewhere using satellite images as a primary source of information. Since there is no precise way to determine the sources and types of light pollution from satellite images, GFZ has developed a smartphone app called *Nachtlichter* that allows citizen scientists to collect useful field data to correlate with the satellite images. To make sure that the information is accurate, GFZ wants a tutorial for its app to ensure the citizen scientists can properly classify the 18 main classifications of lights and their subcategories.

Our project team aims to assist citizen scientists in the classification of lights on the *Nachtlichter* application to accurately correlate the amount of lighting on the ground with the light detected from satellite imaging. In order to accomplish our team's goal, we began by understanding the target audience and what challenges they would face categorizing lights. Next, we used the information gathered to create a mock tutorial. Then, we were able to test the tutorial on the citizen scientists and refine the tutorial from their feedback. Lastly, we finalized the tutorial and made it available for anyone to use while collecting data on GFZ's app.

2. BACKGROUND

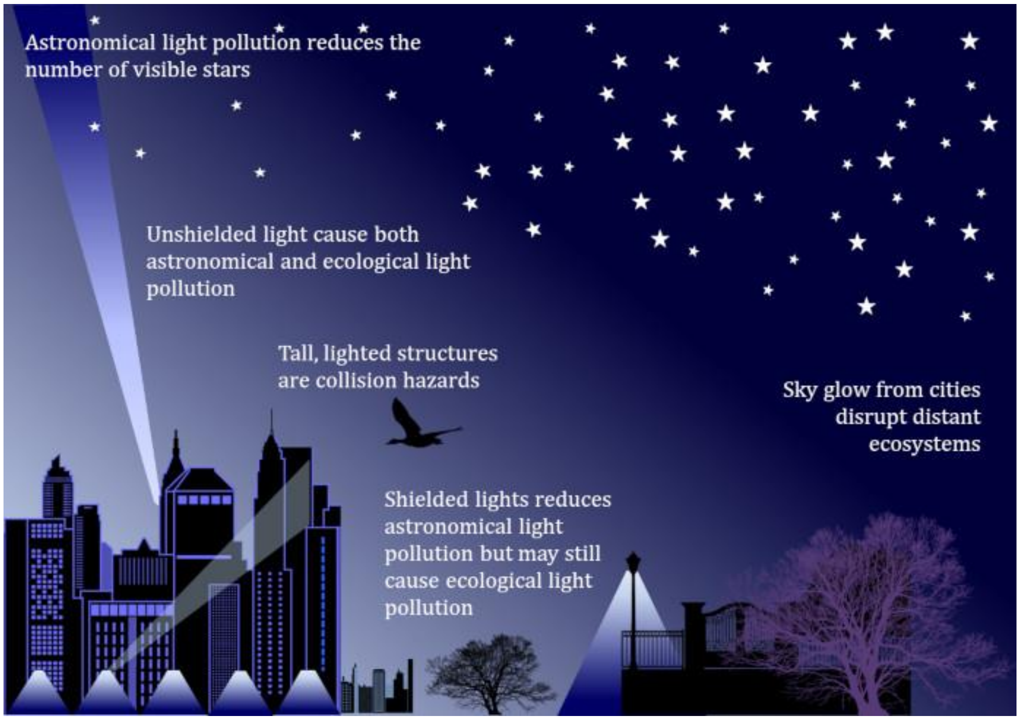
Light pollution, while present across the globe, is not well known or well understood by many, therefore its consequences often go unnoticed. In Europe, there are guidelines like the LIL and GPP restricting light pollution. While some organizations including the EU have begun working towards the goal of restricting light pollution, there is still much more work to be done. In recent years, data on light pollution has been collected using various methods, which utilize field research techniques as well as satellite imagery to identify different types of lights. Most recently community volunteers have been working with scientists to help gather additional data to combat this growing issue.

2.1 The Effects of Light Pollution

Light pollution has many impacts on our planet. The **environment** in particular is severely impacted by light pollution in a multitude of ways. Most animal species depend on natural light in order to function normally. For nocturnal animals, artificial light gives the illusion of daytime, which impacts the sleep cycle of many organisms. The presence of artificial light also has caused a decrease in certain animal populations since predators use daylight to hunt their prey and the prey use the cover of night to hide ("Light Pollution Effects on Wildlife and Ecosystems," n.d.).

Figure 2

Light Pollution Diagram



A diagram of light pollution from illuminated cities at night and how they impact local ecosystems (Le Tallec, 2019)

For **birds**, in particular, the illumination of the skies at night can be harmful since it can **disrupt migration cycles** and hunting groups that would normally use moonlight and starlight to navigate. Studies have shown that millions of birds die each year by colliding with buildings and skyscrapers that have been illuminated by artificial light ("Light Pollution Effects on Wildlife and Ecosystems," n.d.). Migratory bird species depend on seasonal changes and natural cues in order to migrate on time. Artificial light sources, however, have caused many birds to migrate too early or too late and miss ideal conditions for nesting among other effects.

Even within wetland ecosystems there are disruptions caused by artificial lighting. For example, amphibian species such as **frogs and toads** have nightly breeding rituals, which are disrupted by artificial light and can result in a **decline in reproduction and population size** ("Light Pollution Effects on Wildlife and Ecosystems," n.d.).

Artificial light also has an effect on aquatic life such as **sea turtles**. Sea Turtle hatchlings normally find the sea by following a bright horizon on the water, but artificial lights have the effect of drawing the hatchlings away from the sea **causing many deaths each year** ("Light Pollution Effects on Wildlife and Ecosystems," n.d.).

Even **insects** are affected negatively by artificial light, which can draw them to light sources where they are easily consumed by animals that feed on them. This **disrupts the natural order of food webs**.

Humans are also affected negatively by the many different artificial lights that are common all over the world as explained in the section that follows.

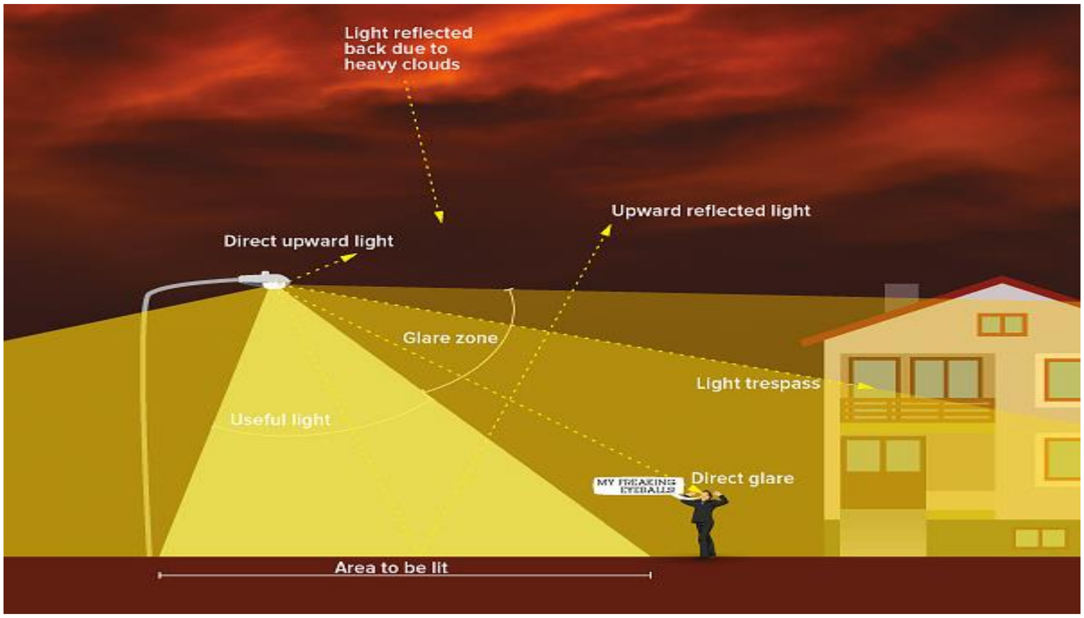
2.1.1 Effects of Light Pollution on Human Health

Humans have evolved in such a way that our regular functions are intertwined with natural light. The widespread use of artificial lighting interferes with this cycle as we no longer are able to experience an entirely dark night in most places around the world. Research suggests that artificial light creates many different health risks for humans, including increased chances for **obesity, depression, sleep disorders, diabetes, and breast cancer** among other conditions due to a lack of sleep ("Human Health," n.d.). Much like most wildlife, humans adhere to a **circadian rhythm**, which is essentially a biological clock. It is a sleep-wake pattern that is governed by the day and night cycle, which artificial light is capable of disrupting.

Melatonin is a hormone that our bodies naturally produce in response to our circadian rhythm in order to keep us healthy. It has the effects of inducing sleep, boosting the immune system, lowering cholesterol, and helping the functioning of the thyroid, pancreas, ovaries, testes and adrenal glands. Artificial light **suppresses the production of melatonin** in the body. ("Human Health," n.d.) The lack of sleep caused by low melatonin production can result in higher blood sugar levels as well as an increased appetite. The lack of melatonin can also lead to breast cancer through increased cell growth and repair in the breast area. (Suni, 2020) There is also an adverse mental effect of sleep deprivation, which can cause mood shifts and lead to depression (Fry, 2020).

Figure 3

Light Effects on Human Health Diagram

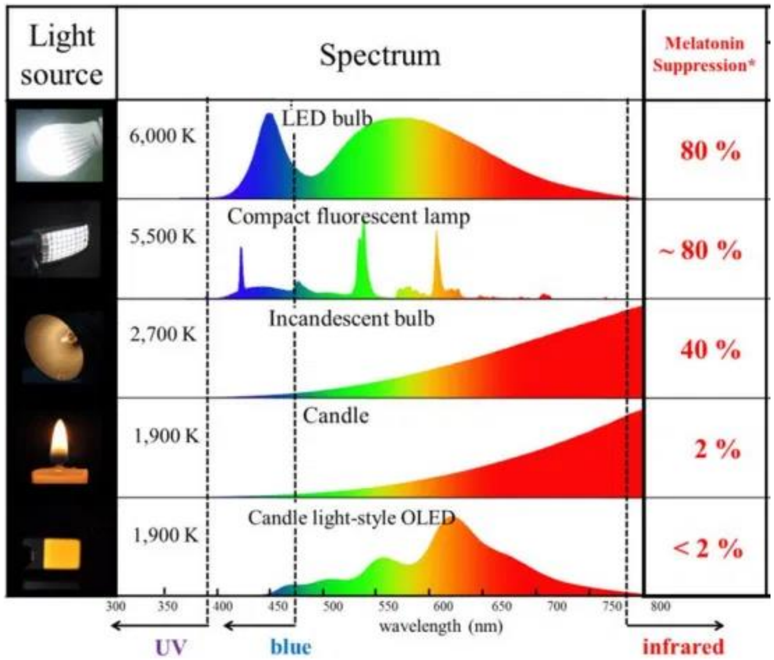


A diagram displaying light beams from street lamps and how they affect people (Gocova, 2013)

Some lights have more negative effects than others. Blue light, in particular, is considered to be one of the more harmful and most common. Most LEDs — used for outdoor lighting, computer screens, and other electronics — produce blue light. The incandescent bulbs of old were far less energy efficient than LEDs and fluorescent lights, but produced less blue light.

Figure 4

Light Spectrum Chart



Various Light Sources and their Spectrum of Light Emission (Glen, 2020)

A 2016 American Medical Association report about blue light exposure recommended only using lighting with 3000K color temperature and below and to shield all light fixtures. In order to further minimize blue light exposure, various apps were created with the ability to adapt electronic devices' screens to match the time of day and reduce the amount of blue light emitted. One other health concern from outdoor lights is the glare that a poorly shielded source can produce, which can decrease vision by reducing contrast. This means that a person's ability to see any incoming danger at night can be affected, and aging eyes in particular are affected the most. The negative effects that light can have on a person's eyes depends on the type of light they are being exposed to. For instance, observing "warm" lighting at night is better for the eyes than to look at "cooler" lighting. This is because warmer lights have a lower temperature than ones classified as being cooler, which is better on the eyes later at night and won't impact sleep as much. ("Human Health," n.d.) While it is important to understand the health risks that artificial lights present, knowing how to distinguish between the various types of lights and the effects of them is equally important.

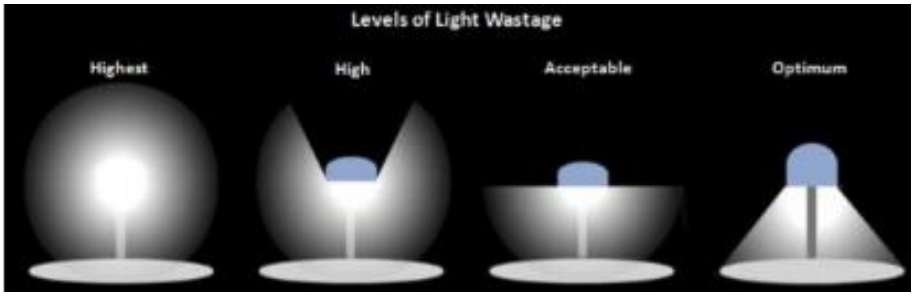
2.2 Government Regulation of Light Emissions

There are regulations regarding the **minimum** amount of lighting required to keep people safe as they travel at night, but there are only guidelines to prevent light emissions. As the emission of light continues to grow across the city of Berlin and the world due to the increase in LEDs, many organizations, including the European Union, have discussed possible regulations and guidelines to help prevent the harmful effects of light emissions. Major advancements in lighting technology over the past decade have made LED lights appealing to the public and has caused many to switch to LED lighting. Many German cities, like the city of Göttingen, have been pushing for more energy efficient street lighting as a result of the climate protection concept presented in 2010. This protection plan was put into place in September of 2010, where Germany set a course with the goal to become more energy efficient by 2050. This includes using all technology advances and innovations in energy efficiency (*Energy Concept*, 2010). Shortly after the concept was released, the city of Göttingen was pushing to replace all of its outdated outdoor lamps with the newly developed LEDs. Since LED lights have been proven to use less energy and have a longer lasting life expectancy, they are perfect replacements for streetlights in cities. Göttingen states that it will be able to save about 80% of its usual energy consumption with these replacements. This has increased the amount of light with blue wavelengths being emitted, which as mentioned before are harmful to human eyes and damaging to the environment. The Berlin state road laws, *Landesstraßengesetze*, currently require pedestrian roads, tunnels, park areas, and other public spaces to be well lit to allow safe passage of all citizens throughout the night (Holton & Mercado, 2015). Again, there are guidelines that control the **maximum** amount of lighting required.

Due to the lack of regulations for light pollution, the European Union (EU) has produced guidelines to reduce the luminance in cities across Europe. The EU Green Public Procurement Criteria for Road Lighting and Traffic Signals, or GPP, has allowed the EU to help steer larger street light manufacturers toward reducing emissions. Some of the suggestions include, for example, that all light sources must have controls to allow them to be dimmed to 50% of their maximum light output; no lighting system may emit light above the horizontal plane (as shown in figure 6 below); and the color temperature of all lighting must be less than 3000 Kelvins in residential areas. More of these suggestions can be found in Appendix E. Since this document consists entirely of guidelines, it lacks regulatory force. But some see it as a first step in the right direction (Barentine, 2019).

Figure 5

Light Wastage Diagram



An example of a GPP Guideline (Donatello, 2018).

On the national level, Germany, Italy, and Slovenia all have organizations that have come together to produce a joint document titled *Standards of Low Impact Lighting* (LIL). The organizations are *Licht und Natur* (Germany), *CieloBuio* (Italy), and *Dark-Sky* (Slovenia). Many of the guidelines in the LIL also align with the suggestions of the GPP. These guidelines can be found in Appendix F. The GPP was designed for a more international level, while the LIL was created because these countries wanted to take this matter into their own hands. Again, although these guidelines are promoted by these organizations to reduce light pollution, they have not been transformed into laws ("Licht und Natur," n.d.). Without binding laws, the installation of harmful lights will continue not just in Berlin, but around the EU and the world. Before governments can make decisions on any of these proposals, they must gather more information so that they can compare the beneficial and detrimental effects of the new lighting technologies.

2.3 GeoForschungs Zentrum Involvement with Light Pollution

There are organizations worldwide that are involved with research into understanding light pollution. These are usually academic or government research centers. One of the organisations is *The International Dark Sky Association*, which is dedicated to preserving the night sky as a shared heritage for all living things (International Dark-sky Association). Another organization is the *GeoForschungsZentrum* (GFZ) which is the German center for geosciences[1].

[1] A deeper description of the GFZ is included in appendix A

GFZ pursues a deep knowledge of the Earth in order to understand natural hazards, the risks they pose, and how to reduce their impact. There are four main research departments in GFZ: Geodesy, Geophysics, Geochemistry, Geosystems. Each department has sub departments focused on collecting data that can be analyzed in order to assess or address problems. Within the Geodesy department, the Remote Sensing and Geoinformatics research group at GFZ, which focuses on remote sensing and geospatial data, has been collecting data on the ground to help understand the extent and severity of light pollution (GFZ, 2019) through a project called *Nachtlicht BüHNE*.

