HAPPY LITTLE ACCIDENTS

Smart environments project

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Chapter 0: Introduction

This year the topic for the Smart Environments project is disasters. The idea of this project is to make a device or object that tackles a particular problem or disaster. This could be either a local disaster or global disaster.

Before the start of this project, everyone had to fill in a form that resulted into a group role being assigned to you, based on these roles the teams were made. Thus our team, Happy Little Accidents, consists of people with many different skills and ways of thinking allowing us to tackle problems in multiple ways. We had a bit of a rocky start due to the struggles of meeting online, but we all got along well and started working on the first chapters of our documentation. Our team leader is highly motivated and makes sure each and every person in our team does what they're supposed to do well before the deadline. We are excited to further work on this project, make use of the different skills we possess, and overcome any obstacles that may come our way.

After a lot of brainstorming, identifying and "filtering" we managed to choose *Identifying drinking water* as a problem that we want to solve. Many countries have inhabitants that do not have adequate access to clean drinking water. Moreover, the rivers in some of these countries contain harmful chemicals due to littering. This causes the water in these rivers to be undrinkable and dangerous. Due to the shortage of water they are forced to drink this water or water out of other rivers. However, not all rivers are contaminated. This creates the uncertainty that people do not know to what extent the water in rivers is drinkable. This is what we will want to find a solution to.

It is important that we understand that water quality related problems shouldn't be a part of the 21st century. Having in mind all the cutting edge technologies that we have at our disposal it seems illogical that 1.8 billion people live without access to proper sanitation. Being one of the 17 sustainable development goals we decided that we can be part of bringing humanity closer to it. In certain areas people are fortunate enough to have clean tap water but there are many places which lack that luxury (even in the most developed countries). As that problem is very relevant and important it is really important to tackle it.

We aim at creating a device that will minimise the risk of consuming contaminated water. The main cause of consumption of water of poor quality, is misinformation or lack thereof. So at its core, our device will test whether the water sample is drinkable or not, and through an app it will provide detailed information to the user on the quality of their water. Our product not only tells the user if their water is drinkable or not, but also gives the reason for why their water is not safe to drink, by listing some of the dangerous contaminants that led the program into deciding that the water is not safe. This will help in the way that if the water is found to contain some amounts of suspended solids (dust or other particles) the user will know that after simple filtration the water should be safe to drink.

We chose for this device because of multiple reasons. We wanted to contribute to solve the problem and therefore we thought a public machine would help everyone. So even when you don't have the money to buy a water quality tester you can grab a cup of water and test it in a public place. We also wanted to make the product not too big, because then people who have the money to buy the machine use it for personal use. So they don't have to travel every time to a public place to test the water. We also wanted to use an app connection, because then people can have a nice overview of the amount of substances in the water. They can also look at the information at a later time, so they won't create a big queue in a

public place. We decided to use a quality tester, because the water quality can be tested at any time and people don't have to use data from for example a month ago.

Chapter 1: Literature Review

Water Scarcity

Over the years there has been a rising demand for water. This water is mostly used to grow food, supply industries and sustain urban and rural areas. Therefore the amount of fresh water is decreasing immensely. Researchers have developed a way in which they can analyse the global water scarcity and make an assessment of where and when the current water usage can lead to water shortage. Furthermore they can see where the water shortage leads to harm to the environment around rivers and other fresh water supplies. This research is based on the combination of three different innovations in measuring water usage and availability. [1]

Droughts

Droughts can be defined in various ways. The most common definition of droughts is: a temporary lack of water which is necessarily but not exclusively caused by abnormal climate change which is damaging to an activity, group, or the environment. Droughts happen at various different scales. They could last from days to years. These yearlong droughts refer to a water shortage over a one-year time period in relation to the same time periods in the past. There are multiple droughts with different characteristics. For example there are meteorological droughts, agricultural droughts, hydrological droughts, and water supply droughts. These types differ in the way in which the soil responds to the lack of precipitation.[2]

Avalanches

An avalanche is a large mass of snow, ice, earth, rock, or other debris that moves down a mountainside in a swift motion. They usually get triggered when a change has occurred in the formation of the snowpack. Then the mass of the snow exceeds the strength of the snow holding it in place. This causes the snow to accelerate rapidly and grow in mass by taking more snow with it down the mountain. Not only can this happen with snow, it can also happen to rocks or other debris. These avalanches can often threaten man's activities and life. Therefore there has been a demand for higher safety measures and has led to new development of technology regarding the prevention of avalanches. [3]

Wildfires

Wildfires have a great impact on the lives of millions of people. A wildfire is a fire that is unplanned and burns natural areas like forests. They can be caused by human activity such as campfires or cigarettes. They can also be caused by natural phenomena like bright sunlight combined with drought or lightning. The risk of a wildfire increases in dry conditions like a drought. High winds can also increase the risk. Wildfires affect us a lot, because it can disrupt many things such as water supply, transportation, communication, food supply, property etc. A big consequence of a wildfire is the pollution of the air with carbon dioxide

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[1] https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0032688 https://doi.org/10.1371/journal.pone.0032688 Hoekstra AY, Mekonnen MM, Chapagain AK, Mathews RE, Richter BD (2012) Global Monthly Water Scarcity: Blue Water Footprints versus Blue Water Availability. PLoS ONE 7(2): e32688.

[2] https://www.annualreviews.org/doi/full/10.1146/annurev.environ.33.081307.123117 Vol. 33:85-118 (Volume publication date 21 November 2008) First published online as a Review in Advance on July 1, 2008. Kallis, Giorgos

[3] https://link.springer.com/chapter/10.1007/3-540-45670-8_13 Ancey C. (2001) Snow Avalanches. In: Balmforth N.J., Provenzale A. (eds) Geomorphological Fluid Mechanics. Lecture Notes in Physics, vol 582. Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-45670-8_13

and deterioration of the air quality. Carbon dioxide pollution contributes strongly with climate change. So a wildfire can have a big impact. [4]

Agricultural pests

Since the beginning of agriculture pests have had a great impact, destroying a part or even the whole crop. Agricultural pests include: animals, fungi, plants, viruses and bacteria. Agricultural pests can have a huge impact on our lives, because it can cause hunger and even a famine. Agricultural pests have been very influential throughout history and it is still a big problem. For quite a long time pests have been stopped by using pesticide, however pesticides have disadvantages. Because some pesticides are inactive for the crop which is used for. Pesticides can also be harming for plants and/or animals that live in the area and even some pesticides are damaging for humans. So pests are still a big issue for the agricultural sector.[5]