The ***Nachtlicht BüHNE* project**, which translates to ‘night light stage’, aims to work with citizen scientists to raise knowledge and awareness about light pollution in Berlin. This project stems from GFZ’s use of satellite imagery to monitor light pollution. While the images allow for the big picture to be understood, they can only capture information as accurate as the smallest pixel, which is 750m x750m. Also, since satellites are never in the exact same position as they take pictures, the resulting light pollution patterns vary depending on when the picture was taken. Images captured from satellites also do not indicate what or how many lights are contributing to the pollution.

To resolve these issues, scientists rely on ‘ground truthing’, a process wherein data is collected ‘on the ground’ to establish the ‘truth’ of what the satellite images actually represent. Citizen scientists can provide a ground truth through direct observation and thereby corroborate inferences made from satellite data. A group of citizen scientists is collaborating with GFZ to develop an **app called *Nactlichter*** that will allow anyone to contribute to the *Nachtlicht BüHNE* project. *Nacthlichter* will allow citizen scientists to go to a specific area on a map and record all relevant data related to light pollution including: classification of lights, quantity of lights, and in some cases the size, color, or if they are shielded.

If several people begin classifying lights on streets, a detailed profile can be built of an area. The detailed profile will allow scientists at GFZ to connect the data to better interpret the satellite images and understand the true severity and sources of light pollution. Understanding the scope and severity of the problem will allow for a plan to be developed to mitigate the problem. In addition to the collection of data, this project serves as an opportunity for people to become involved in something bigger, become educated, and raise awareness for the issue. If successful, this method of citizen science collaboration will be expanded to more projects (GFZ, 2019).

In order for GFZ to analyze and make meaningful connections, accurate data collection is important. The importance of data collection has led GFZ to the conclusion that its **app should include a tutorial** to help teach citizen scientists how to correctly classify and count lights.

2.4 Methods of Light Pollution Measurement

Currently, there are two methods for measuring artificial light emissions: field surveys and remote sensing. Remote sensing using satellites and aircrafts can take large areas of measurements of light emission quickly, while the field surveys act to verify and correct these measurements (ground truthing).

2.4.1 Measuring Light Pollution via Field Surveys

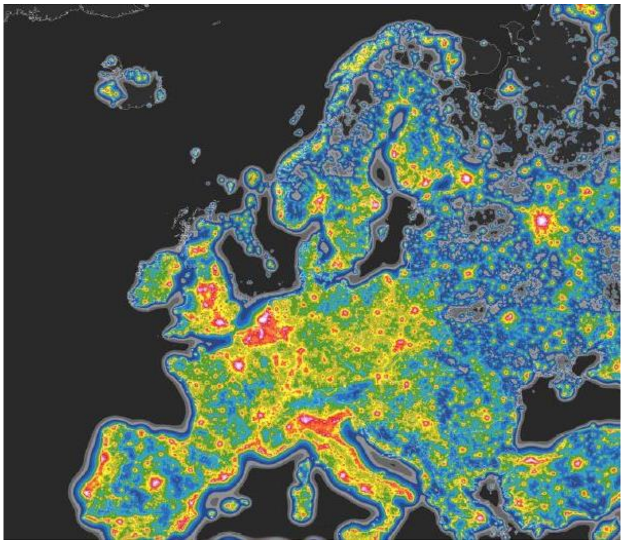
The most traditional and direct method in measuring artificial light sources is field survey. By direct observation, the data collected tends to have high accuracy. However, because of the rapid increase of areas with high numbers of lights, such a method often proves to be logistically difficult and time consuming. It is almost impossible these days for researchers to run down a street and count the sheer numbers and types of light fixtures within the time constraints of their projects. With technologies such as aircrafts and satellites, remote sensing is often preferred for large scale data collection.

2.4.2 Measuring Light Pollution via Remote Sensing (Satellites)

The quickest method to gather large samples of light pollution is through **satellite imaging**. With the quick advancement and availability of low-orbit geo-survey satellites, research institutes interested in large areas on the ground have been gaining more freedom to obtain measurements from big image datasets. These measurements provide a holistic view of the artificial light in cities, states, and even a whole country or continent. Typical representations of these data are maps with color codes corresponding to varying levels of sky brightness.

Figure 6

Satellite Imaging Photo

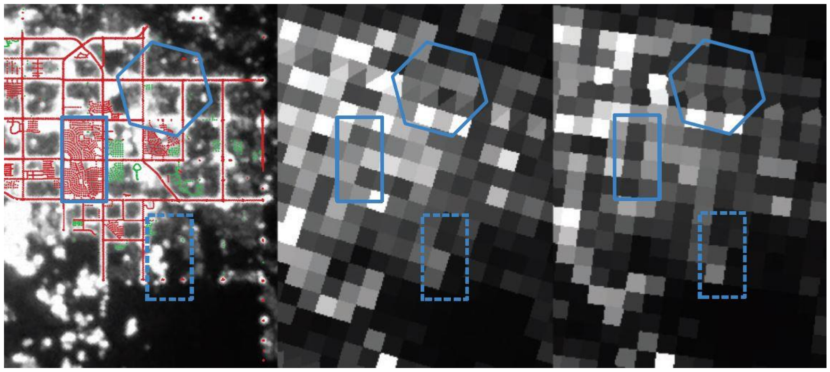


An example of satellite imaging of artificial lighting. (Falchi, 2016)

If there's a need for determining the contribution of different types of lights at a bright spot, satellite images often present several challenges. Because of the constant change in the Earth's atmosphere, such as varying cloud coverage and natural skyglow, images are not consistent across different times of day and across seasons. The resolution limit of the satellite cameras often makes it difficult to determine even the rough number of light sources at bright spots, likewise with the types of lights. These and other issues create subtle but significant variability when attempting to yield consistent data over the same captured area at different times. Although there are studies aiming to use intelligent image processing algorithms to minimize such inconsistency, developing them often proves complicated and expensive.

Figure 7

Aerial Images of Tucson AZ



Christopher Kyba's team attempted to develop processing algorithms over images of Tucson, AZ. (Kyba, 2020)

Ground surveys are thus often necessary to confirm the measurements of light sources at a distance. The sponsor of our research project, GFZ, has initiated multiple programs and studies to explore the efficiency of using citizen science to ground-truth satellite images.

2.4.3 GFZ's System to Classify Artificial Light

The classification of lights is important to GFZ in order to understand the light pollution data collected from satellites. Not all lights produce the same amount of pollution. A classification that citizen scientists can use, will result in the collection of data to help give GFZ scientists a clear understanding of the severity and scope of light pollution. **GFZ has a system with six groups that contain all 18 light classifications**. The six groups are shown in figure 8. Along with the classifications there are subclassifications. These subclassifications help gather more information to better understand the pollution caused. The subclassifications further denote the size of the light, the degree of shielding, brightness, and color (Altıntaş, 2020).

The classifications are designed to make field surveys easy for citizen scientists to contribute and collect data. Field surveys' data will provide a deeper understanding of lights and how they contribute to pollution. In order to make data collected in field surveys easy for citizen scientists the groups of classifications are done by lights that are commonly found together to increase the collection of accurate data.

Figure 8

Nachtlichter Table of Contents

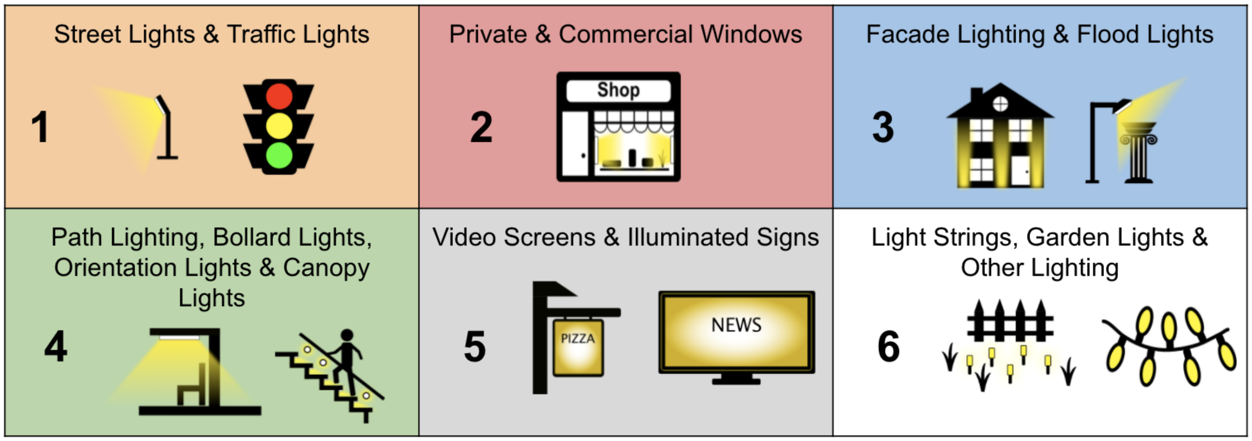


Table of Contents from Nachtlichter App Tutorial

Group One contains **street lights and traffic lights**, figure 9 shows all group information. The first classification is street lighting, categorized because they are used to illuminate streets. There are three subclassifications that refer to how shielded the light is: (1) if not shielded the light shines in all directions; (2) if partially shielded it still has light shining upward but some is obstructed; (3) and if fully shielded it has light shining only downward. The next classification is traffic lights. A note to classify traffic lights is to count a unit of colored lights as a single traffic light so a typical unit is red/yellow/green but a unit can also include a light for turning, or a unit could even be walking signals for pedestrians.

Figure 9

Light Group 1 Chart

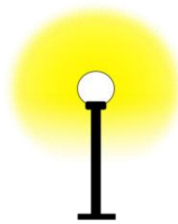
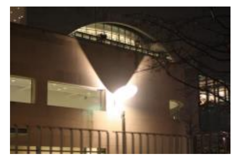
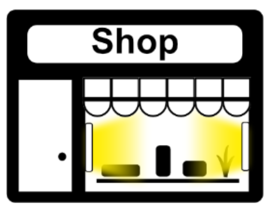
Group 1	Nachtlichter Logos	Example Images
Classification 1: Street Light Subclassification: Unshielded		
Classification 1: Street Light Subclassification: Partially Shielded		
Classification 1: Street Light Subclassification: Full Cut Off		
Classification 2: Traffic Light		

Chart of the first light classification group with illustrations and photos (Altıntaş, 2020)

Group Two contains **private windows**, **commercial windows**, **outdoor lights mounted on buildings**, **lit doorways**, and **house numbers** and **doorbells**. All information for group 2 can be seen in figure 10. While windows do not give off light, light pollution from inside goes through the glass so they are important to account for. The best way to imagine the size of the window for this classification is about the size of a person or about $2m^2$. The fourth classification is illuminated showcase windows. Similar to the third classification, the major difference is these windows will be larger, around 8-12m² or about four to six people. A note for this classification is even if individual lights can be seen in a window it is classified as an illuminated window or showcase window. The fifth classification is outdoor lights mounted on buildings. These lights are typically used to light up facades or entryways and there are three subclassifications for if the light is shielded, partially shielded, or not shielded. The sixth classification of lights is if a building has an illuminated house number or doorbell.

Figure 10

Light Group 2 Chart

Group 2	Nachtlichter Logos	Examples Images
Classification 3: Private Windows		
Classification 4: Commercial Windows		
Classification 5: Outdoor Lights Mounted on Building **Subclassification: Unshielded**		
Classification 5: Outdoor Lights Mounted on Building **Subclassification: Partially Shielded**		

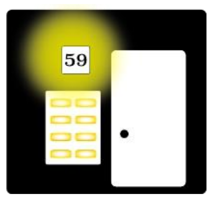
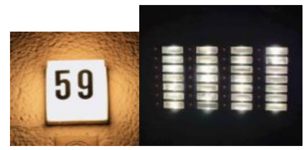
Classification 5: Outdoor Lights Mounted on Building **Subclassification: Full Cut Off**		
Classification 6: Illuminated House Number and Doorbell		

Chart of the second light classification group with illustrations and photos (Altıntaş, 2020)

Group Three contains **facade lighting** and **flood lights**. Information displayed in figure 11. The seventh classification of lights is facade lighting. This is categorized by if a facade is illuminated and the lights are not visible. Since the lights are not visible this light classification is done by estimating the illuminated area with three subclassifications. The first subclassification is small, which is used if the lit area is small, which can be imagined as roughly the size of a person. The next subcategory is middle, which can be imagined as if the lit area is around the size of a one-two story home. The final subcategory in facade lighting is tall/large, which is used for buildings, houses or structures that have several floors, usually thought of as anything larger than a two story building. If a facade is lit but the lights are visible, then they should be counted as floodlights. The next and eighth classification is flood lights. These are visible lights that illuminate a facade usually of stadiums, churches, or other buildings, often used as lighting for security, and can have other uses. Flood lights also have three subcategories to determine if the light is, fully, partially, or not shielded.

Figure 11

Light Group 3 Chart

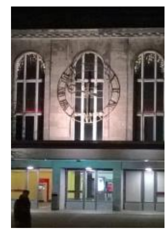
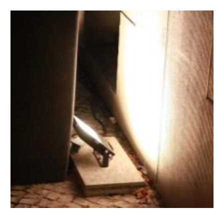
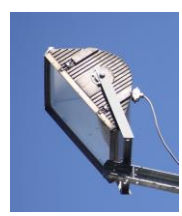
Group 3	**Nachtlichter Logos**	**Examples Images**
Classification 7: Facade Lighting **Subclassification: Small**		
Classification 7: Facade Lighting **Subclassification: Middle**		
Classification 7: Facade Lighting **Subclassification: Large**		
Classification 8: Flood Lights **Subclassification: unshielded**		
Classification 8: Flood Lights **Subclassification: Partially Shielded**		
Classification 8: Facade Lights **Subclassification: Full Cut Off**		

Chart of the third light classification group with illustrations and photos (Altıntaş, 2020)

Group Four contains **path lighting**, **bollards**, **orientation lights** and **canopy lighting**. The information can be seen in figure 12. The ninth classification is for path parking lot lighting. This lighting can look the same as street lights, but the different classification is due to what they are being used for. The tenth classification is for bollards that have lights. Bollards are vertical posts, usually short, that can be located in a variety of places, oftentimes used for providing light for pathways. The eleventh classification is orientation lights. Orientation lights are classified because they are usually weak lights on the ground to illuminate the ground or designate a pathway, this lighting is also used as decorative lighting in areas. The twelfth light classification is for canopy lights. Canopy lights are lights that are under a roof so there is no light shining upwards. These lights are usually used to light up gas stations, bus stops, or even covered house entrances.

Figure 12

Light Group 4 Chart

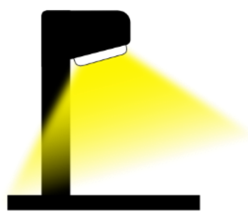
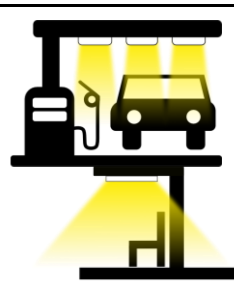
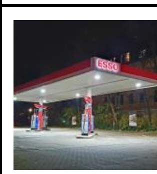
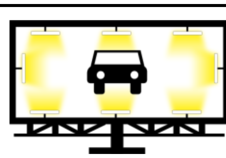
Group 4	Nachtlichter Logos	Examples Images
Classification 10: Bollards		
Classification 11: Orientation Lighting		
Classification 12: Canopy Lights		 

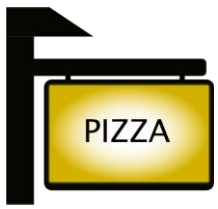
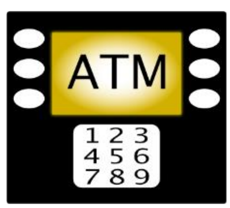
Chart of the fourth light classification group with illustrations and photos (Altıntaş, 2020)

Group Five contains signs with **exterior lighting**, signs with **interior lighting**, and **video screens**. Information is displayed in figure 13. The thirteenth classification is for signs that are illuminated by one or more nearby external lights. The fourteenth classification is for self-illuminated signs that use no external lights for illumination. The fifteenth classification is video screens. This classification is for any video screens located outdoors. There is a subcategory with four sizes for both classifications of signs and video screens. The small sub category is for signs/screens the size of a laptop screen; the middle category is for signs/screens the size of a big television; large signs/screens would be the size of a person; and the extreme classification is for any signs/screens that are significantly larger than a person.

Figure 13

Light Group 5 Chart

Group 5	**Nachtlichter Logos**	**Examples Images**
Classification 13: External Illuminated Signs **Subclassification: Small**		
Classification 13: External Illuminated Signs **Subclassification: Middle**		
Classification 13: External Illuminated Signs **Subclassification: Large**		
Classification 13: External Illuminated Signs **Subclassification: Extreme**		

Classification 14: Internal Illuminated Signs **Subclassification: Small**		
Classification 14: Internal Illuminated Signs **Subclassification: Middle**		
Classification 14: Internal Illuminated Signs **Subclassification: Large**		
Classification 14: Internal Illuminated Signs **Subclassification: Extreme**		
Classification 15: Video Screens **Subclassification: Small**		
Classification 15: Video Screens **Subclassification: Middle**		

Classification 15: Video Screens **Subclassification: Large**		
Classification 15: Video Screens **Subclassification: Extreme**		

Chart of the fifth light classification group with illustrations and photos (Altıntaş, 2020)

Group Six contains **light strings**, **garden decorations**, and any **other lights**. Information is also displayed in figure 14. The sixteenth classification is for light strings, which are usually used as decoration. To classify light strings citizen scientists, use the approximate length of a human to estimate how long the light string is. The seventeenth classification is garden decoration lights. These are often small lights to illuminate areas in a garden. Finally, the eighteenth classification for lights is other light sources. This classification is for all lights that do not fit into other categories. There are three subcategories that help classify by size. The Small subcategory is for lights that are about the size of a hand, middle is for lights that are about the size of an outstretched arm, and large/tall is for lights that are about the size of a person or larger.

Figure 14

Light Group 6 Chart

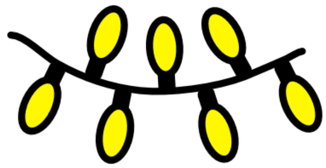
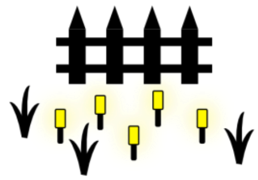
Group 6	Nachtlichter Logos	Examples Images
Classification 16: Light String		
Classification 17: Garden Lights		

Chart of the sixth light classification group with illustrations and photos (Altıntaş, 2020)

The classification for lights in Berlin helps to provide clear information to researchers and scientists to assess light pollution.

2.5 Collecting Light Pollution Data Through Citizen Science

Citizen science refers to the engagement of the general public (citizens) in gathering data for scientific research projects. It provides a strong advantage in ensuring a satisfactory quantity of data. The idea of commissioning those among the public in what the scientists are doing will improve the level of their general knowledge in the study subjects. This in turn becomes a program to raise the public awareness of the study subject. GFZ is aiming to do exactly so with its efforts in creating a mobile application for outdoor light categorization surveys.

For example, GLOBE at Night, a citizen science project led by Dr. Kyba and colleagues, has been active since 2006. The project provided the citizen scientists a standardized index of artificial skyglow at night, which effectively helped them to quantify this specific form of light pollution (Kyba, 2013). The Remote Sensing Section of GFZ has been developing a mobile application available to the general public that serves as a common platform to gather light pollution information down to the specific streets in cities.

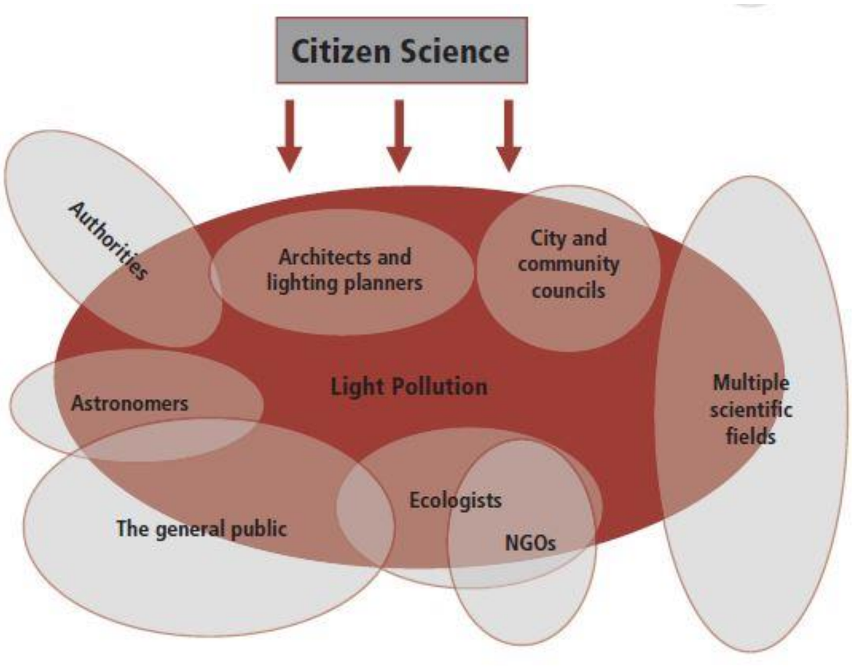
A common criticism of citizen science is that it lacks rigor. As a method to compensate for the quantity of data collection, it tends to miss the mark on the data's quality (Aceves-Bueno, 2017). This is often due to the insufficient knowledge of the research subject among the general public, as well as the unclear data collection standards provided by the researchers. One solution to these problems is to provide adequate education and training to the citizen scientists beforehand.

Developing training to citizen scientists can be a challenging task all by itself. The difficulty is maintaining the balance between delivering a rigorous standard in data collection and constantly motivating the trainees during the process. When a citizen science project emphasizes solely scientific rigor, it is essentially ignoring the human factor. The participants losing interest is often a much more serious problem than having somewhat inaccurate but complete data. Thus, motivating them becomes an area of study itself.

One study addressed the relevance of collecting lighting data on a personal level (Schroer, 2018). This means explaining how light pollution affects the participants based on their professions and hobbies (Figure 20). In doing so, each person develops unique, internal reasons to participate.

Figure 15

Public Groups in Relation to Citizen Science Diagram



Relating light pollution to different public groups can be effective (Schroer, 2018).

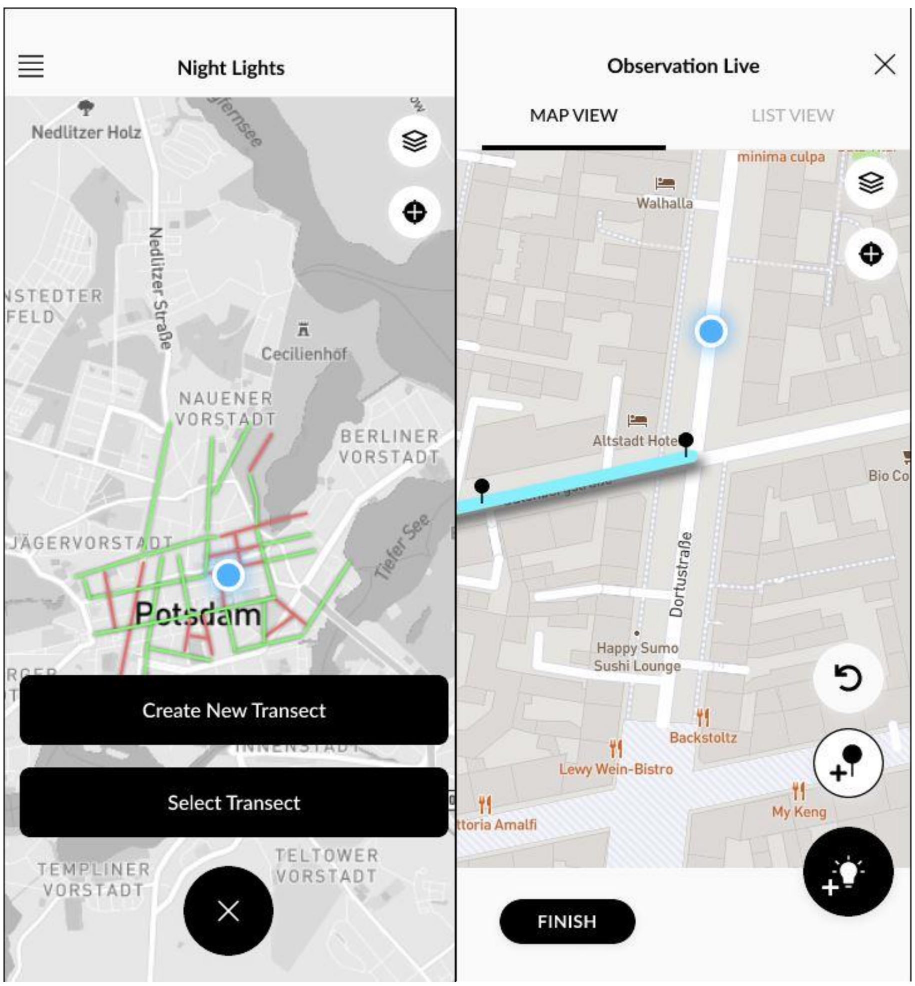
2.5.1 GFZ's Field Survey App: *Nachtlichter*

GFZ has been developing its mobile application, *Nachtlichter*, in order to provide a common platform to conduct ground surveys of light fixtures. App participants can select pre-determined transects or create their own to count and classify lights of various streets in their neighborhoods, by traversing through the required or desired area to count the numbers and types of lights.

As GFZ has its own categorization of these fixtures, the distribution of the app will further standardize it. A few screenshots from the app are shown below in figure 20.

Figure 16

Images of *Nachtlichter* App

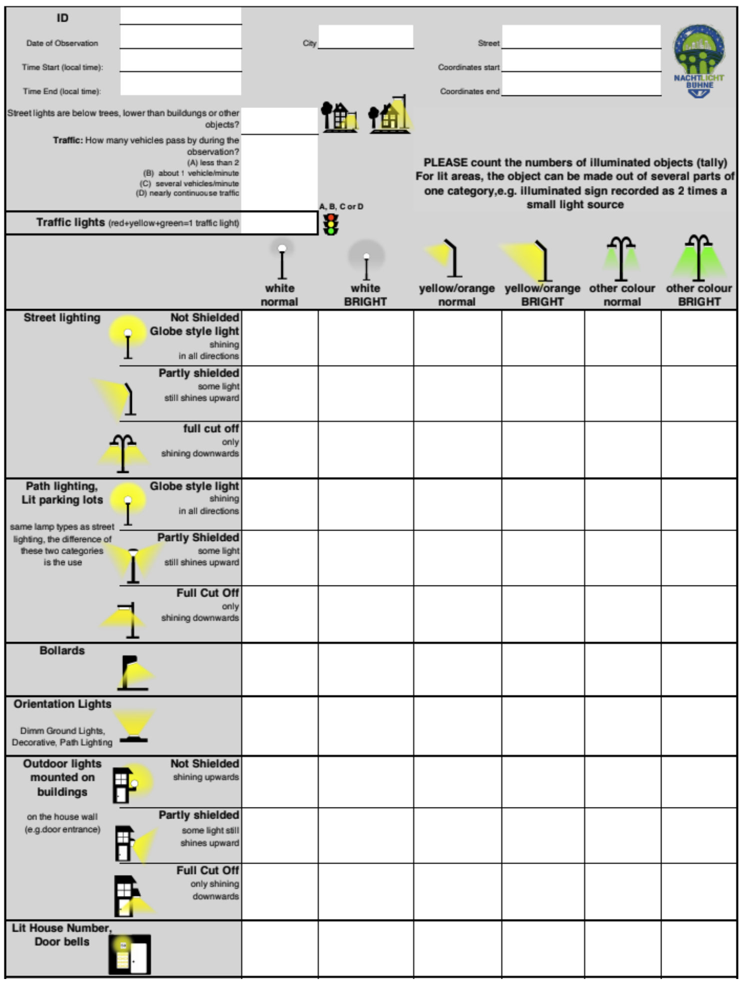


The current beta version of GFZ's app, Nachtlichter.

The creation of the app resulted directly from a paper trial version where GFZ had their participants count lights and record them on a sheet of paper. The image below shows an example of what the paper version looked like. The complete version of the paper trial can be found in Appendix D.

Figure 17

Paper Version of App



ID

Date of Observation

Time Start (local time):

Time End (local time):

City

Street

Coordinates start

Coordinates end

NACHTLICHT BÜHNE

Street lights are below trees, lower than buildungs or other objects?

Traffic: How many vehicles pass by during the observation?
(A) less than 2
(B) about 1 vehicle/minute
(C) several vehicles/minute
(D) nearly continuouse traffic

A, B, C or D

Traffic lights (red+yellow+green=1 traffic light)

PLEASE count the numbers of illuminated objects (tally) For lit areas, the object can be made out of several parts of one category,e.g. illuminated sign recorded as 2 times a small light source

		white normal	white BRIGHT	yellow/orange normal	yellow/orange BRIGHT	other colour normal	other colour BRIGHT
Street lighting	Not Shielded Globe style light shining in all directions						
	Partly shielded some light still shines upward						
	full cut off only shining downwards						
Path lighting, Lit parking lots (same lamp types as street lighting, the difference of these two categories is the use)	Globe style light shining in all directions						
	Partly Shielded some light still shines upward						
	Full Cut Off only shining downwards						
Bollards							
Orientation Lights (Dimm Ground Lights, Decorative, Path Lighting)							
Outdoor lights mounted on buildings (on the house wall (e.g.door entrance))	Not Shielded shining upwards						
	Partly shielded some light still shines upward						
	Full Cut Off only shining downwards						
Lit House Number, Door bells							

GFZ's Paper Version Trial.

This was GFZ's first attempt at correlating their satellite pictures with the number of lights in specific areas. GFZ was able to get feedback from two groups named the ***Nachtlicht BüHNE*** Team and the ***Erfurt Studierenden*** group. The feedback they received was a good first test to show how helpful ground truthing can be to GFZ's research. Following this paper trial, GFZ presented the idea to reinvent the paper version and instead create a version for the mobile phone. With the creation of this app *Nachtlicher*, GFZ hopes to increase the number of participants since collection of data has become easier. Our group worked closely with GFZ to create a light category tutorial tailored specifically for the effective use of *Nachtlichter*.

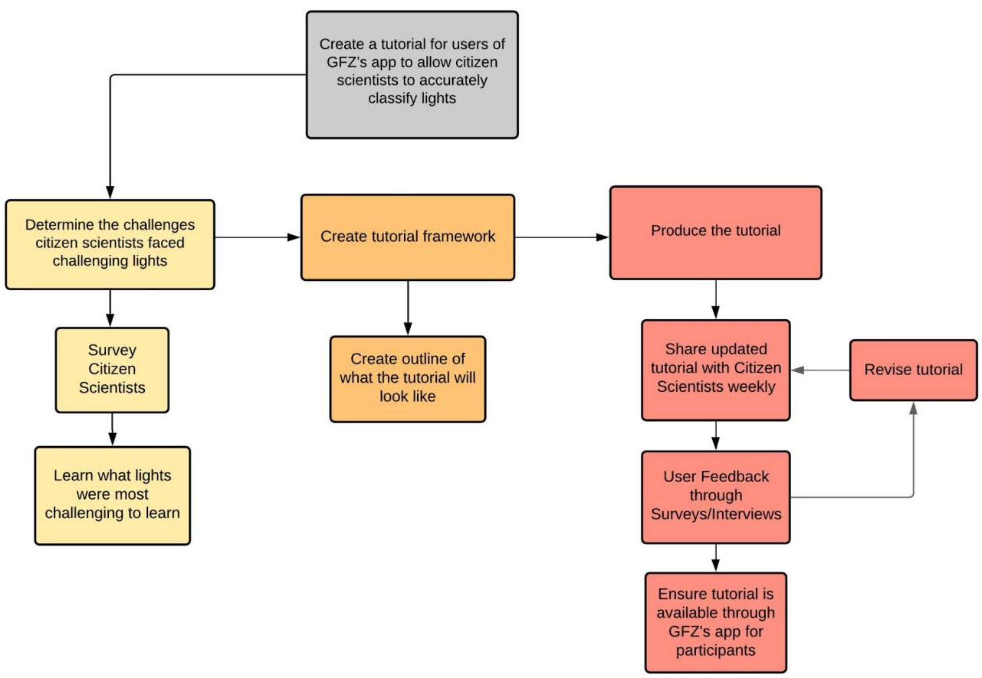
3. Methodology

The goal of this project was to create a tutorial for participants of GFZ's mobile app to allow citizen scientists to classify lights accurately. The objectives that we arrived at to complete the project are listed below.

1. Determine the challenges citizen scientists faced while categorizing lights.
2. Create the framework for the tutorial.
3. Produce the tutorial.