Extreme Cold

Extreme Cold can come with different types: just moderate snowfall, hours during blizzards that are blinding, freezing rain and icing. Extreme cold can have a big impact, because firstly the low temperature can be very dangerous. Secondly it immobilizes a whole region, because some power supply will be affected and traffic will be affected. The National weather service refers to extreme cold as deceptive killers, because most deaths come indirectly from the storm. For example traffic incidents by icy roads or blinding blizzards. You can also get hypothermia from exposure to very low temperatures. So it is important to be protected, because it can have a huge impact on society.[6]

Heatwave

A heat wave is a period of abnormal hot weather that lasts two or more days. Heat waves are one of the most dangerous natural hazards. Heat waves can have bigger impacts than most people think. Between 1998-2017, more than 166.000 people died due to heat waves. Not only because of the heat itself, but heat waves can cause a lot of other trouble such as water shortage, but also a strain on energy and transportation. This can cause power shortages or blackouts. [7]

Hurricane

Hurricanes are thunderstorms called tropical cyclones. When a storm reaches a maximum sustained wind of 74mph it is called a hurricane. They originate from the Atlantic Ocean, Caribbean Sea, Gulf of Mexico and the eastern North Pacific Ocean. Unmanned aerial vehicles or drones have been used for damage assessment. The drones were used to

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[4] World health organization. (2020, November 15). World health organization. Received from Wildfires: https://www.who.int/health-topics/wildfires#tab=tab_1

[5] Wayne D. Rasmussen, K. M. (2020, November 25). *Pest and disease control in crops*. Retrieved from britannica: https://www.britannica.com/topic/agriculture/Pest-and-disease-control-in-crops

[6] Horry county. (2020, November 15). *Winter Storms & Extreme Cold*. Retrieved from horry county: https://www.horrycounty.org/Departments/Emergency-Management/Natural-Disasters/Winter-Storms-Extreme-Cold

[7] https://journals.ametsoc.org/bams/article/77/7/1497/55589 Changnon, S. A., K. E. Kunkel, and B. C. Reinke, 1996: Impacts and Responses to the 1995 Heat Wave: A Call to Action. *Bull. Amer. Meteor. Soc.*, **77**, 1497–1506, https://doi.org/10.1175/1520-0477(1996)077<1497:IARTTH>2.0.CO;2.

capture data for disaster response after hurricanes. Many of the people who used drones were hobbyists. [8]

Tsunami

A tsunami is a series of waves. They can be caused by earthquakes or volcanic eruptions under the sea. As the waves travel inland, they become bigger and bigger. The speed of a tsunami depends on the depth of the ocean instead of the distance from the source. Tsunami's can cause death due to drowning, but also other injuries due to physical impact. After the survivors are rescued there is great need for drinking water, food, shelter and medical care. This article is about the relationship between social participation and disaster risk reduction actions. There are three risk reduction actions examined: Following disaster related news, preparing emergency kits and/or having a family emergency plan and having an intention to migrate.[9]

Floods

With increasing ocean temperatures, water levels are expected to rise, causing massive flooding around the world. Not only will the floods be more devastating than before, they will also occur in areas that don't normally expect flooding, and therefore don't have the infrastructure to deal with them accordingly. First step is prevention. Flash floods (flooding of low elevated areas, caused by extreme rainfall, or meltwater from land ice/snow) have great velocities and erosive powers, only strong, solid structures can withstand the water. The best way to save the most amount of lives would be to inform the endangered people early enough, so they have time enough to escape to higher ground, where the water levels won't be a threat. This obviously has many negatives from: causing chaos and panic, to trillions of Euros in damages to areas involved. Floods where velocities are relatively low, and the direct danger isn't comparatively immense often occur in alluvial plains of large rivers. Despite not having as many erosive forces as flash floods, they can be equally costly, as most major cities around the world are situated on these plains, and many million acres of farmland can be destroyed. They are perhaps even more difficult to predict, as rainfall hundreds of kilometers away can be the cause of flooding in an area where no abnormal events are expected. Best is to be ready for the flooding, by investing in protective infrastructure ranging from temporarily closing openings with sandbags, to extensive geoengineering. [10]

Earthquakes

Seismic activity is more likely to occur in areas of plate tectonic boundaries. This makes it easier to target aid to specific areas around the world where earthquakes are more likely to occur than others. Countries like The Netherlands are relatively safe from major earthquakes, as the country happens to be far away from such a plate boundary. Accurately

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[8] https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0227808 Greenwood F, Nelson EL, Greenough PG (2020) Flying into the hurricane: A case study of UAV use in damage assessment during the 2017 hurricanes in Texas and Florida. PLoS ONE 15(2): e0227808. https://doi.org/10.1371/journal.pone.0227808

[9] https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0130862 Witvorapong N, Muttarak R, Pothisiri W (2015) Social Participation and Disaster Risk Reduction Behaviors in Tsunami Prone Areas. PLoS ONE 10(7): e0130862. https://doi.org/10.1371/journal.pone.0130862

[10] https://d1wqtxts1xzle7.cloudfront.net/31114954/PlateJHydrology2002.pdf?1365733419=&response-content-disposition=inline%3B+filename%3DFlood_risk_and_flood_management.pdf&Expires=1605565887&Signature=b-pcTPFEL-SyrKeL5Gw~b3bC9N9L2tVrUONlcYO~GL4-I~mxIzoCfCbOhjnJHCgybkQdwALIhzqzV2bArOvyPhOiFeisHR5Kyd0kWy3MQeYPZBoiHFLsf1Vt~dsaZrsAbBzD-bFGfpZYC0tlVHTPUZkQSYpTsAqQvU1RVU5k4hLKkTvdGJ1jEuIw25GHvhOeLPeicxnI7SGyVev--3-KZ-XmFC~33WohFXv~85TYX~kHh2oJd8kxfZR54V7FNCcMPrhQur07di5rmvAkCmiYZvQBdLLMV~Q-XxjOESpusHuDN2qp7UCXh1vncwulqUCfXTU~7q8PEpD96vmIcoR3EA__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA Erich J. Plate* Hydrology and Water Resources Planning, Universitat Karlsruhe (TH), Kaiserstrasse 12, D 76128 Karlshrue,Germany

predicting earthquakes sufficiently in advance to evacuate an area is incredibly complex, and near impossible, due to the amount of factors that come into play. The most effective way to battle earthquakes, is not to prevent them, but rather to be prepared for when/if such an event happens. Wealthy countries that are prone to earthquakes like Japan, have invested billions of dollars into infrastructure, and emergency response, that despite having an earthquake of 9.1 magnitude (2011, 4th biggest ever recorded) only a relatively small 16,000 reported casualties, compared to roughly 160,000 casualties the year before in Haiti, which experienced an earthquake of magnitude 7.0 on the richter scale. This shows how preparation, and immense investments can save lives in the hundreds of thousands.[11]