Figure 18

Methodology Flow Chart



The full flow chart of the project methodology

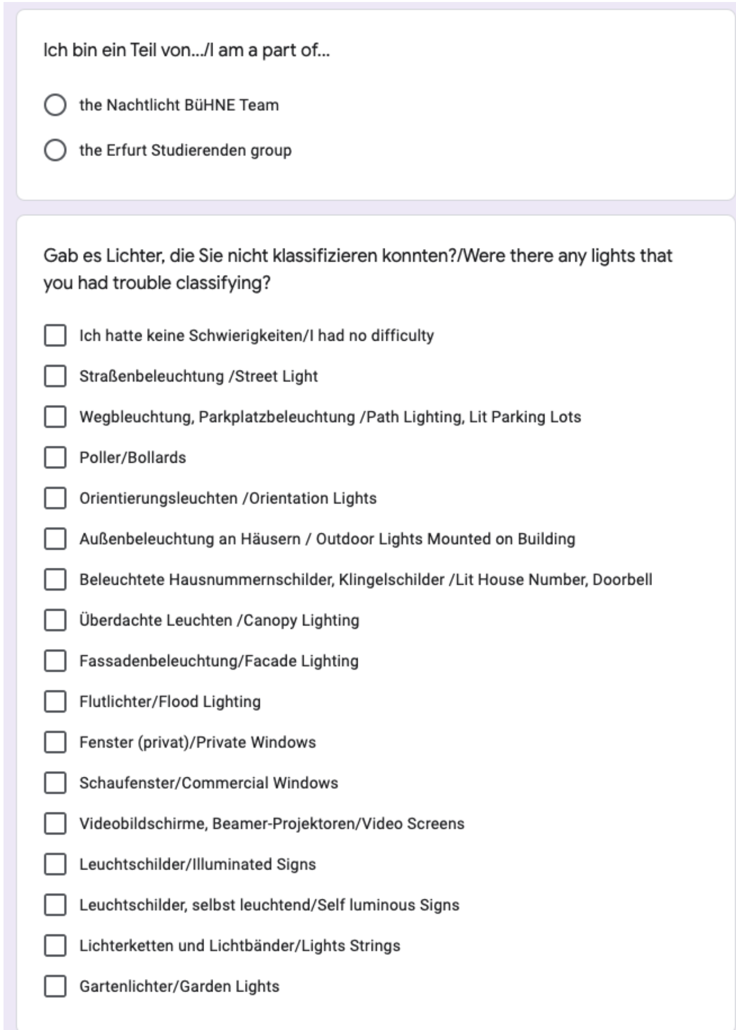
3.1 Assessing the Challenges of Citizen Scientists Using the GFZ App (*Nachtlichter*)

The **first objective** was to learn the challenges that arise when categorizing lights. This allowed our group to structure the tutorial to best prepare the citizen scientists who will be using it to classify all lights properly. This step in the progression of this project gave us the ability to adapt the tutorial to all citizen scientists in order to help them overcome challenges they faced in categorizing lights during the paper version trial.

We acquired this information and completed this objective by setting up a Google form with questions geared towards the paper version that the citizen scientists filled out the previous year. Our sponsor had given us the opportunity to reach out to two different groups of social scientists who had completed this paper version. The groups are named the ***Nachtlicht BüHNE* Team** and the **Erfurt Studierenden Groupe**. A part of the survey is shown in the screenshot below.

Figure 19

Objective 1 Google Form Survey



Ich bin ein Teil von.../I am a part of...

- the Nachtlicht BüHNE Team
- the Erfurt Studierenden group

Gab es Lichter, die Sie nicht klassifizieren konnten?/Were there any lights that you had trouble classifying?

- Ich hatte keine Schwierigkeiten/I had no difficulty
- Straßenbeleuchtung /Street Light
- Wegbleuchtung, Parkplatzbeleuchtung /Path Lighting, Lit Parking Lots
- Poller/Bollards
- Orientierungsleuchten /Orientation Lights
- Außenbeleuchtung an Häusern / Outdoor Lights Mounted on Building
- Beleuchtete Hausnummernschilder, Klingelschilder /Lit House Number, Doorbell
- Überdachte Leuchten /Canopy Lighting
- Fassadenbeleuchtung/Facade Lighting
- Flutlichter/Flood Lighting
- Fenster (privat)/Private Windows
- Schaufenster/Commercial Windows
- Videobildschirme, Beamer-Projektoren/Video Screens
- Leuchtschilder/Illuminated Signs
- Leuchtschilder, selbst leuchtend/Self luminous Signs
- Lichterketten und Lichtbänder/Lights Strings
- Gartenlichter/Garden Lights

Google Form Survey created for objective 1.

The form includes seven questions as follows. First, the participants must state which group they belong to. The next few questions included in our questionnaire asked for difficulties that arose while the participants worked through the paper version. It specifically asks what lights were most difficult to classify from the ones present on the paper version. We ask them to explain why they found those lights to be challenging. Then, we asked them to express their difficulties deciding between brightness and colors of the lights. Once we gathered our information on the intended audience, we were able to cater our tutorial to teach the most difficult lights to all citizen scientists and create our mock tutorial.

3.2 Developing a Tutorial for GFZ’s *Nachtlichter* App

Our second objective was to **create the framework of our tutorial** to teach citizen scientists how to classify lights. This step in the project was important for us to get a basic outline of what the tutorial would look like in the end.

We created the framework of our tutorial in the form of a PowerPoint presentation. In this presentation we outlined from start to finish the order of the tutorial and what a participant would see as they progress through it. While utilizing the feedback gathered from the survey in objective one, we focused on including **specific explanations to help classify lights** that were previously unclear during the paper version. For example, the differences between a dim, normal and very bright light, how to count private windows, and expressing specific differences between each light category. Our tutorial also has the option for a participant to state whether they are new or returning to the tutorial for more clarification. If new is selected they proceed through the tutorial as designed, while returning participants will be presented with a table of contents that they can skip around the tutorial to light categories they would like more help with. The tutorial was designed to **follow the logical progression of classifying light types** that a person would typically see going down a street by starting on an intersection. This progression is expressed through the six color groupings that GFZ has presented to us. These sections were designed to teach a participant about a light type and to affirm their knowledge through a mini quiz. Each light category has a mini quiz that presents a live photo of a light that the participants must choose the correct responses to.

Once we completed the framework of the tutorial with all the core information that we thought was essential to include, we were able to send out our tutorial to citizen scientists to begin receiving feedback to then improve our tutorial.

3.3 Production of the Tutorial

The third objective was focused on the **production of the tutorial**. The tutorial was given to volunteers and citizen scientists for testing, feedback was collected and revisions made. Feedback from 35 people was utilized. The feedback from those who tested the tutorial provided a different perspective to clarify areas that may have caused confusion. Through six cycles of testing, feedback, and revision, a final tutorial was developed that effectively teaches how to classify lights. The tutorial is connected to GFZ’s app *Nachtlichter* for citizen scientists to view.

For the duration of *Nachtlichter*, the tutorial will be available through it. The availability of the tutorial is important to GFZ so citizen scientists can access it to increase data collected and the accuracy of the data. *Nachtlichter* provides citizen scientists a platform that simplifies data collection while the tutorial works to teach citizen scientists how to accurately count and classify lights.

To achieve the third objective, testing, feedback and revisions were done in iterations to determine effectiveness and improve the tutorial. In order to get feedback, **a focus group was arranged** with **10 of the citizen scientists** working with GFZ. The framework of the tutorial was presented and reviewed as well as questions answered. The citizen scientists provided helpful feedback on features that should be considered for the future like a revealing image and improving visuals. With this feedback the next step was transferring the framework into ActivePresenter8. Slides were moved into the software then interactive elements added. Some of the interactive elements were buttons to go between each slide and direct new/returning participants to the appropriate slides. We also made each of the mini quizzes functional so that a participant could select an answer and check if it was correct. Feedback led us to include being able to hover over the illustration for a light type and have the photo be magnified. A second meeting with the citizen scientists was arranged to receive more feedback on a more developed version of the tutorial. The feedback provided involved alterations to text, images, and quizzes to increase the clarity.

In order to test the effectiveness of the tutorial volunteers were asked to classify lights in a given area, all were given the paper version of *Nachtlichter* but only half received the tutorial. After being exposed to the paper version of *Nachtlichter* and the tutorial, the volunteers were interviewed for their thoughts and experience. Volunteers were asked these seven questions: "What did you think of the tutorial? Did any parts of the tutorial confuse you? Did the tutorial help you understand the classifications? How long did it take you to classify lights? Do you feel confident in your ability to classify lights? Is there anything we can do to improve the tutorial?[2]" Feedback from the interviews was then used to improve the effectiveness of the tutorial. For new volunteers the most updated tutorial was given. The editing and feedback continued until a final version of the tutorial was complete. The final tutorial was transferred to GFZ and was made

[2] Survey Questions listed in the appendix H

available for citizen scientists use in GFZ’s app *Nachtlichter*. The app participants will be able to access the tutorial when they start the app to learn the light classifications.

4. Results and Analysis

Following the project methods yielded results showing an increase in confidence and a decrease in confusion for participants who viewed the tutorial prior to classifying lights. Initial surveys revealed the lights on the paper version of GFZ’s app *Nachtlichter*, resulted in some confusion and had a learning curve for participants to feel comfortable. The creation and testing of the tutorial with the paper version of *Nachtlichter* provided a good comparison showing the effectiveness of the tutorial. The tutorial **improved confidence** of participants, **decreased confusion**, and **increased accuracy** of light classification.

4.1 Challenges Using the *Nachlichter* App

The survey sent to citizen scientists who had previously used the paper version of *Nachtlichter* indicated areas for the tutorial to address. Twelve people have completed the survey and the responses indicate that the most confusing classifications include streetlights, path lights, lights mounted on buildings, lit house numbers, private windows, and string.

Figure 20

Light Type Difficulty Feedback Table

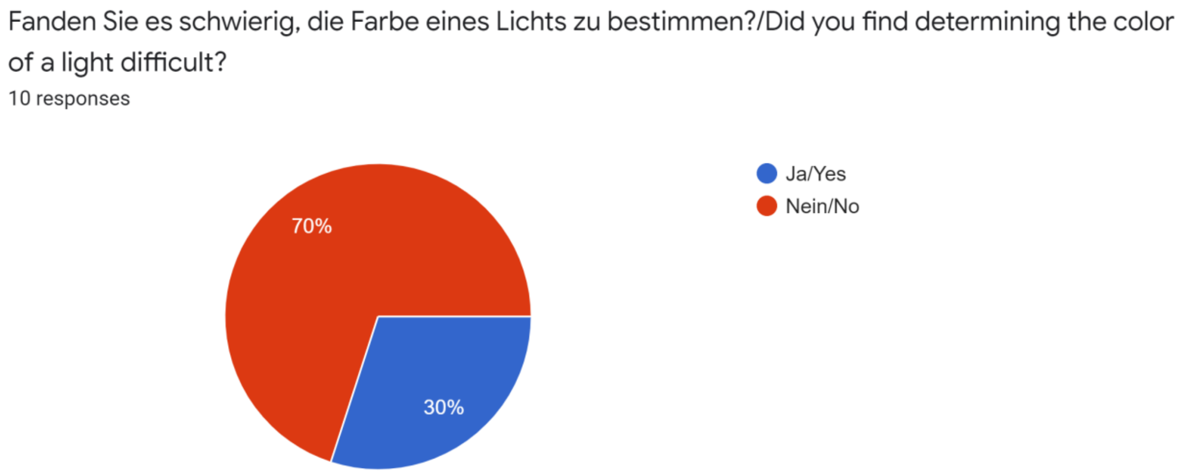
Type of Light	Votes
No trouble	1
Streetlights	1
Pathway Lights	2
Lights mounted on house	1
Lit house number	1
Private Windows	2
String Lights	1

Table of lights that citizen scientists stated to be difficult to classify

In addition to the light classifications that several had trouble with, ten of the respondents reported confusion when identifying the brightness and color of lights. The survey also included a section where individuals could submit a written response to clear up why they had confusion. The written feedback suggests it is common for participants to initially have some confusion, but as time progressed the participants found it easier to classify. Confusion was common with lights that appeared to fit into multiple classifications. Another area of confusion was determining the color and brightness of the lights. Some of the participants felt there should be a third option of dim to go along with the options of normal and bright. There was also confusion with brightness based on what color the lights are, the confusion stemmed from lights that were multicolored as there was no option for multiple colors. This feedback from the paper version of *Nachtlichter* has helped identify the common areas that cause confusion. This helped in developing better descriptions to help classify for the tutorial.

Figure 21

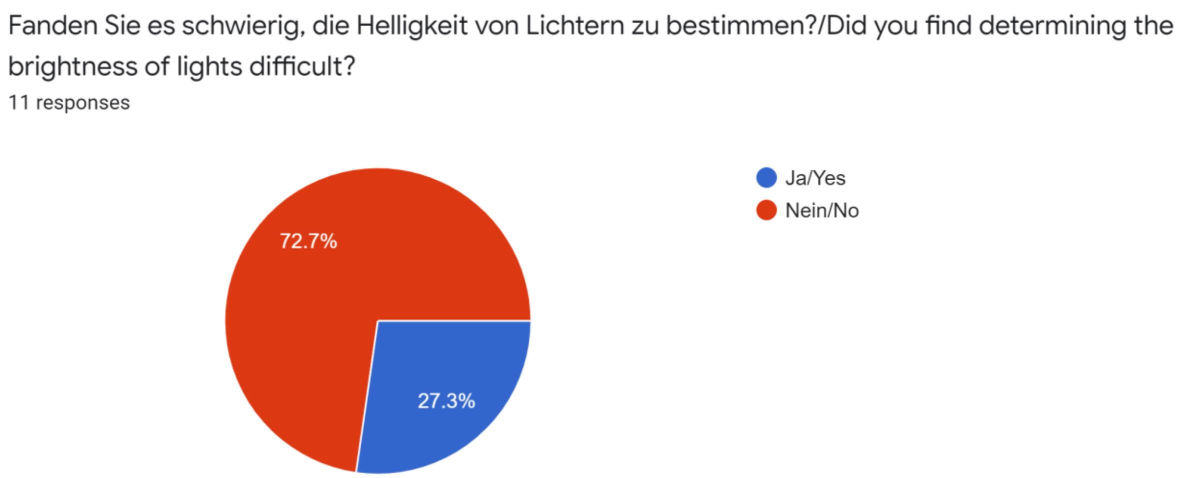
Color Classification Feedback Chart



Pie chart created by Google form from 10 responses on whether they found color of lights difficult to classify

Figure 22

Brightness Classification Feedback Chart



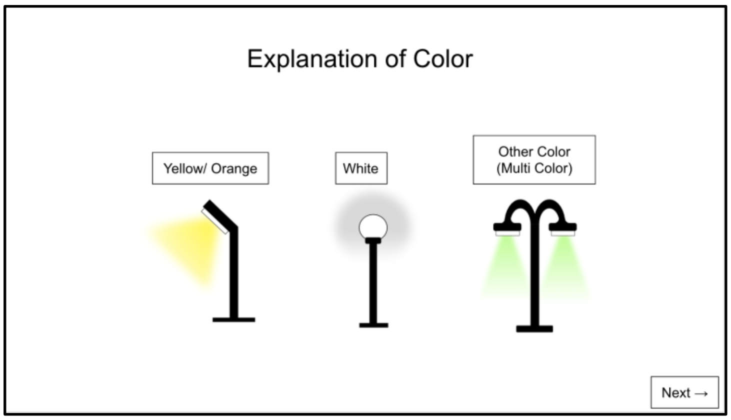
Pie chart created by Google form from 10 responses on whether they found brightness of lights difficult to classify

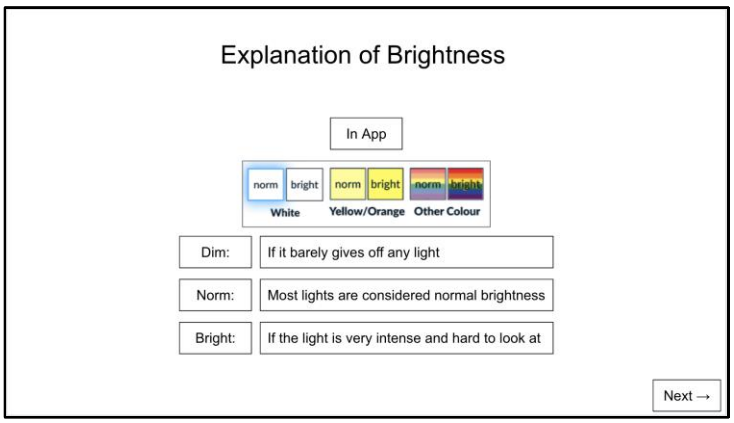
4.2 Framework of the Tutorial

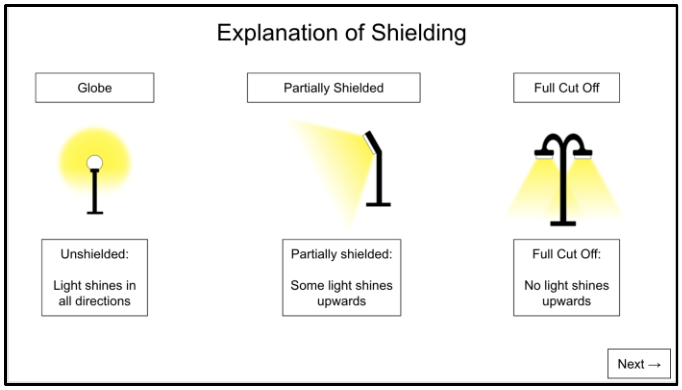
After the completion of objective one, we were able to take into account the information collected from the survey while structuring our outline of the tutorial. We began the framework with a few introduction slides. The goal for those slides was to introduce the tutorial and what the participants are about to go through. There was also an added motivational slide to ensure participants do not get overwhelmed and complete the tutorial. Next, we also added our first attempt at explaining the subcategories of lights. These include shielding, brightness, and color. Example screenshots of these slides are shown below. The framework in its entirety can be found in Appendix I.