Food Shortage

Shortages of food can be caused by all natural disasters, as it's more of a consequence of these unfortunate events. Therefore preventing major natural disasters will play a major factor in solving global food shortages. Saying that, impoverished countries are more prone to famine and food insecurity, often caused by harsh climates, or inadequate support from the government. Main solution to this is education, give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime. Obviously this is a long term solution, and while major economies or organisations provide the necessary resources, for sustainable food production, it's a necessity to provide aid in the meantime.[12]

Nuclear disaster

SWAN (Short for Smart Working robot for Anti-Nuclear disaster) is a remote-controlled robot developed to help with the prevention of nuclear disasters. It is able to reach places that are difficult for humans ro reach, is of course immune to radiation and has access to multiple tools that can be used for the prevention of nuclear disasters.[13]

Volcanic eruptions

Scientists can try to predict when a volcano will erupt by looking at the history of the volcano's activity, looking at the activity in the ground IE the amount of earthquakes, measuring how much gas leaves the volcano or by measuring its temperature and/or other forms of activity through satellites. By recognising the eruption of volcanoes early on the damage done can be reduced.[14]

Elevator accidents

Nearly all accidents associating elevators involve the workers working on the elevator, there aren't many cases where simple users get badly hurt. Over 50% of fatal elevator accidents

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[11] https://royalsocietypublishing.org/doi/full/10.1098/rsta.2014.0373 Koshimura Shunichi, Shuto Nobuo, 2015, Response to the 2011 Great East Japan Earthquake and Tsunami disaster*Phil. Trans. R. Soc. A.*37320140373 http://doi.org/10.1098/rsta.2014.0373

[12]https://www.researchgate.net/profile/Christopher_Barrett2/publication/41424901_Measuring_Food_Security/links/0912f50e6512036c9e000000/Measuring-Food-Security.pdf Christopher B. Barrett, et al. Measuring Food Insecurity. Science 327, 825 (2010);

[13] SWAN Robot for Nuclear Disasters

Yuuji Hosoda, Hiroshi Yamamoto, Makoto Hattori, Hiroshi Sakairi, Tarou Iwamoto, Masataka Oowada, Akihiro Kanno & Yuuji Saitou (2002) 'SWAN': a robot for nuclear disaster prevention support, Advanced Robotics, 16:6, 485-488, DOI: 10.1163/156855302320535782

[14] Predicting Volcanic Eruptions

Author unknown, Lumen, Date unknown

occur when the people involved aren't following the correct lockout/tagout procedures, basically meaning that someone turns the power on whilst there are still workers inside the elevator shaft. About 49% happen due to deficient fall protection such as guardrails or scaffolding. On top of that, 25% of fatal accidents due to the elevator shaft itself not meeting the proper standards or unauthorized personnel entering the elevator shaft.[15]

El Niño

El niño is a weather phenomenon which is declared when surface temperature in the Pacific ocean rises with 0.5°C for three consecutive months and the atmospheric conditions and rainfall patterns change accordingly. Happens every 2-7 years and causes marine life changes as well as changes on land for people such as: increased number and severity of storms, rainfalls, floods and even increasing the risk of some diseases transmitted by insects. On the other side of the Pacific the consequences are contrary droughts, wildfires and colder ocean waters. [16]

Tornadoes

Tornadoes can be classified in two categories-supercell (stronger and bigger) and non-supercell (smaller and weaker). The way of forming is almost the same for both types: when high pressure air masses with low temperature meet a low pressure air masses with high temperature at different speeds and directions the air starts moving in circular motion. Then as the sun heats the colder air it starts to rise which causes a forming of huge air mass moving in circular motion from the ground to the clouds. Besides the destructive power of tornadoes they are often combined with severe thunderstorms. Tornadoes can be forecasted by constant following of wind movement.[17]

Technological disasters

Technological disasters are man-made and usually unpredictable events which can have various consequences and on top of that for various time periods. Technological disasters can be caused either by human mistakes, equipment failures or natural events. Examples for short-term incidents are: physical traumas on humans, fires, food and water shortage. On the other hand there are: exposure of people, soil or water to hazardous materials which may have long term effects. Safety procedures in case of such disasters are of essential necessity.[18]

Power Outage

Solutions for power outage are summed up in this article:

Fuel cells: generate power with a chemical process with hydrogen and not with combustion.

pros: zero emission

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[15] Elevator Accidents
Edward Smith, Machine Accident, 2018

[16] National Geographic Partners, LLC. El niño 101. https://video.nationalgeographic.com/video/news/101-videos/00000144-0a2e-d3cb-a96c-7b2f021b0000?gc=%2Fvideo%2Fenvironment%2Fnatural-disaster

[17] NATIONAL GEOGRAPHIC STAFF (AUGUST 28, 2019). Tornadoes, explained
https://www.nationalgeographic.com/environment/natural-disasters/tornadoes/

[18] American Public Health. Association Types of Disasters and Their Consequences.
https://www.medscape.com/viewarticle/513258_14

cons: high costs and hydrogen is very expensive (at the moment)

Solar energy + storage: get solar energy from solar panels and stores the energy on batteries

pros: zero emission,

cons: you need a large area of solar panels to generate enough energy for a household, depends on season, time of the day and weather conditions

CHP: combined heat and power, also captures heat when generating power with fuel.

pros: generate heat and power instead of only power

cons: bad for nature, because of the combustion

Diesel generator: generates power with fuel

pros: low costs, ready for generating a lot of fuel

cons: bad for nature, because of the combustion

Problem: Society depends on electricity, without it, the modern world is nothing

Our modern society fully depends on electrical power. Traffic, hospitals and many other sectors will suffer from lack of power. Due to terrorist attacks and extreme weather events a complete blackout of the power network is not inconceivable.

In this video is explained what would happen in the Netherlands when the electricity network would shut down for only 8 hours. The video did not explain what happens after that, because in 8 hours almost nothing functions anymore in the Netherlands, I think that is way too fast. After 2 hours communication with your smartphone is impossible, from then you need to have a radio on batteries to get informed about the development in the blackout. [19]

Sinkholes

In this video Grady Hillhouse explains how sinkholes form. Usually a sinkhole is formed by erosion. In a city a hole in a water pipe can cause water to flow through the soil which causes erosion. When a lot of soil is eroded away there is a big bubble of air and when the bubble of air reaches the surface a sinkhole is formed, something heavy can get sucked into the sinkhole which takes the surroundings with it in the hole.[20]

[19] https://www.bloomenergy.com/blog/power-outage-solutions-how-businesses-can-protect-themselves-from-blackouts Vijay Srivatsan, Head of Product Management, Bloom Energy, https://www.tab-beim-bundestag.de/en/pdf/publications/books/petermann-etal-2011-141.pdf Petermann, T., Bradke, H., Lüllmann, A., Poetzsch, M., & Riehm, U. (n.d.). *What happens during a blackout Consequences of a prolonged and wide-ranging power outage*. NOS op 3. (2019, June 22). *The chaos that arises when the lights go out everywhere* [Video file]. Retrieved November 18, 2020, from https://www.youtube.com/watch?v=U3Smc2NBSaE

[20] Hillhouse, G. (Producer). (2017, June 28). *How Do Sinkholes Form?* [Video file]. Retrieved November 17, 2020, from https://www.youtube.com/watch?v=e-DVIQPqS8E

Chapter 2: Identification of General Problems and Challenges

Awareness of wildfires:

For wildfires awareness is one of the biggest problems. It is difficult to detect the fire when it starts, because forests are quite big. When the fires are detected, it has often already spread very far, and it will have spread even further once the firefighters arrive.

Undetectability of agricultural pests:

A pest can affect all the agriculture in an entire region, so a complete region can run out of food. Agricultural pests are difficult to detect, so often times a large part of the crops have already been destroyed. If there is a new pest it could take a long time to find a good solution for the pest. Pesticide isn't always a correct solution, because it can cause harm to other animals or people.

Infrastructural problems during extreme cold:

A problem with extreme cold is that a whole region's infrastructure can be disrupted. Many cities have plans for heatwaves, but not for extreme colds. They are not very prepared for the impact on the critical infrastructure.

Food shortage due to drought / water scarcity:

The lack of water during a drought can lead to the destruction of the plants and crops. So farmers are not able to produce as much food as usual.

Preparation for a heatwave:

Heatwaves can have bigger impacts than most people think, so not everyone is well prepared. They can cause health risks, but also water shortage or power outages for example.

Damage evaluation in case of a hurricane:

After a hurricane it is difficult to determine how much damage has been done. It is important to collect all the data on the damage for the reconstruction to begin. Proper damage evaluation leads to more efficient disaster response.

Damage impact by an earthquake:

The damage caused by an earthquake can cause cascading events such as loss of electricity and damaged roads and other smaller disasters. Due to these cascading events it is very difficult for emergency services to help people.

Poor strategy in case of a flood:

Not everyone is well enough prepared in case of a flood. People need to know which evacuation routes they can use in case the infrastructure collapses or how to find their way in the case of a power outage when they will not be able to use their phones or other devices.

Chapter 3: Identification of Relevant Problems

Identifying drinking water

In this time water scarcity is an increasing problem. The population on earth keeps on growing, creating an increase in the amount of fresh water needed to provide for all people. Due to this problem many third world countries are having a water crisis. Rivers in some countries are contaminated with trash and feces which makes the water undrinkable and causes the amount of fresh drinking water to decrease immensely. However, due to the water shortage they are forced to drink this water. Furthermore, these people are unaware to what water is drinkable and what is not drinkable. Water scarcity is an interesting topic to find a solution to because in the future not only will less developed countries be affected by this but due to global warming it will have an effect on the whole world.

Wildfires

A rising problem throughout the years are wildfires. With global warming increasing rapidly we need to find a proper solution to stop the big impact. A recent example of wildfires in Australia which were a tremendously big problem. A lot of nature combined with cities were destroyed by these continuous wildfires. Because of these wildfires a lot of animal species are in danger, because some of them are threatened with extinction. Another big problem of these wildfires is that the burned trees cause a great pollution of carbon dioxide, which enhances global warming. So we really need to try to minimize the damage. Big problem of wildfires is that the beginning of the fires are difficult to locate and it is hard to know that there is a fire. When people are aware of a wildfire the fire can already be really big which makes it hard to extinguish. So it is really important to find a solution for this problem.

Power outages

Power outages are a problem in itself. But the main concern about them is that a natural disaster can often cause them. When such an events occurs (even without natural disaster beforehand) people tend to panic, depending on the scale of the outage it can have an impact on economy, for people on life support without a backup power source it means their end. Many of the everyday tasks we perform have a direct connection with having power. Electricity has a major role on our lives and in the future it'll play an even bigger role that's why we have to look for ways to deal with power outages. What's interesting is that even though almost every country in the world could be hurt in an event of power outage there is no collective solution on this problem

Food shortage

Food shortage has slowly been on the rise since the last few years. The world's population keeps growing as well as the demand for food. The production could not keep up with the growth in demand. Also the food prices have increased. Many countries encountered food insecurity after the global economic crisis in 2008 and 2009. Mostly in middle-income countries, which have had an economic setback. Natural disasters and hazards can also cause food insecurity and impact the agricultural sector. This has an impact on the supply of

food, the increase of food prices, a decrease in farm income and employment. Poverty is a result of natural disasters, which causes food insecurity and malnutrition.

Traffic accidents

Traffic accidents are a huge problem in the modern world, almost everyone travels by car to work, to home or to something else. The more cars there are on the road, the more traffic there is. If a traffic accident occurs it usually takes a long time before the traffic is running normal again, that is because of the slow reaction time of humans. Explained in this video[21]. The accident might be already solved and you can still be stuck in the traffic jam because it takes ages before people ahead start accelerating after each other. Traffic accidents are also a relevant subject in the Netherlands. A smart solution is needed for this problem. Don't forget the environment too, a lot of cars standing still while the engines are still running is bad for nature and makes more CO_2.