Figure 23

Framework Subcategory Explanations





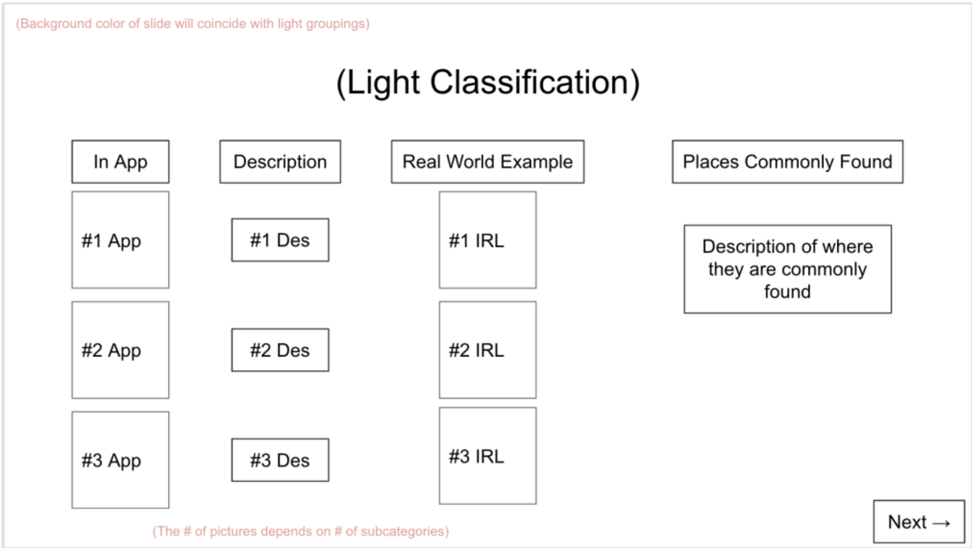


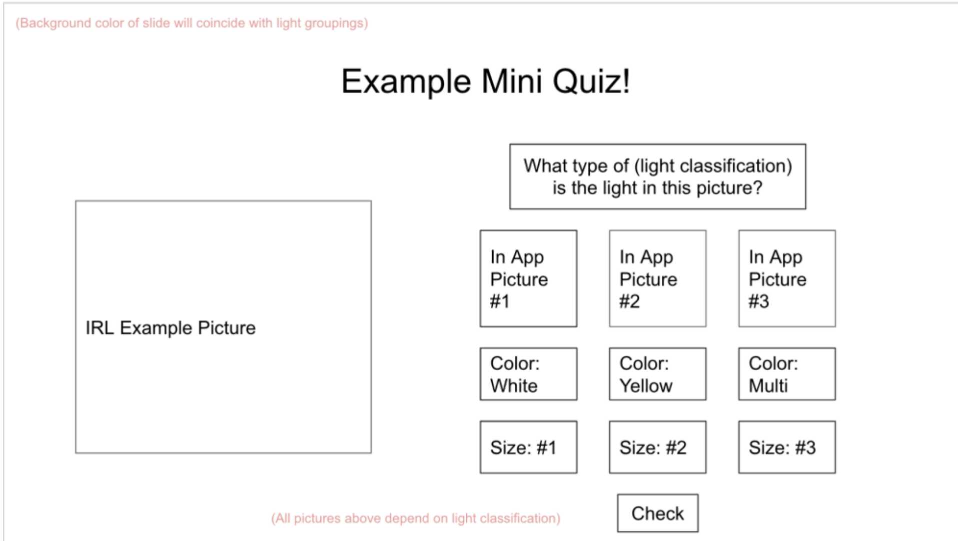
Our framework slides with explanations of color, brightness, and shielding

Following those explanations, we also created an outline of how the light categories will be presented in the tutorial as well as the quizzes that follow each light category. These outline slides can be found in the figure below.

Figure 24

Framework Light Category and Quiz Outlines





Outlines for the all quizzes and light categories from framework of tutorial

Once we established an outline for both the light categories and quizzes that we found to possess all needed information, we created a slide for each one of the 18 light categories with at least one quiz for each. This framework slideshow was our first iteration of the tutorial and acted as our base for our first round of feedback from our feedback loop in objective three.

4.3 Feedback to Make Improvements to Tutorial

This section discusses how the methods from objective three were completed. This includes the feedback loop that was created by sending citizen scientists iterations of our tutorial and testing the effectiveness of the tutorial with volunteers.

4.3.1 Citizen Scientists' Feedback on Tutorial Framework

The framework continued to get developed as we took the results from our first objective survey into consideration. Our next goal was to complete a version of the tutorial that possessed all the core information needed while ignoring the aesthetics for now. Once this version of the tutorial was completed, we decided to start asking citizen scientists for feedback. Our sponsors organized a meeting with seven citizen scientists with whom they meet every two weeks to discuss the app and classification of lights. During this meeting we were able to present our first iteration of the tutorial to seven citizen scientists. Many were surprised at the amount of work and effort that had been put into this tutorial already. Only two weeks ago they were dividing the 18 light categories into six different color groups and we have incorporated the order of these color groupings to be the logical flow of our tutorial. The figure below shows a table that we have designed to act as the table of contents. This table will also be used within the tutorial as a way for the participants to skip to certain light classifications that they need further help with after they have completed the tutorial.

Figure 25

Nachtlichter Table of Contents

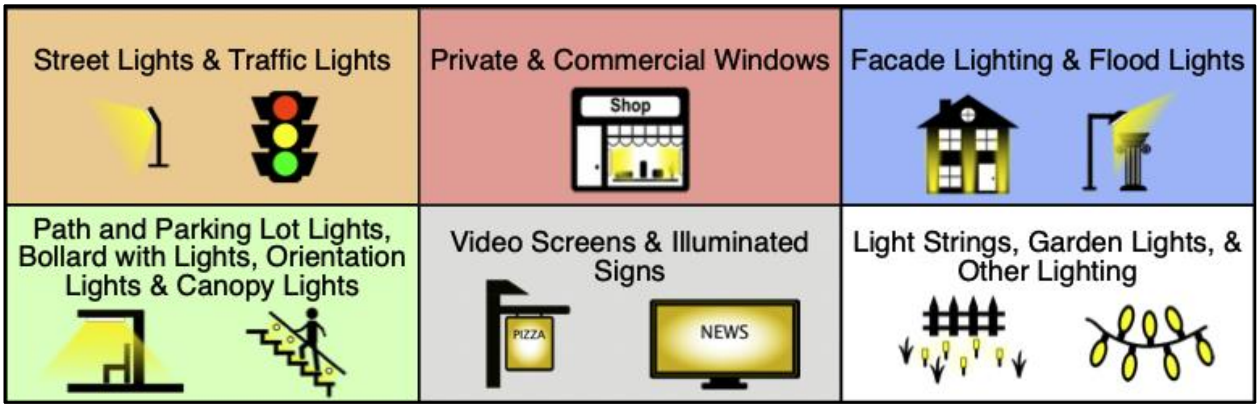
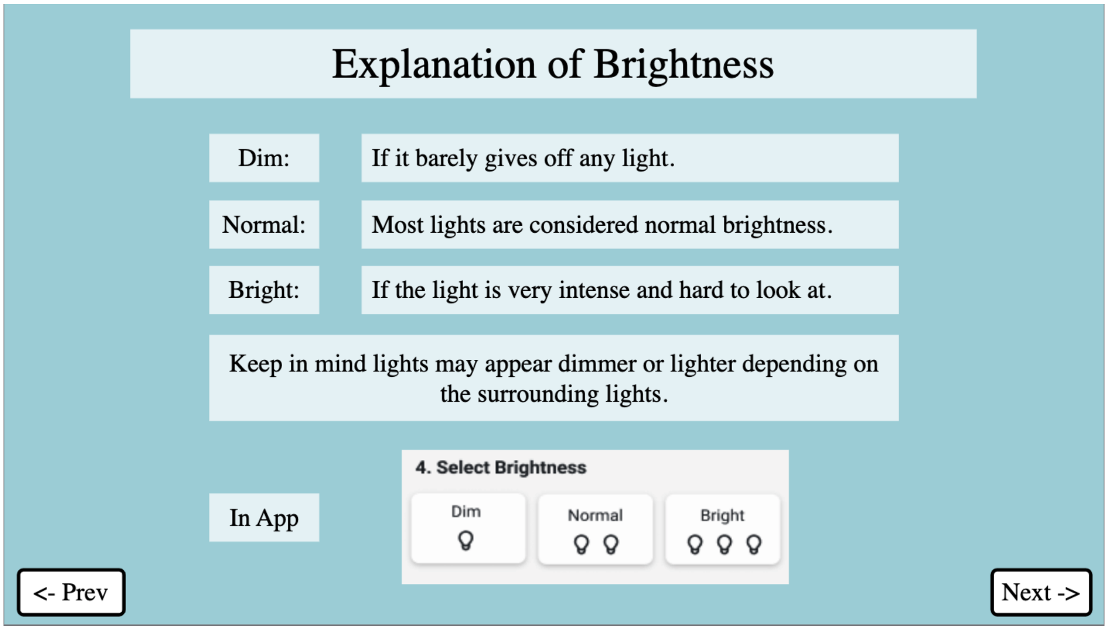


Table of Contents from Nachtlichter App Tutorial.

The citizen scientists also had a few opinions on what could be changed. One important topic of discussion was the way the brightness of lights was explained in the tutorial. When deciding the brightness of a light to be dim, normal, or very bright, it is important to take the surrounding lights into consideration. For example, if a building behind a street light is bright, the street light might seem like a normal brightness although it could also be labeled as very bright. The updated explanation of the brightness of lights is shown below, which includes a description to keep in mind the surrounding lights while classifying.

Figure 26

Explanation of Brightness

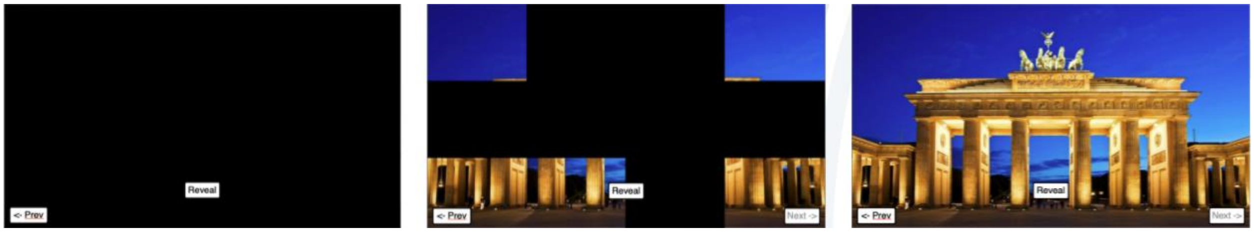


Explanation of Brightness in Nachtlichter App Tutorial.

A motivational piece to add to the tutorial was also discussed. The idea was to slowly reveal an interesting picture as the participant makes their way through the tutorial. The citizen scientists and our sponsors arrived at a final decision for the picture to be of a well-known German figure who will be standing under a light of some sort. The thought was to reveal pieces of the picture one by one as the participant makes their way through the tutorial. Using this picture will act as a motivational piece to help keep the participants entertained. Below are screenshots from the tutorial showing the progression of revealing the mystery image. The picture presented in the figure below is a placeholder, for GFZ has not submitted the official photo yet.

Figure 27

Nachtlichter Reveal Photo



Three screenshots of a random picture being revealed in the tutorial.

Although we did not focus on the aesthetics of the framework, we addressed the topic. A few citizen scientists commented on the background and advised us to make sure it is not too bright for participants. Taking this into consideration, most slides now have a calming color as its background to prevent any stress on the eyes of participants. This will prevent anyone's eyes from hurting during the duration of the tutorial. The question of having the tutorial available on mobile phone as well as the computer was also discussed. We came to the decision that we will attempt to make it available on the phone, yet we expect most participants to take the tutorial at home, where they will also create their account for the app.

At the end of the meeting, we came to an agreement to send weekly updates of our tutorial in the new software form. This will allow us to keep our sponsors updated on our progress and give them the ability to give us feedback weekly. The citizen scientists also agreed to meet with us again once we made more progress.

4.3.2 Citizen Scientists' Feedback on Tutorial Prototype

After our final edits to the basic framework, we were able to transfer all the information into the ActivePresenter8 software. Our goal for this iteration of the tutorial was to create a functioning tutorial including working buttons, quizzes, and all other interactive features we planned for in objective two. Once a working version of the interactive tutorial was completed, we scheduled another meeting with the same group of citizen scientists that gave us feedback on our framework.

4.3.3 Volunteer Classification Results

Volunteers were selected to test the effectiveness of the tutorial and provide feedback. The volunteers were college students primarily from Worcester Polytechnic Institute. The feedback from testing indicates that the tutorial is effective. The tutorial appears to be effective in different ways. From 14 volunteers, the seven who viewed the tutorial before beginning reported having **more confidence and less confusion** when they began; the **accuracy also improved** for counting and classifying lights. The volunteers who did not see the tutorial felt "overwhelmed" when they first began, having only the instruction to classify lights and the paper version of *Nachtlichter*. These participants reported taking time to understand how classifications worked and did not feel confident due to concerns and uncertainty with some of the classifications. The volunteers who viewed the tutorial before beginning had exposure to what classification would require of them as well as important information to help them classify lights. The tutorial exposure allowed these volunteers to feel prepared for classifying with the paper version of *Nachtlichter*, preventing the overwhelming feeling that volunteers without the tutorial described. One of the most telling results from the volunteer interactions was the effectiveness of improving data collection. The area being surveyed contained nine normal traffic lights and eight traffic lights for pedestrians for a total of seventeen. The volunteers who did not see the tutorial recorded total traffic lights at nine, presumably only counting the nine normal traffic lights. The tutorial notes that pedestrian lights count as individual lights. The volunteers who viewed the tutorial all reported seventeen traffic lights. This result indicates that by viewing the tutorial the volunteers were educated on light classifications resulting in more accurate data collection.

5. Conclusions and Recommendations

Light pollution is a problem that affects human health and the environment. Despite this, there are minimal regulations and laws for having too much lighting. While satellites collect data on light pollution, not all of it is accurate, and none of the data indicates what lights contribute the most to pollution. Trying to better understand light pollution, the German research institute GFZ is working with citizen scientists to classify and map lights in Berlin. GFZ developed a classification of lights and is developing an app so that anyone can become a citizen scientist and use the app to collect data. The concern is citizen scientists' understanding of the 18 classifications and subcategories of lights GFZ developed. In order to ensure the app participants, have the information needed to successfully classify lights, a tutorial was needed. Those who attempted to classify lights identified areas of confusion, which aided in creating an effective tutorial. Subsequently, this project team developed a framework for the tutorial containing many base features and ideas. With feedback from meetings and participants who tested the tutorial, the team made revisions that enhanced the effectiveness and clarity. The tutorial has proven to be an effective teaching tool and will be useful to provide a level of understanding to citizen scientists before they begin classifying lights. With a good understanding of light classification to allow accurate data collection, GFZ hopes to form a connection of the luminance readings from satellites to the number of lights at a specific location.

5.1 Recommendations

With GFZ's release date of *Nachtlichter* placed after the IQP completion, this team recommends giving GFZ full access to the tutorial, as further modifications will be necessary before its integration with the app. The tutorial should be transferred to GFZ along with instructions of editing in ActivePresenter8. These instructions were sent to our sponsors. Minor adjustments should be made to address any feedback being received. In addition, a major piece that will be required is the creation of a German copy of the tutorial. When the tutorial is finalized, it can be linked with *Nachlichter* and published to help citizen scientists before they begin classifying, or whenever a refresher is needed. We recommend that GFZ do the following.

5.1.1 Make Adjustments from Citizen Scientists Testing Tutorial

Regardless of the transition of the ownership of the tutorial to GFZ, the citizen scientists at GFZ should continue testing the tutorial. Feedback from these citizen scientists with suggestions on how to improve the tutorial should continue to be collected. This information was proven to be very useful in the producing faze of the tutorial. At the moment *Nachtlichter* is still in development and alterations are being made to some logos and images. This requires adjustments in the future to include updated logos and screenshots to match what is in *Nachtlichter*.

5.1.2 Translate the Tutorial to German

All citizen scientists that we have been in contact with from GFZ's *Nachlicht Buhne* campaign speak German. Only a few of them are proficient enough in English to understand the entirety of the tutorial. Therefore, we recommend creating another version of the tutorial in their native language to maximize their learning. We recommend GFZ to translate the current English version to a German copy and make both versions available when *Nachtlichter* redirects its participants to them. Because of the interactive features added in ActivePresenter 8 while producing the tutorial, there aren't any existing functions in the application itself to auto-translate all content without undoing the interactive elements. Hence, we recommend translating the tutorial manually.

5.1.3 Directly Link the Tutorial with the App *Nachtlicher*

When all changes have been made to the tutorial and *Nachtlichter* is available, the tutorial should be linked in the app. The tutorial itself should be hosted along with the *Nachtlicht BüHNE* project information. *Nachtlichter* can then have a direct link to the tutorial so anyone using the app can go directly to the tutorial.

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APPENDICES

A. Sponsor Description

The GeoForschungsZentrum (GFZ) was officially founded in Potsdam on January 1st 1992 as Germany's national research center for all geosciences. The geoscience roots precede the foundation of the company, as Potsdam was home to several research institutions.