Radioactive Contamination

With the threat of global warming becoming greater and greater with every second, our society is in dire need of a green, sustainable energy source. A possible solution is nuclear fusion, however the risks of another Chernobyl make it too dangerous a fix. Once an area gets contaminated with radiation it can remain dangerous to visit or inhabit the area for decades, and in the worst cases centuries. On top of that nuclear weapons are a great menace, especially in the hands of unpredictable forces such as North Korea. Should a third World War occur, there's a high chance these weapons of mass destruction are being put to use. Therefore finding a cheap and efficient way to cleanse an area of radioactive contamination can be of great help in the battle against global warming by eliminating a large danger of nuclear reactors, and it can help with recovering from a possible future World War.

[21] https://www.youtube.com/watch?v=iHzzSao6ypE GCP Grey, 31 aug.2016

Chapter 4: Problem Selection and Motivation

We chose *Identifying drinking water* as the problem we'd like to work on for this project. Water is an essential resource for human life. That being said, 1.8 billion people live without access to adequate sanitation. That's why the united nations have included "access to clean water" as one of their 17 sustainable development goals. Therefore, as a group we decided to contribute to bringing humanity a step closer to achieving that goal. We plan to make a device that will identify what water is safe to consume, and inform the user if there is any danger. We are lucky to live in a country, where we essentially have a limitless amount of water from the tap, with the comfort of knowing that it is safe to drink. For others, that comfort isn't a given. Some countries don't have drinkable water from the tap, and many don't have access to water at all. Knowing that, we chose to tackle this problem over the others, as no human should gamble with their health each time they go for a drink of water.

Chapter 5: Potential Solutions

Cup

The cup is meant to determine whether the water in it is drinkable or not. With this cup you do not need an external device. You simply put water in the cup, from a water source, and then you can click a button to analyse the water. All the sensors that are needed to analyse the water are connected to the cup itself. There is also a LED light on the cup. After the water is analysed the LED light will turn to green if the water is drinkable. If the water is not drinkable the LED light will turn red.

Map

The problem of water scarcity as we mentioned before is that people are unaware of the water quality. A solution for this problem is to create a map of the water quality throughout a region. Professional people can test the water quality and determine a color from green to red to the water. Each colour has an advice, so for example: Green: Good water quality, drinkable. And Yellow: not good water quality, Don't drink this unless it's necessary. And then Red has extremely bad water quality which people shouldn't drink. With this information people can know if the water is drinkable. Also on the map the date of testing and which testing method is used are visible and, so people can determine if the water the recommendation is still applicable. So then people can determine with a device or app if the water quality is good or bad.

Public Machine

The water testing machine is similar to the cup, however it has about the size of a regular drinking fountain and stands in a public place where everyone can use it. You can pour the water you'd like to test into the machine, and the machine then tells you how safe it is to drink (for example on a scale of 1 to 10, a colour slider that goes from green to red, etc.). You can then place your cup or bottle underneath a dispenser in order for the machine to return your water. If technologically possible, the machine could also clean your water for you to a certain extent, for example by simple filtering or by adding substances that kill bacteria. The machine will clean itself after every time it is used, so that water tested in it does not get contaminated with dirt/bacteria from the previously tested waters.

Fishes (sensors floating in water)

This idea is to make a device that is designed like a fish that you can put in a river and then it collects the data in one part of the river that is being tested. There are more fishes like this used to test different parts of the river. Then the data of the water quality in the river is sent to a app on a phone. The device is bound to a stick that is put in the ground of the river. The current of the river makes the water go through the fish. In the fish the sensors analyse the water quality. Then the fish sends the data to a phone. When all the data of all the fish are sent to the app, people can see in which part of the river the water is drinkable and where the best quality of water is located.

APP

The device would transfer data to a mobile application. The user would be informed about the water he is testing on terms of easy to comprehend data such as temperature and Ph and “n%” safe to drink water. Other features could be daily water log, benefits, and random fun water trivia.

Sensor you put in water

A long thin probe, that can be placed in a sample of water. The probe contains all the required sensors needed to test the water. The other end of the probe is connected to the Arduino board via wires, which come from the sensors found in the probe. The Arduino is programmed to read the data from the sensors, interpret it and determine to what extent is the water sample drinkable. After interpretation, it is displayed on a monitor, with information on the drinkability of the water, with information on what impurities are present in the sample.

Chapter 6: Solution Selection

Brainstorm process

To come up with the solution for our problem we first talked about the solutions we had already and in which way it could impact the awareness of the water quality. Every option had some advantages and disadvantages, but we chose to have a generala tester so people could easily test river water and tap water. And a thing we liked a lot was the public machine, because in many countries that are as wealthy they can have a general tester in their city so people can test the water. But then we came to a problem that some people will not walk or travel for more than 15 minutes to test the water, so for people who can afford it we also thought that they should be able to have a device.

To display the result we were thinking about an app because it is easy to see your result, but we were also thinking about just having a simple screen that shows if it is safe to drink.

Project Idea

Our project idea is a device around the size of a microwave which can test the water and it will give the information by using an app on your phone. So it will work as follows: You can use a cup or bottle which you can pour your water which you want to test in. Then you place the cup in the machine in a public place or at your home. The machine will test your water by using different test sensors. With the information it will generate a recommendation. So for example: the water is safe to drink. The data and the recommendation will be sent to an app on your mobile phone so you can easily see on your device if the water is safe to drink. By using an app people can easily look at the results afterwards so the public spaces will be less crowded. We also want a screen that displays only the recommendation and the status of checking, so people without mobile devices can still use it.

We also had an idea of gathering information by using a map, so researchers could know the water quality in the region and with that information maybe improve the water quality. But this idea is a bit off topic, because we focused on awareness. However this feature could be useful to see differences in water quality.

Motivation

We chose this idea, because we felt with this idea we could really have an impact for all people that are not sure of the water quality. Because we don’t only test rivers, but also tap water so it could be used for everyone. Also with an option to put it in public, it makes it so everyone can use it even if you are less fortunate. Also by using an app and a screen everyone can use it and people can easily look at the results on their app to analyse for themselves how good the quality is. So the main motivation of this idea is that everyone can use it and this is really important for this topic, because some people who are not sure of the water quality don’t have the money to always buy clean water from stores.

Things to think about:

- How to connect phone to device
- Cleaning the sensors
- What type of screen

Who does what?

We chose to make a task division of modules for everyone. We made the modules a bit general, because the project might shift into a different direction and this task division would still be useful. We choose the modules: Programming, electrical circuits, design, app development, documentation, planning, safety plan and research on sensors. People have main tasks of some modules and optional tasks. These optional tasks are there to help other people if a task is falling behind or needs more attention than before. You can find the table of the tasks below:

Name:	**Main tasks**	**Optional tasks**
Eva	Planning, design and documentation	
Jesper	App design/development, documentation	Programming
Sander	Programming, documentation	Electrical circuits
Leon	Electrical circuits, research sensors, safety plan and documentation	Programming
Shanti	Design and documentation	
Jochem	Electrical circuits, research sensors, safety plan and documentation	Programming
Stefan	Electrical circuits, safety plan and documentation	Programming

Chapter 7: Methodology:

Additional Equipment:

- TDS sensor
- Turbidity Sensor
- PH sensor
- Water Samples
- Construction material
- Insulation

The general idea is that the device will contain a rod that will act as a probe in its centre, and underneath is a platform to place your water sample; the rod will be either manually inserted into the sample, or will be lowered automatically. The rod will contain all the required sensors that are needed for the data collection from the water. The sensors are connected to the Arduino board, located in the device, the Arduino will then send the data to a server, where it will be analysed and processed. Having a centralised system over a local one, will allow more data analysis, and the entire state of the water to be analysed simultaneously. After the data is collected and analysed, a recommendation will be determined, based on global standards, on whether the water is safe to drink. You can then see these results on your smartphone through an app.

The device will be designed to resemble a microwave, providing an insulation to all the electronics, by hiding all the wirings out of sight, and reach of the water. Once the water sample is placed, and the probe is in position, the user will press a button on the device to start the analysis. The LCD screen on the device will inform the user on the progress of the test, and once complete will display the recommendation. When the analysis is complete, the data is sent to the application, and the user can then view the detailed results on their mobile app.

Sensor we will use:

TDS sensor [22]

Turbidity sensor [23]

PH sensor [24]

Display sensor [25]

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[22] https://opencircuit.nl/Product/Gravity-Analoge-TDS-sensor-meter-voor-Arduino How it works: https://wiki.dfrobot.com/Gravity__Analog_TDS_Sensor___Meter_For_Arduino_SKU__SEN0244

[23] https://opencircuit.nl/Product/Gravity-Analog-Turbidity-Sensor-For-Arduino How it works: https://wiki.dfrobot.com/Turbidity_sensor_SKU__SEN0189

[24] https://www.benselectronics.nl/ph-sensor.html How it works: https://www.botshop.co.za/how-to-use-a-ph-probe-and-sensor/

[25] https://www.bol.com/nl/p/nieuw-iic-i2c-met-1602-lcd-display-scherm-board-module-voor-arduino/9200000091996909/

What does each sensor measure:

We have chosen to use three different sensors that measure different factors of the water. The PH sensor will measure how acidic or alkaline the water is. This factor can tell us if there are dangerous substances inside the water. If the acidity or alkalinity is too high there might be very dangerous substances in the water that can harm a person. Furthermore, we will use a TDS sensor to measure how many dissolved solids are in the water such as minerals, salts, and metals. This way we can see if there are certain dangerous particles or chemicals dissolved in the water. Additionally, the last sensor we will use is a turbidity sensor, this sensor measures the cloudiness of the water that is caused by individual particles that are mostly invisible to the naked eye.

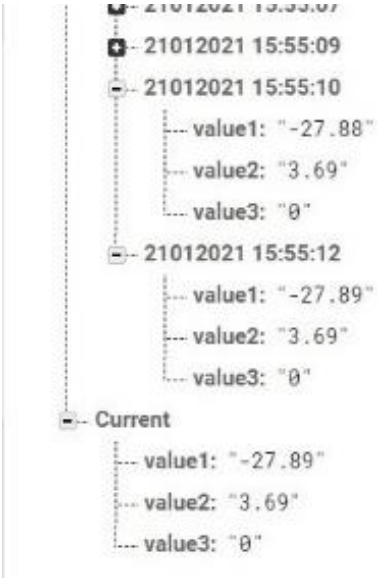
How to validate the sensors:

In order to validate the sensors we want to buy different waters from a shop, with a known pH, ppm and turbidity. We will use demi-water as the standard, as the sensors ideally won't read any impurities from it, and the pH will be 7.

Then to test acidity we can put some acid in the water sample (something simple like concentrated lemon juice). To test the turbidity sensor we can just put a gram of dust or so into 99ml of water and we know the concentration is 1%. Same with the TDS (total dissolved solids) sensor.

Connection from the device to the app

The Arduino is connected to a laptop with a running Python program. The Arduino sends through serial communication the sensor values using this line of Arduino code: "`Serial.println(String(phValue) + "_" + String(voltage) + "_"+String(int(tdsValue)));`". The python program continuously reads the serial port of the Arduino, it decodes the values coming in and separates the individual sensor values. The python code stores the value it gets from the Arduino under a timestamp in firebase (online realtime database). It also stores the code under Current, which changes every time so we get a real time (± 1 second). As seen in the picture on the right. Then we also made an app in MIT App Inventor which reads the data under current and displays that data.