The current vision of GFZ is the firm belief that a thorough, geoscientific understanding of the interaction between the Earth environment and human activities is key to developing solutions to natural risk and hazard management. This holds true both on the level of global changes and regional impacts. That being said, the mission of GFZ is to use their expert knowledge in geosciences to help realizing such a vision. The main challenge ahead of its mission is devising solutions to maintain environmental sustainability in human development in the midst of climate change. To this end, GFZ has undertaken many different research projects all across the globe.

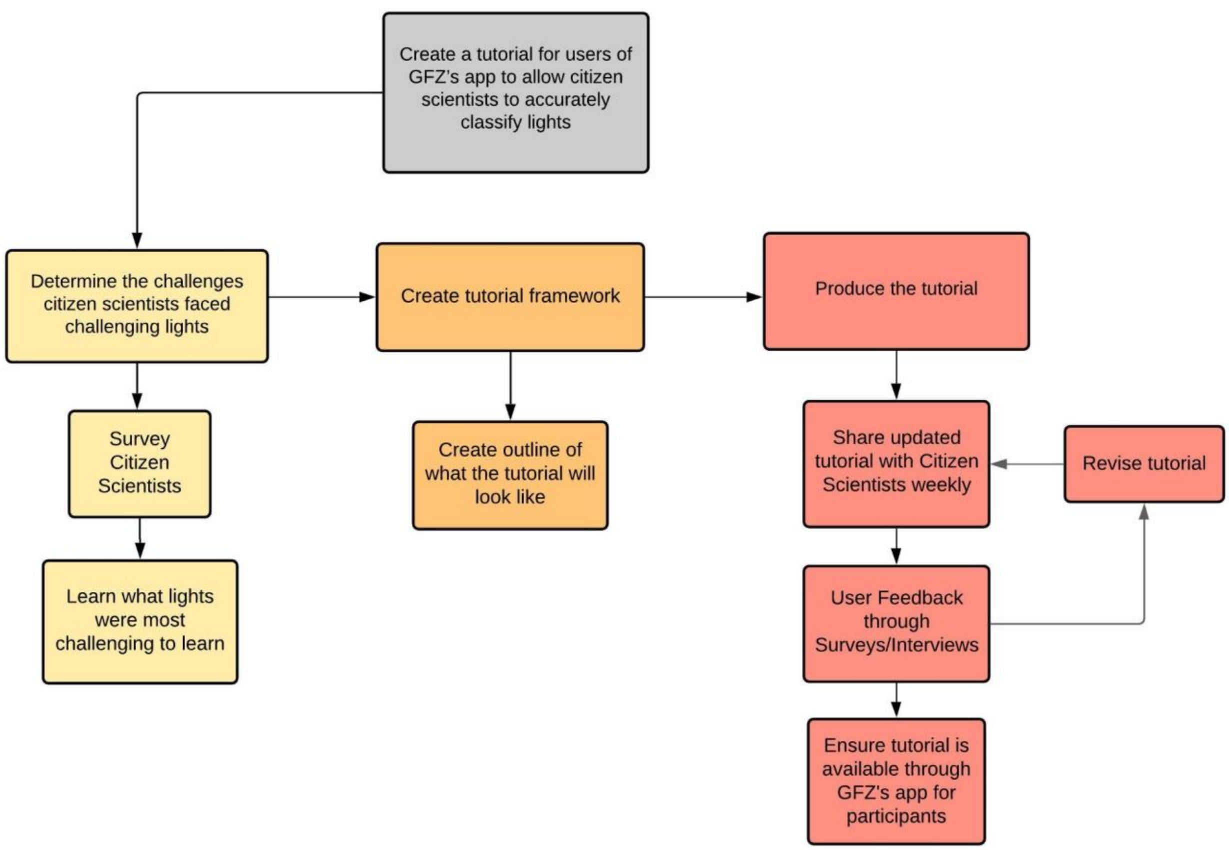
Among many of its projects, GFZ has helped launch multiple satellites into space for geoscientific surveying, led the International Continental Drilling Program (ICDP), developed early warning systems for natural disasters, and inaugurated new buildings and labs. The organization's employees are spread among four different departments: geodesy, geophysics, geochemistry, and geosystems. Across each of these departments, there are 1291 total employees. Through the quality of work, research, projects, as well as the number of employees the 2020 budget for GFZ was 95 million euros. The funding that makes up the budget was 30 million euros from third party investors, and a total of 65 million euros from BMBF and MWFK Brandenburg groups.

One of the research sections within the geodesy department is the Remote Sensing and Geoinformatics. This section will be the one that works with this IQP project group. Led by professor Dr. Doris Dransch, the major research activity this section carries out is developing methods to process large sets of data from sensor measurements and model simulations, in order to extract valuable information that would help yield solutions to a problem. In fact, most of the section's source of data comes from satellite imagings. That said, it often works closely with the European Space Agency (ESA) and other similar organizations worldwide. It also has its own infrastructures, including a spectroscopy laboratory, a fleet of 10 unmanned aerial vehicles (UAVs), as well as an agricultural meteorology monitoring network. In the past year of 2020, the section has initiated three new projects: the scientific preparation and support of the hyperspectral satellite mission EnMAP, development of a satellite simulation system for the Copernicus Hyperspectral Imaging Mission for the Environment (CHIME), and the Tectonics and Volcanoes in South America with InSAR. As a national research institute, the data collected will be available to the public. It offers services in consulting technological development in products that employ remote sensing, developing an online learning platform for hyperspectral remote sensing, and creating a web platform for the general public to analyze Earth's night light emissions. Their work has caught the eye of many universities across the globe as well with whom they have established 49 total professorships as of April of 2020. Some examples include University of Johannesburg, South Africa and China University of Geosciences, Wuhan.

Following GFZ's core belief, this IQP project's main goal is to develop an online training platform in order to teach people about night-time artificial light sources and their effects on human health and the surrounding environment. The motive arose from the lack of outdoor mappings for commercial, private and public lighting. By introducing this online training platform, the general public will not only be able to better understand the harmful effects that artificial light could have on their life, but also help organizations like GFZ gather information and statistics on how much artificial light is being emitted. Through the program on the app, one is expected to be able to classify light sources more accurately, and therefore becomes a more reliable source of surveying. All the information on such an application regarding urban light sources will be stored in databases, which are used by GFZ to determine a more specific outdoor lighting map in order to assess light pollution, as well as to test the efficiency of this training platform.

B. Project Schedule Charts

Tasks	March 22	March 29	April 5	April 12	April 19	April 26	May 3	May 10
Interview Citizen Scientists								
Create Mock Tutorial								
Test and Receive Feedback from Tutorial								
Edit Tutorial								
Establish Final Tutorial								



C. GFZ's Mobile App Prototype

The prototype can be explored via the following link:
https://www.figma.com/proto/wbByai0oCkb5XqdjK5c26H/Prototypes?node-id=234%3A32555&viewport=779%2C1025%2C0.11420705914497375&scaling=scale-down

D. GFZ's Paper Version Trial

ID			
Date of Observation		City	Street
Time Start (local time):			Coordinates start
Time End (local time):			Coordinates end
Street lights are below trees, lower than buildings or other objects?			
Traffic: How many vehicles pass by during the observation? (A) less than 2 (B) about 1 vehicle/minute (C) several vehicles/minute (D) nearly continuous traffic	A, B, C or D		
Traffic lights (red+yellow+green=1 traffic light)			

PLEASE count the numbers of illuminated objects (tally)
For lit areas, the object can be made out of several parts of one category, e.g. illuminated sign recorded as 2 times a small light source

		white normal	white BRIGHT	yellow/orange normal	yellow/orange BRIGHT	other colour normal	other colour BRIGHT
Street lighting	**Not Shielded Globe style light** shining in all directions						
	Partly shielded some light still shines upward						
	full cut off only shining downwards						
Path lighting, Lit parking lots same lamp types as street lighting, the difference of these two categories is the use	**Globe style light** shining in all directions						
	Partly Shielded some light still shines upward						
	Full Cut Off only shining downwards						
Bollards							
Orientation Lights Dimm Ground Lights, Decorative, Path Lighting							
Outdoor lights mounted on buildings on the house wall (e.g. door entrance)	**Not Shielded** shining upwards						
	Partly shielded some light still shines upward						
	Full Cut Off only shining downwards						
Lit House Number, Door bells							
Canopy Lighting under a roof e.g. covered house entrance lit area of gas station, bus shelter etc.							
ID			Date				

Category	Size	white normal	white BRIGHT	yellow/orange normal	yellow/orange BRIGHT	other colour normal	other colour BRIGHT
Facade Lighting without visible lamps (If lamps are not visible or not countable, please estimate the lit area. If you can see the lamps, use flood lights below.)	**small** size of a person						
	middle Size of a one story house						
	large Larger than one story house						
Flood lights (stadium, church, security lighting…)	Shining **upwards**						
	Shining **sideways**						
	Shining **downwards**						
Windows residential, commercial, glass door etc.	size of a person (2m²) (**please** count ALL lit windows you can see, even if it is a high-rise apartment)						
Windows (Commercial) Shop	size of 4-6 people (8-12m²) (even if you can see the individual lamps, signs, or video screens inside, count this as a window)						
Video screens Outdoors	**small** size of a Laptop screen						
	middle Size of big screen TV						
	large size of a person						
	extreme extreme size						
	ID			**Date**			

		white normal	white BRIGHT	yellow/orange normal	yellow/orange BRIGHT	other colour normal	other colour BRIGHT
Illuminated signs with exterior lights one or more lights placed e.g. on the top, bottom, close vicinity illuminates the face of the sign	**small** size of a Laptop screen						
	middle Size of big screen TV						
	large size of a person						
	extreme extreme size						
Self-luminous signs with interior lights (No lamp visible, light source inside sign)	**small** size of a Laptop screen						
	middle Size of big screen TV						
	large size of a person						
	extreme extreme size						

		white normal	yellow/ orange normal	other colour normal
Light strings chains of lights	length of a person (= 2 meter)			

	normal	BRIGHT
Garden decoration lights		

		white normal	white BRIGHT	yellow/orange normal	yellow/orange BRIGHT	other colour normal	other colour BRIGHT
other Light Sources	**small** size of hand						
	middle about the size of an outstretched arm length						
	large size of a person						
	extreme extreme size						

NACHTLICHT BÜHNE

Comments

E. European Union Green Public Procurement Criteria for Road Lighting and Traffic Signals (GPP)

A pdf document is linked below from the "A Guide to the green public procurement of road lighting" from December 2018. In this document they express their research and potential plan to reduce light pollution.

https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/contentype/product_group_documents/1581682046/190320_Road_lighting_guidance_email.pdf

F. Germany, Italy and Slovenia's Low Impact Lighting (LIL)

1. Energy Consumption

    Lighting installation can only be qualified as Low Impact Lighting (LIL) if the target energy consumption in a given municipality per capita per year is lower than 15 kWh. This target value includes all losses on cables and also includes all outdoor public illumination (also facade illumination).

2. Blue-Light Content

    Correlated Colour Temperature (CCT) of all luminaires must be equal or lower than 2200 K AND must emit under 500 nm energy flux lower than 6% of the total emitted in the entire visible range. In case of an average illumination level below 5 lx it is allowed to use luminaires with CCT from 2200 K up to 2700 K AND energy flux must be lower than 10% of the total emitted in the entire visible range under 500 nm.

3. Upward Light Output Ratio

    The Upward Light Output Ratio (ULOR) of a luminaire must be 0.0%. This needs to be valid during the whole lifetime of the luminaire and also when the luminaire is dirty.

4. Prohibitive Rules

    It is not allowed to illuminate highways and motorways, including their exits and junctions, roads allowed for motorized traffic only, roads outside settlements, junctions and roundabouts outside settlements.

5. Pole Distance

The distance between poles must be at least 3.7 times greater than the pole height.

6. Maximum Luminance

The luminance of the main roads in cities and towns is not allowed to exceed 0.5 cd/m2.

7. Curfew

For all luminaires there must be implemented a curfew (reduction of power and lumen output in late hours, i.e. outside peak traffic hours) from 100% down to 10% or less in case of adaptive lighting systems, or at least 50% reduction in absence of adaptive lighting.

8. Standards

EN 13201 or national standards which are adopted from EN 13201 must not be implemented.

9. Lifetime

The Lifetime (MTBF-mean time between failure) of luminaires must be at least 100.000 hours or 25 years.

10. Luminaire Efficacy

The minimum efficacy of a luminaire at full power needs to be at least:

luminaire below 1900K (like amber)	50 lm/W
luminaire below 2200K (like pc-amber)	95 lm/W
luminaire between 2200K and 2700K	100 lm/W

A lower luminaire efficacy is allowed when the pole-distance: pole-height ratio exceeds 6:1 or when a mechanical shielding is necessary in order to reduce unwanted illumination of nearby houses or natural environment.

11. Illumination Utilisation Factor

At least 70 % of the lumen output must target the road/street/walking area. Lower utilisation factor down to 40 % is allowed in following cases:

narrow paved bicycle path

narrow paved pedestrian path

12. Protection of People

To secure the basic human right to sleep in a dark environment, which is important for good sleep, the maximum allowed illumination on windows after 22:00 o'clock (standard time) is:

0.01 lx when window is at least 20 m from illuminated public place

0.02 lx when window is at least 10 m from illuminated public place

0.05 lx when window is at least 5 m from illuminated public place

0.10 lx when window is at least 2 m from illuminated public place

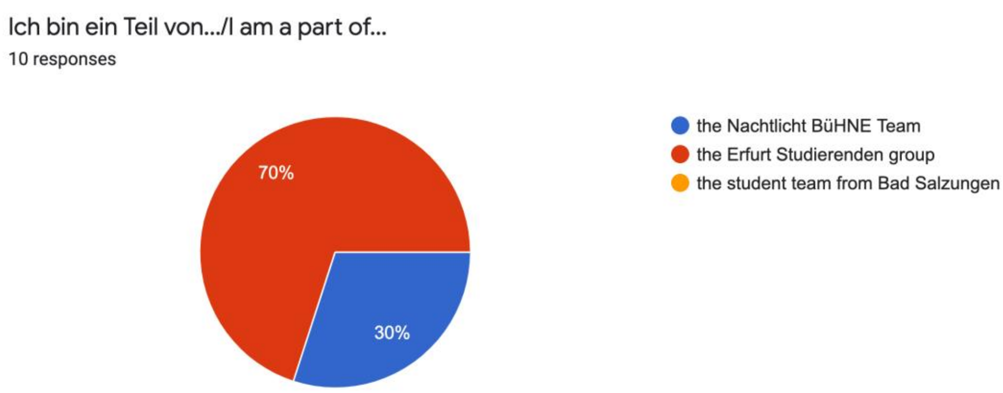
0.50 lx when window is less than 2 m from illuminated public place

Parking places on highways and other roads which are used for car drivers and truck drivers and where drivers may sleep in their vehicles may be illuminated but with the following limitations:

CCT must be below 2200 K

Illumination levels must be below 1 lx

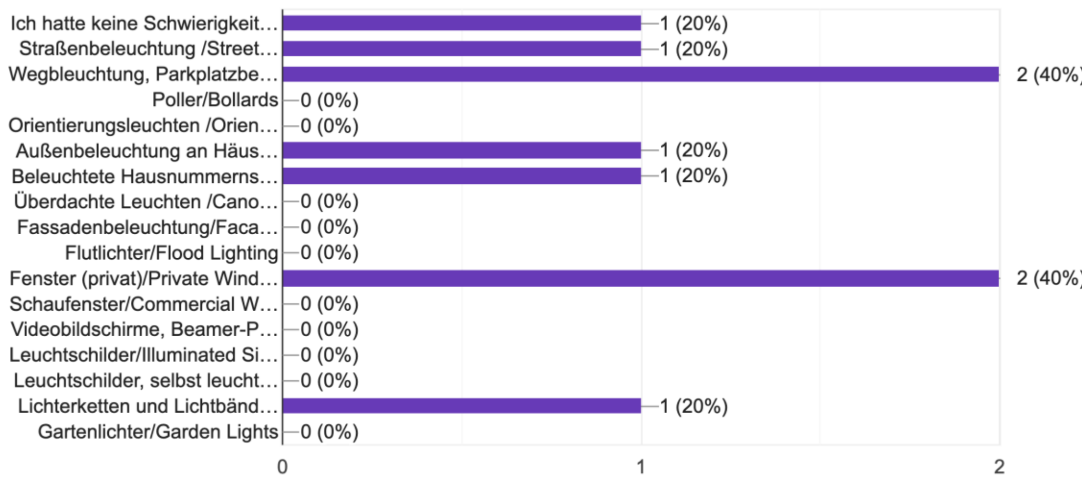
G. Survey of GFZ's Light classification for WPI Students (Results)



i.

Gab es Lichter, die Sie nicht klassifizieren konnten?/Were there any lights that you had trouble classifying?

5 responses



ii.

Wenn ja, was war schwierig an der Klassifizierung der Lichter?/If yes to any, what was hard about classifying the lights?