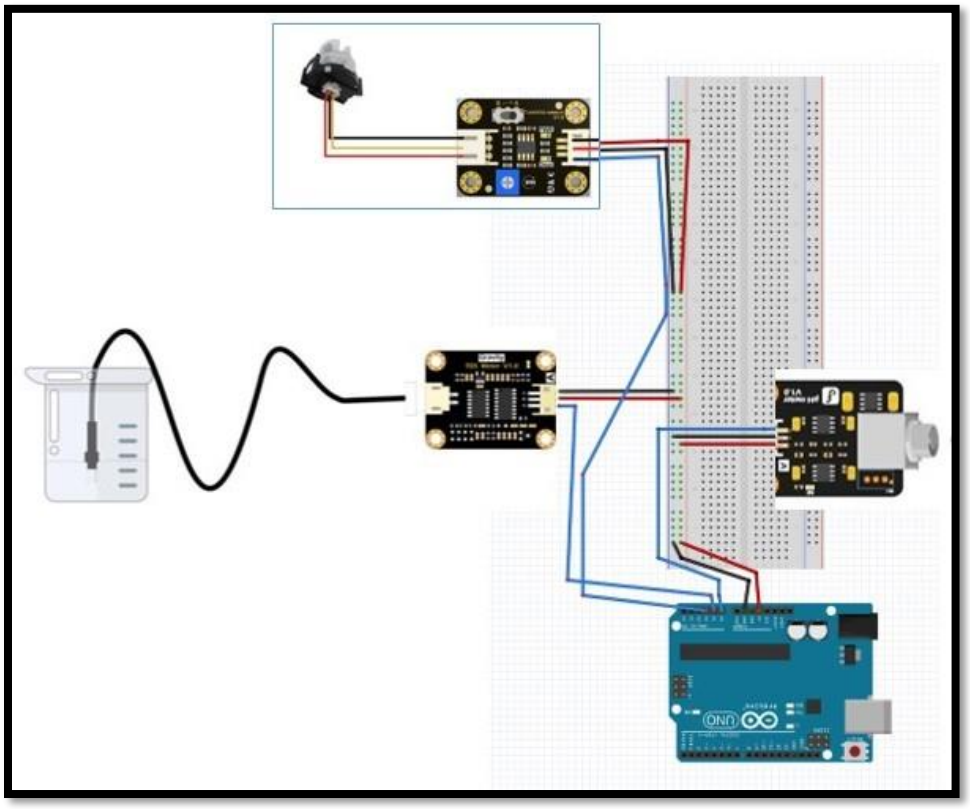
Construction box

For the construction we have chosen to use a plastic box. This is because plastic is waterproof, so the Arduino doesn't get damaged by water. We chose a simple box, because due to the recent COVID-19 measurements we weren't able to create a box specially made for our device. Therefore we opted for this box option, because it provides the safety that we want and the option to modify the box, without creating it ourselves.

Chapter 8: Results and Conclusion

For the final result we went for the basic scenario, because due to the COVID-regulations we thought it would be already difficult to make the product with the right calibration and have the connection work properly. So we went for the basic scenario in the end. We thought about the use of the map, but we thought that it is more important to have a good testing machine than additional information on a map. However a map could be useful for later research.

Diagram of the circuit:



This picture is the diagram that shows how the sensors are connected to the Arduino. The sensor at the top of the diagram is the turbidity sensor. The one on the left is the PH sensor and the and the one on the right is the TDS sensor. In this picture the Arduino UNO is the blue figure on the bottom.

Calibration:

We started out by testing the sensors, and getting more acquainted with them in the process.

TDS-sensor:

The TDS sensor was fairly easy to understand and was already quite nicely calibrated. However you could calibrate it a bit more, but you will need to have an additional

temperature sensor and different test materials. The sensor has an accuracy of 10%.[26] So that means if the sensor reads 270pmm it could be 297 ppm. So therefore we adjusted the maximum values.

PH-Sensor:

The Ph-sensor however wasn't pre-calibrated, so we needed to do that ourselves as described in chapter 7. We have calibrated it by using demineralised water for the first time to set a first calibration value of 22.8. Then we tested it with two bottle of water from the supermarket. Which had a PH of 6.0 and 7.6 Then we changed it a bit and tested it different times and adjusted the calibration until it was good. See the table below:

	Calibration of 22.8	**Calibration of 21.8**	**Calibration of 21.3**	**Calibration of 21.55**
7.6 Ph water	7.90	6.70	6.00	6.42
6.0 Ph water	8.88 and 8.6	7.97, 7.91	705	7.51

So we came to the conclusion a calibration of 21.50 should be good. This number may seem much but we looked up reference, which you can find in the footnote which also had a calibration of around 21. [27] The Ph sensor has a accuracy of 0.5. So this means we need to set the value 0.5 higher and 0.5 just to be sure[28].

Turbidity-Sensor:

The turbidity sensor was also pre-calibrated and the output was initially the amount of volt from 0 to 4.5 Volt. However the turbidity is often measured in NTU(Nephelometric Turbidity Units). To calculate the NTU value the site provided a formula: NTU = -1120.4*(input voltage)^2 + 5742.3*(input voltage) – 4325.9. The offset of the turbidity sensor is 0.3V[29]. If you look at the offset within the formula you can see the turbidity sensor isn't very accurate combined with that Arduino can't read many decimals. So we decided to use it more as a reference. So the NTU is above for example 1000 then it is definitely not safe to drink, however we can't exactly measure therefore the NTU value is more of additional information.

[26] https://wiki.dfrobot.com/Gravity__Analog_TDS_Sensor___Meter_For_Arduino_SKU__SEN0244

[27] https://circuitdigest.com/microcontroller-projects/arduino-ph-meter

[28] https://circuitdigest.com/microcontroller-projects/arduino-ph-meter

[29] https://wiki.dfrobot.com/Turbidity_sensor_SKU__SEN0189

Results

We then worked on putting the sensors together on a single Arduino, and tested a glass of tap water, giving the following results:

Tested values of tap water	
Ph	7.15
Turbidity	4.2V
Total dissolved solids (TDS)	252ppm

To make sure the water is safe we have found maximum values for that the sensors should have to make the water drinkable, approved by the WHO.

Value range for safe drinking water		values for good drinking water	Adjusted values due to sensor inaccuracy.
PH [30]	6.5-8.5	6.5-8.5	7-8
Turbidity [31]	<5 NTU	<1 NTU (On the website they stated >4.2 V)	<1 NTU (On the website they stated >4.2 V)
Total dissolved solids (TDS) [32]	<600 pmm(parts per million)	<300 pmm	Safe drinking water: 540 ppm Good drinking water: 270 ppm.

[30] https://www.who.int/water_sanitation_health/dwq/chemicals/ph_revised_2007_clean_version.pdf World Health Organisation. 2017.