5 responses

Straßenbeleuchtung von Fußgängerüberwegen (Zebrastreifen) da es ein selbstleuchtendes Licht ist (leuchtet in zwei Richtungen, um für Autofahrer erkennbar zu sein), leuchtet aber orange auf den Zebrastreifen nach unten

Die Länge der Lichterketten und deren Helligkeit, bei Privaten Fenstern die Bestimmung der Helligkeit

Unsicherheiten, ob sehr geringe Lichtintensitäten (beispielweise Lichtabstrahlungen an Fensterrollläden vorbei) mit registriert werden

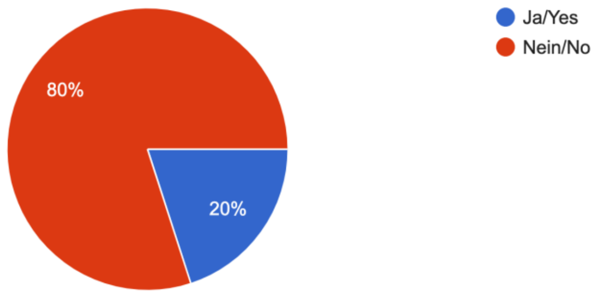
sometimes the lights were hard to identify specifically, since the direction was not clearly visible.

Sometimes the lamps seem to fit Into two categories. Mike mounted on wall and canopied for a lamp with a small roof above IT.

iii.

Fanden Sie es schwierig, die Helligkeit von Lichtern zu bestimmen?/Did you find determining the brightness of lights difficult?

10 responses



iv.

Wenn ja, wie schwer war es, die Helligkeit der Lichter zu bestimmen?/If yes, what was hard about determining the brightness of the lights?

3 responses

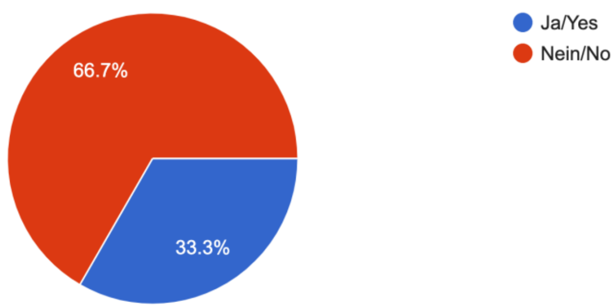
Die Differenzierung - eine Option "schwaches" Licht würde helfen.

Es war lediglich zu Beginn etwas schwierig. Aber später haben wir uns reingefunden und dann war es sehr leicht.

v.

Fanden Sie es schwierig, die Farbe eines Lichts zu bestimmen?/Did you find determining the color of a light difficult?

9 responses



vi.

Wenn ja, wie schwer war es, die Farbe der Lichter zu bestimmen?/If yes, what was hard about determining the color of the lights?

5 responses

Manchmal war es schwierig, festzulegen, ob ein Fenster noch als "weiß" oder schon als "gelblich" zählt. Das war aber auch eher selten der Fall.

Bei Licht, was von einem Fernseher o.ä. ausgeht

Auch hier war es nur zu Beginn etwas uneindeutig, aber dann haben wir die Unterschiede besser erkannt :)

//

Sometimes Light Was mulitcoulor. Mike Red, blue and White in one Single lamp

vii.

H. Survey Questions for Tutorial Testing Volunteers

Tutorial:

What did you think of the tutorial?

Did any parts of the tutorial confuse you?

Did the tutorial help you understand the classifications?

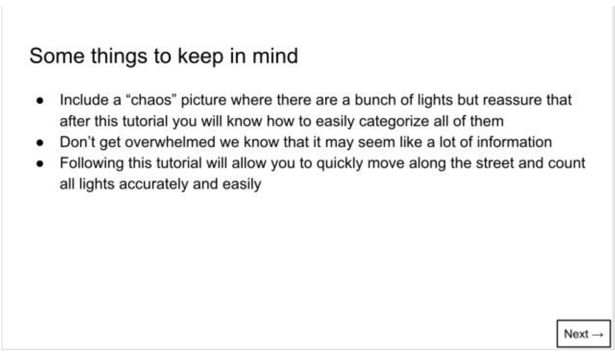
How long did it take you to classify lights?

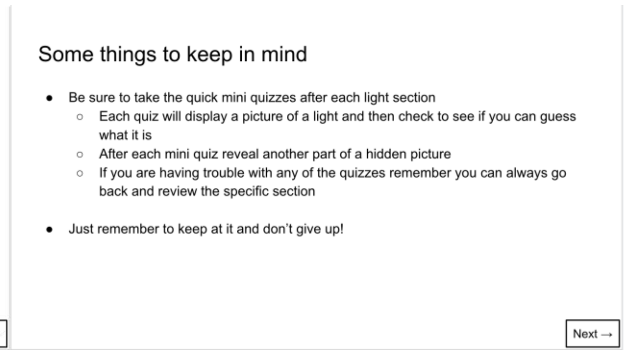
Do you feel confident in your ability to classify lights?

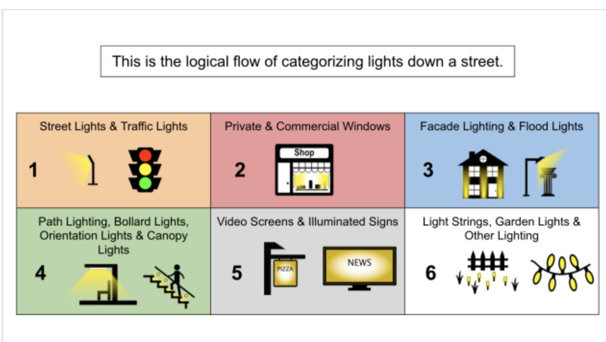
Is there anything you would change about the tutorial?

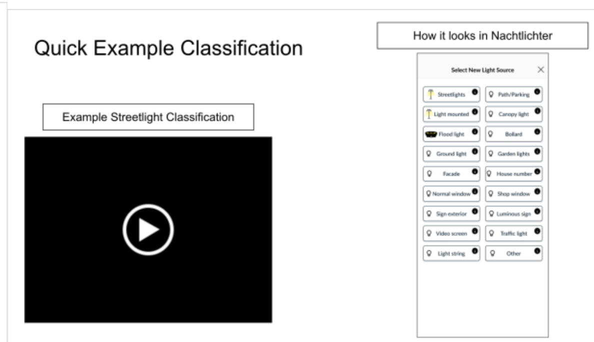
How long did it take you to get through?

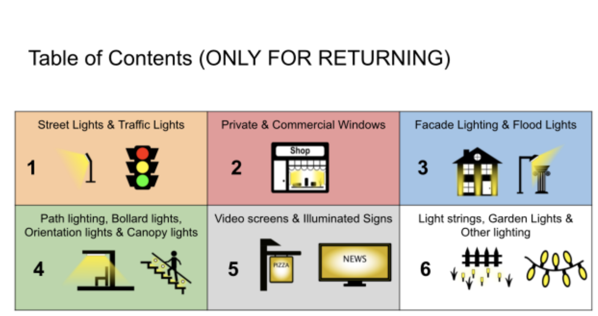
I. Framework of Tutorial

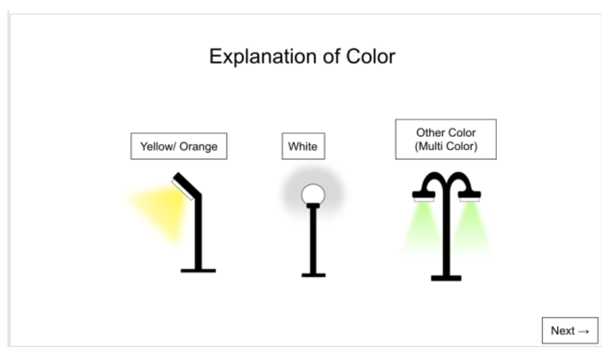


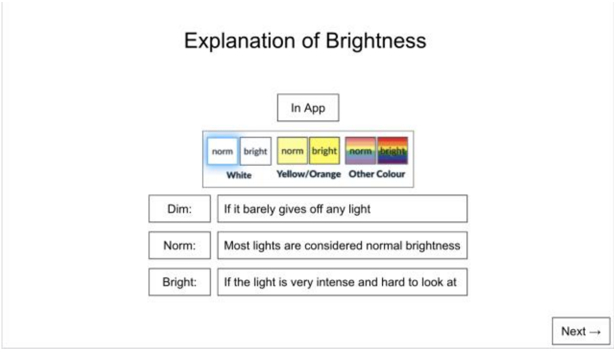


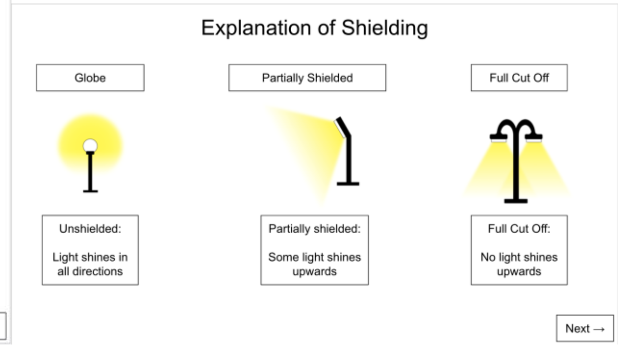




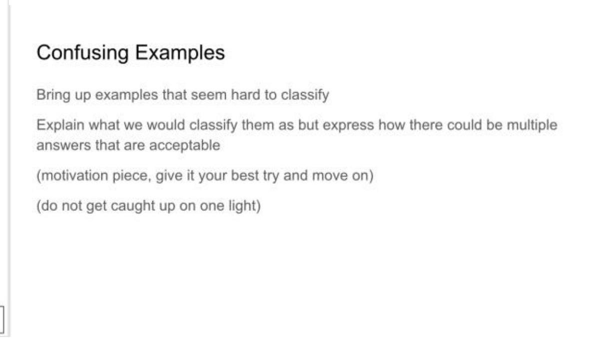




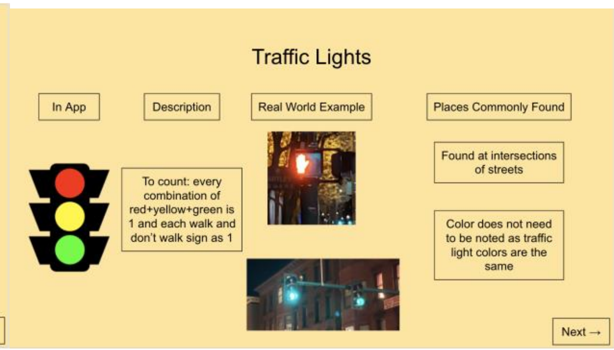

Explanation of Brightness
In App
norm
bright
norm
bright
norm
bright
White
Yellow/Orange
Other Colour
Dim:
If it barely gives off any light
Norm:
Most lights are considered normal brightness
Bright:
If the light is very intense and hard to look at
Next →

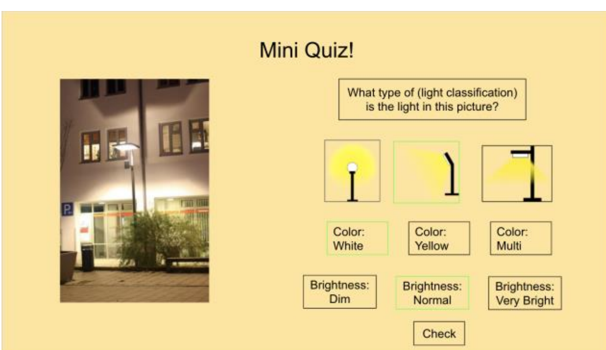

Explanation of Shielding
Globe
Partially Shielded
Full Cut Off
Unshielded:
Light shines in all directions
Partially shielded:
Some light shines upwards
Full Cut Off:
No light shines upwards
Next →

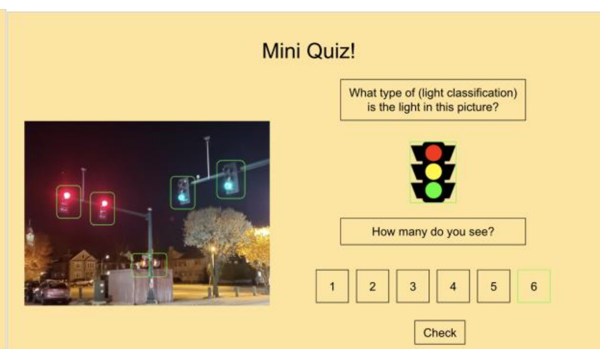

Explanation of Size for Streetlights
In App
Taller:
Lights are higher than buildings & trees
Shorter:
Lights are shorter than buildings & trees
Streetlights Taller
Streetlights Shorter
Next →

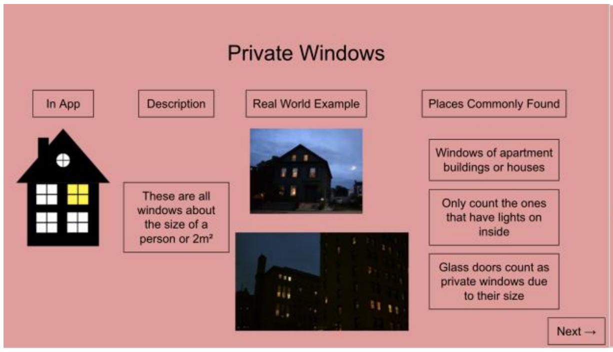

Confusing Examples
Bring up examples that seem hard to classify
Explain what we would classify them as but express how there could be multiple answers that are acceptable
(motivation piece, give it your best try and move on)
(do not get caught up on one light)

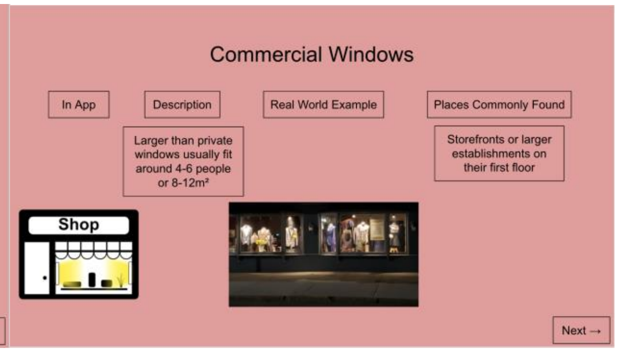

Street Lights
In App
Description
Real World Example
Places Commonly Found
Globe Style
Partially shielded
Full cut off
Commonly found in the median or next to the street
Next →

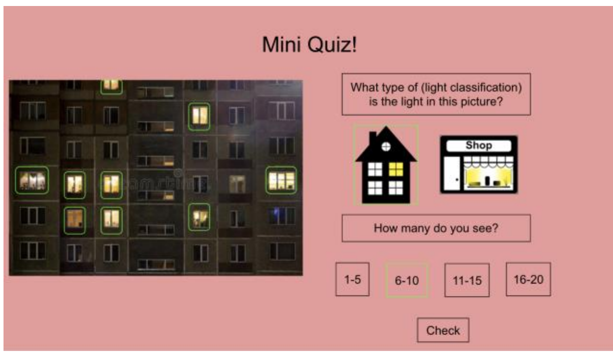

Traffic Lights
In App
Description
Real World Example
Places Commonly Found
To count: every combination of red+yellow+green is 1 and each walk and don't walk sign as 1
Found at intersections of streets
Color does not need to be noted as traffic light colors are the same
Next →

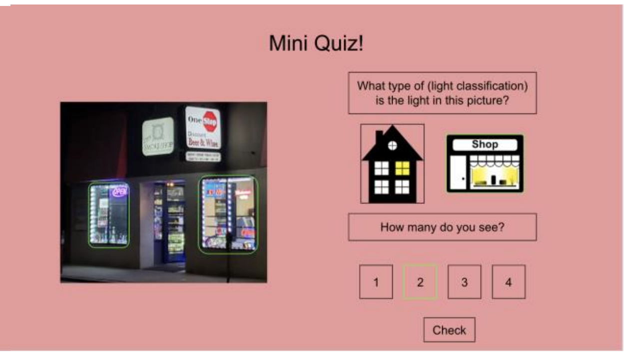

Mini Quiz!
What type of (light classification) is the light in this picture?
Color: White
Color: Yellow
Color: Multi
Brightness: Dim
Brightness: Normal
Brightness: Very Bright
Check

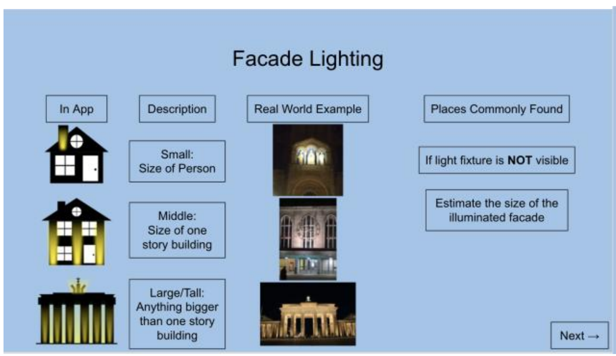

Mini Quiz!
What type of (light classification) is the light in this picture?
How many do you see?
1
2
3
4
5
6
Check