[31] https://www.teachmemicro.com/arduino-turbidity-sensor/ Roland Pelayo

[32] https://www.kitchenarena.in/total-dissolved-solids/#:~:text=According%20to%20World%20Health%20Organization,water%20is%20considered%20as%20disagreeable VS Chaitanya. 30 Jan 2018. Kitchen Arena

Conclusion:

As you can see both the Ph sensor and the TDS sensor work properly, because we have nice values and we can indicate how much particles are in the water and the ph. This is already really great for testing the water quality. Also the app properly connect with the Arduino and even if you are not there you could in theory see the data. You can see the app in the picture on the right.

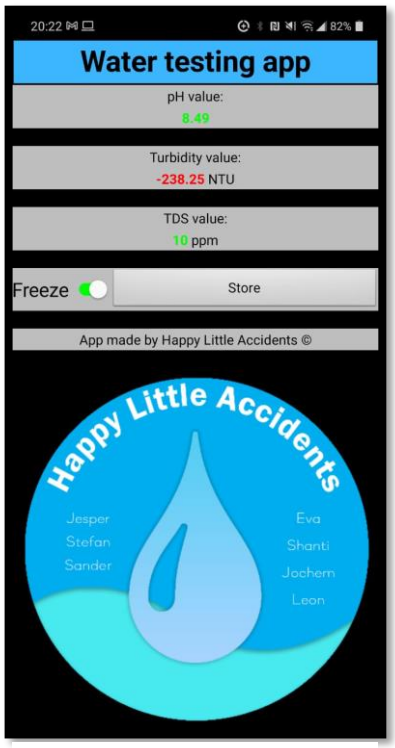


Figure 1 Water testing app

However the turbidity sensors gives quite strange values.. Because on the website they tell if a value is greater than 4.1V the turbidity is less than 0.5NTU. So this would mean that our tested water is good. However if you look at the formula from the website it says the value should be around 4.2, but the margin where it is not drinkable anymore is really small because it is like 0.01, which the turbidity sensor can't measure. However it gives a nice view if it's really dangerous, however it is not accurate enough to really determine the small differences and therefore not accurate enough to determine safety based on turbidity. There we use it as a reference and isn't red or green in the app.

If you put the glass in the sensors and you wait 2 minutes you can see the values on the app. If the value is green of the Ph and TDS the water is drinkable based on those 2 sensors. As said before the turbidity isn't green or red, because of the inaccuracy.

Discussion

We didn't run into a lot of problems during the start of this project. The fact that almost everything had to be done online did make some things such as communication a bit difficult, because we worked primary on the documentation. However later on in the project we ran into a couple of problems: some of them had to do with the COVID-19 measurements and others with for example the sensors. We have divided them into three different categories:

Sensors:

A problem we did run into was that the turbidity sensor didn't measure the turbidity in NTU but simply in percentages of voltage. After some searching we found a formula in a picture on the company's website to convert the measured data to NTU. However this is a too little margin for Arduino to detect and therefore we can't make an accurate estimation. Therefore in hindsight we should have bought a more accurate sensor. However with the shipping time during the pandemic it can take weeks for a sensor to be here.

We also assumed the TDS sensor was already calibrated, but we aren't completely certain about this so the results could be slightly off.
A possible way to improve on our project in the future is by adding more sensors to get a better view of the water's drinkability. Right now we have the most important sensors used for testing water quality however they only look at the Ph, amount of dissolved solids and turbidity and it doesn't look at what kind of solids are dissolved in the water for example,

which can play a huge part in determining whether the water is drinkable or not. Therefore you could add multiple sensors to make it more accurate.

Design:

In the start of the project we had a few different designs of what the product should have looked like. However due to the new corona measures in December and January, we did not get the option to work on the design together in the SmartXP or use the tools there. This had significant impact on the look of our product, we had to compromise and eventually we went with a simple plastic box. With this we took in mind that we were making a product that worked with water, and therefore we could not have a wooden box due to the fact that wood would eventually rot. Because of this we thought it would be wise to use plastic.

Solving the problem:

The goal of this device as to solve the problem about water scarcity by identifying the water quality. With this machine you could identify the dissolved solids and the Ph and the turbidity. As said before to make this really accurate you should add more sensors like a chlorine sensor. And in developing countries there could be diseases in water which the machine unfortunately can't detect. However the machine is practical, because you could get a bowl or a cup of the test the water quality really easily, just by putting a cup underneath it and test it for 2 minutes. It could also scale pretty good If you add more sensors, because its rather small you could have it in public spaces and even for personal use. With more sensors it could save problems with clean drinking water.

The Cost to make this device is made out different aspects. we paid for the sensors now: €14.10 TDS sensor, €11.10 Turbidity sensor and €30.00 for the PH-sensor. So for the sensor we spend a total of around 55 euros (without shipping costs). We used a plastic box as a case combined with tape. This was because of the COVID-measurements. So for this product you would have to pay around 60 euros. However if you want to have more accurate test you will need extra sensors and maybe a better casing. So it could be a lot more expensive if you add those. Sensors because for example a sensor to measure nitrate costs around 100 euros.[33]

Also you can use better Ph sensor to test it more accurately. However they are expensive and cost around a 1000 euros. However our relatively cheap options gives a rough, but useful indication about the values of the water. So if the water isn't near a threshold you have a good indication of the safety of the water.

App:

For the app we first had the idea to work with processing, because we had already had some courses into working with processing and after a couple hours of working on the app we could make an app from a processing sketch. We came however to the conclusion that no library supports a connection from a laptop to the app. So we couldn't continue with that.

[33] https://www.conrad.nl/p/soeks-ecovisor-f2-combimeter-nitraat-watergehalte-2226743?vat=true&WT.mc_id=gshop&gclid=CjwKCAiA9bmABhBbEiwASb35V8D2U91k5kNctenAPho2reMoNrmItfoL6qc6DqDt6bNC_GjyYBQxPBoCpIgQAvD_BwE&gclsrc=aw.ds&tid=9774089998_102830953594_pla-1150822110922_pla-2226743&WT.srch=1&vat=true&insert_kz=8J

Then we tried to connect an esp8266 to the Arduino, because an esp8266 can easily be connected to an app, but unfortunately we couldn't make a connection between the Arduino and the esp8266. So in the end we went for the option explained in the methodology.

Conclusion:

So in the end we had to make some decisions that weren't optimal for example with the sensors and we needed to change the design because of the measurements. But by making these choices we could make the product we wanted to make when we first came up with the idea.

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