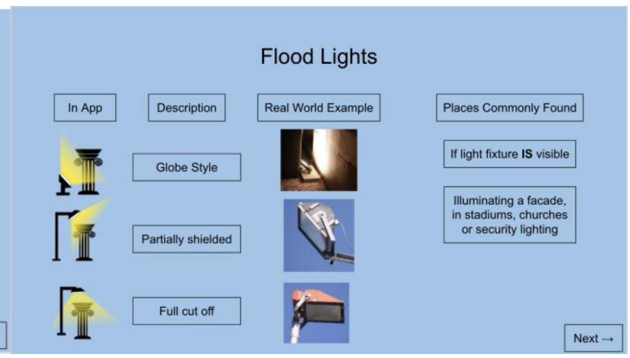

Private Windows
In App
Description
Real World Example
Places Commonly Found
These are all windows about the size of a person or 2m²
Windows of apartment buildings or houses
Only count the ones that have lights on inside
Glass doors count as private windows due to their size
Next →

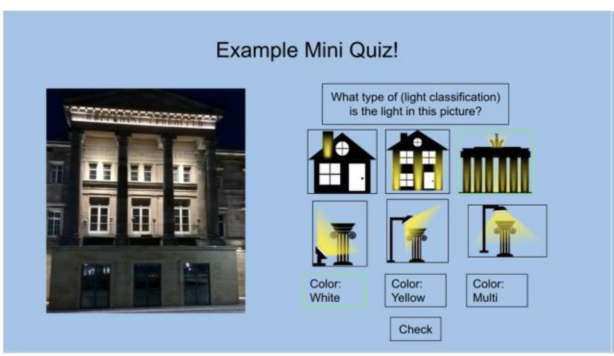

Commercial Windows
In App
Description
Real World Example
Places Commonly Found
Larger than private windows usually fit around 4-6 people or 8-12m²
Storefronts or larger establishments on their first floor
Shop
Next →

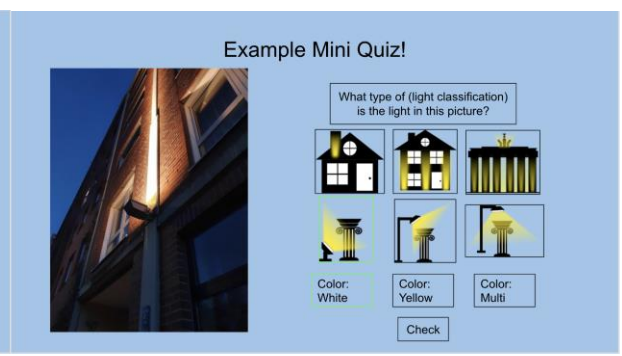

Mini Quiz!
What type of (light classification) is the light in this picture?
Shop
How many do you see?
1-5
6-10
11-15
16-20
Check

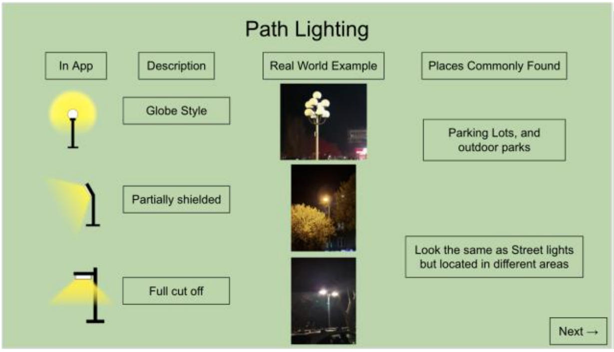

Mini Quiz!
What type of (light classification) is the light in this picture?
Shop
How many do you see?
1
2
3
4
Check

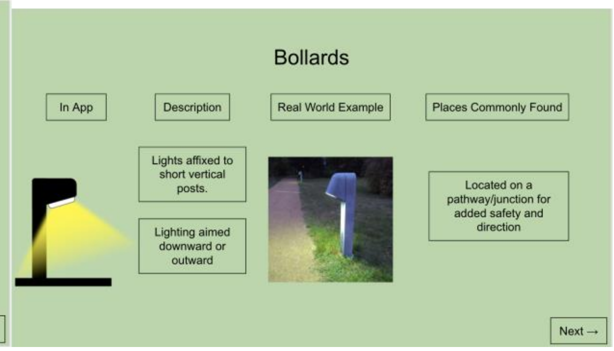

Facade Lighting
In App
Description
Real World Example
Places Commonly Found
Small: Size of Person
Middle: Size of one story building
Large/Tall: Anything bigger than one story building
If light fixture is NOT visible
Estimate the size of the illuminated facade
Next →

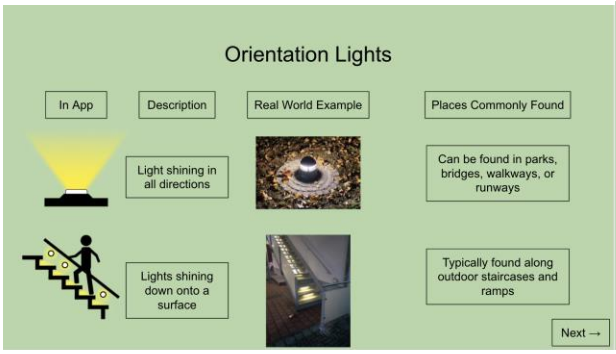

Flood Lights
In App
Description
Real World Example
Places Commonly Found
Globe Style
Partially shielded
Full cut off
If light fixture IS visible
Illuminating a facade, in stadiums, churches or security lighting
Next →

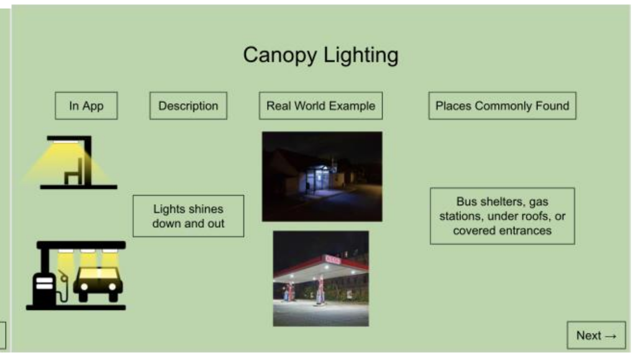

Example Mini Quiz!
What type of (light classification) is the light in this picture?
Color: White
Color: Yellow
Color: Multi
Check

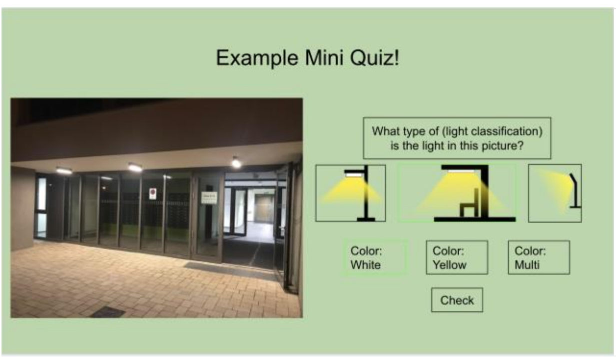

Example Mini Quiz!
What type of (light classification) is the light in this picture?
Color: White
Color: Yellow
Color: Multi
Check

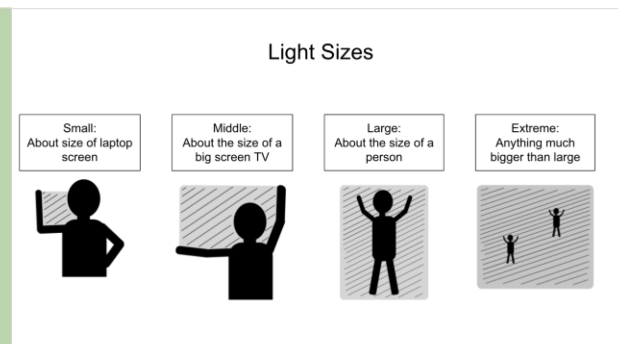

Path Lighting
In App
Description
Real World Example
Places Commonly Found
Globe Style
Parking Lots, and outdoor parks
Partially shielded
Look the same as Street lights but located in different areas
Full cut off
Next →

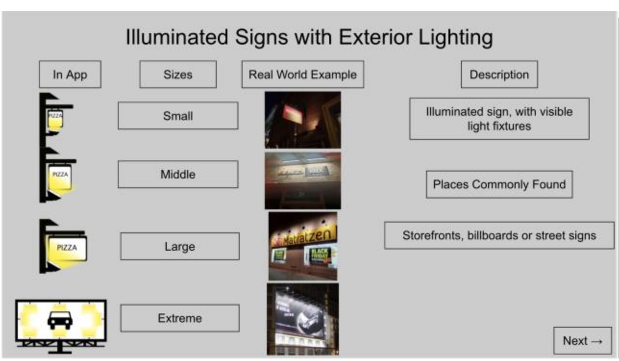

Bollards
In App
Description
Real World Example
Places Commonly Found
Lights affixed to short vertical posts.
Lighting aimed downward or outward
Located on a pathway/junction for added safety and direction
Next →

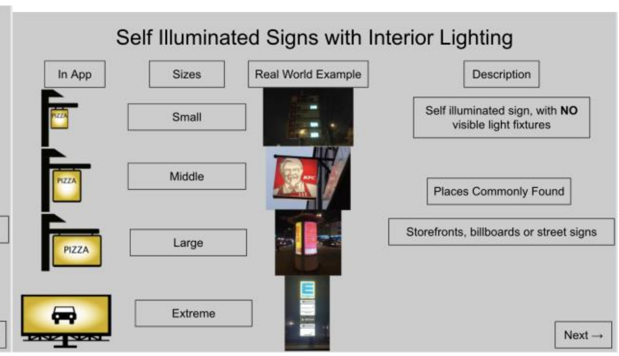

Orientation Lights
In App
Description
Real World Example
Places Commonly Found
Light shining in all directions
Can be found in parks, bridges, walkways, or runways
Lights shining down onto a surface
Typically found along outdoor staircases and ramps
Next →

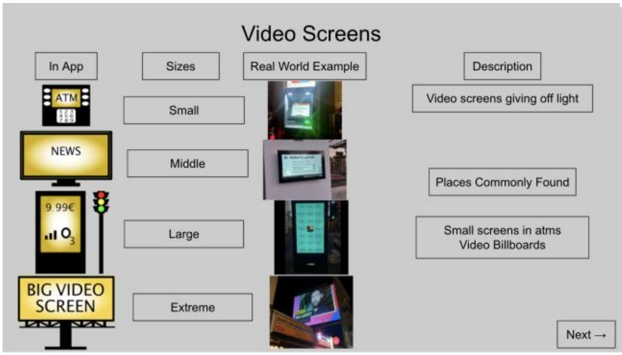

Canopy Lighting
In App
Description
Real World Example
Places Commonly Found
Lights shines down and out
Bus shelters, gas stations, under roofs, or covered entrances
Next →


Example Mini Quiz!
What type of (light classification) is the light in this picture?
Color: White
Color: Yellow
Color: Multi
Check


Light Sizes
Small: About size of laptop screen
Middle: About the size of a big screen TV
Large: About the size of a person
Extreme: Anything much bigger than large


Illuminated Signs with Exterior Lighting
In App
Sizes
Real World Example
Description
Small
Illuminated sign, with visible light fixtures
Middle
Places Commonly Found
Large
Storefronts, billboards or street signs
Extreme
Next →

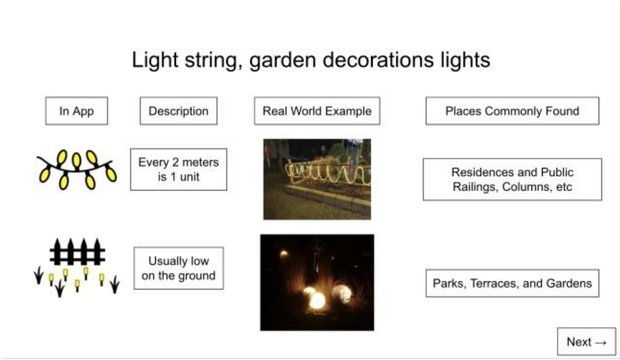

Self Illuminated Signs with Interior Lighting
In App
Sizes
Real World Example
Description
Small
Self illuminated sign, with NO visible light fixtures
Middle
Places Commonly Found
Large
Storefronts, billboards or street signs
Extreme
Next →

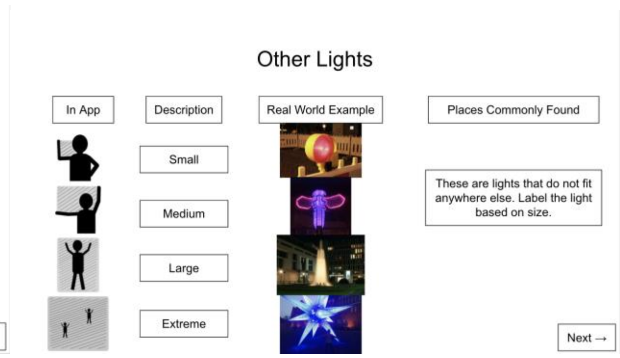

Video Screens
In App
Sizes
Real World Example
Description
Small
Middle
Large
Extreme
Video screens giving off light
Places Commonly Found
Small screens in atms
Video Billboards
ATM
NEWS
BIG VIDEO SCREEN
Next →

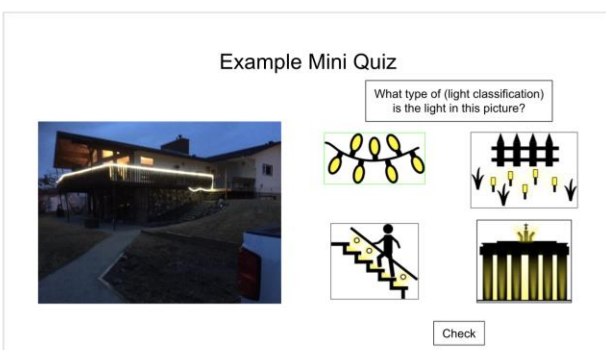

Example Mini Quiz!
What type of (light classification) is the light in this picture?
PIZZA
ATM
NEWS
BIG VIDEO SCREEN
Check

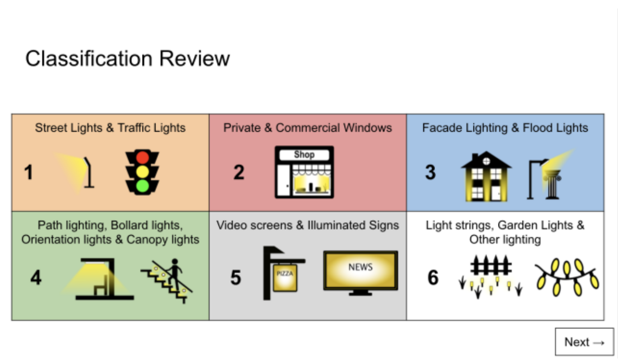

Example Mini Quiz!
What type of (light classification) is the light in this picture?
PIZZA
ATM
NEWS
BIG VIDEO SCREEN
Check


Example Mini Quiz!
What type of (light classification) is the light in this picture?
PIZZA
ATM
NEWS
BIG VIDEO SCREEN
Check


Light string, garden decorations lights
In App
Description
Real World Example
Places Commonly Found
Every 2 meters is 1 unit
Residences and Public Railings, Columns, etc
Usually low on the ground
Parks, Terraces, and Gardens
Next →


Other Lights
In App
Description
Real World Example
Places Commonly Found
Small
Medium
Large
Extreme
These are lights that do not fit anywhere else. Label the light based on size.
Next →


Example Mini Quiz
What type of (light classification) is the light in this picture?
Check


Classification Review
Street Lights & Traffic Lights
1
Private & Commercial Windows
2
Shop
Facade Lighting & Flood Lights
3
Path lighting, Bollard lights, Orientation lights & Canopy lights
4
Video screens & Illuminated Signs
5
PIZZA
NEWS
Light strings, Garden Lights & Other lighting
6
Next →

After launching the app...

You will be prompted to create an account after a few welcome messages.

This username will be the only information shown to us and the public.

Next →

Simply Select your Street

Select your street by tapping one of the green lines. These represent already available "transects"

If your street does not have a green line already you can choose to create a transect

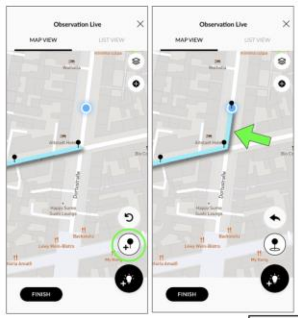
Next →

How to create a transect...

Start at one end of a street and press the plus pin button as circled in green.

Then, count all lights on the street.

Finally, when at the other end of the street click the plus pin button again.

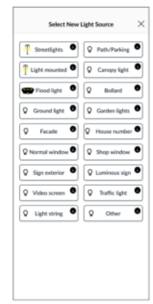


Next →

Classification Quiz

- Can all classifications be correctly identified
- Select right classification from different pictures
- Similar to mini quiz except the selection process will be as similar as we can get to what the app looks like as shown from the picture on the right
- Include a password based on how many they got right, the software should allow us to record this information

(once app is more complete will include screenshots from app)



Send off

- Include a password based on how many they got right, the software should allow us to record this information
- Congratulations of completing the tutorial
- Good Luck!