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I

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

McLaren

Julian Klep
Jildan Lekanne gezegd Deprez
Joris Köster
Alyson Benthem
Nate Luff
Martin Adelbert

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Chapter 0: Introduction

We are Team 4: McLaren and our general goal is to help tackle climate change. As a group, we want to face the problem of incorrect recycling. We aim to do this by investigating if and how a recycling information system can contribute to a better understanding of how to recycle.

Many recyclable materials are thrown into the wrong bin and therefore cannot be recycled. We would like to see if a system that informs the user about the bin they have to use for their product, helps to better the situation. If the trash is thrown into the right bin, more material can be recycled. On the campus of the University of Twente this problem is encountered almost every day. The material that is lost because it was not recycled, contributes to the deterioration of the climate. That is why we wanted to find a solution for this problem.

The solution was to create a smart garbage disposal system that scans a barcode from items that have been bought from the cafeteria. Once the item is scanned, a colour coded light will turn on that shows the correct bin for the item to be put into. The website will display recycling information about the last scanned item including images and facts. It could then be possible to look up information about items that can't be scanned, such as organic material.

In 2016 a study *[21]* was done which revealed that nearly 9 million tons of trash was produced, out of which half of it ended up in incineration and recovery. There was also a study in the form of an online questionnaire that was done amongst university students which revealed that they have a limited amount of knowledge about waste separation but are positive about it and believe that they separate it well themselves. It was also revealed that students and staff produced 20 kg of waste each on the UM campus (which was also influenced by guests and other non-members of the university). The aim is to do a similar study amongst the garbage bins in University of Twente to see how many people recycle and then compare the results of that with the results of the garbage bin which is implemented with our smart system.

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Chapter 1: Literature Review

Publication 1 *[1]* - Vertical Farming:
Vertical farming could be the solution of providing the growing human population with food. Vertical farms can be established in any ambient building, of course, which comes with a lot of logistical advantages. Crops can be grown where they are consumed, such as in cities or neighbourhoods. Vertical farming also uses space very efficiently, since the farms are vertical, much less surface is used to produce a lot of crops. Vertical farms also use nutrients in an efficient way, nutrients that are not used, are using regular farms, washed away. Vertical farms, on the other hand, reuse these excess nutrients by keeping them in the system.

Publication 2 *[2]* - Vertical Farming:
As the need for more food arises in the world due to the rapid growth of the population which is expected to reach 9 billion by 2050, finding more arable land has become an issue, since around 80% of it is already being used. A proposed solution to this would be vertical farming, which involves growing crops in high-rise buildings on a massive scale. Since the crops will be grown indoors in a controlled environment, the changing of seasons would also not affect the production. Vertical farming doesn't come without any challenges though, as lighting which could be done by LEDs could prove to be expensive compared to using natural sunlight. Another problem closely related to lighting is heating, which would use up a massive amount of energy. Overall, vertical farming includes many advantages over traditional farming such as adaptability and efficiency, but its implementation has numerous setbacks.

Publication 3 *[3]* - Vertical Farming:
This video focuses on a vertical farming base in Wyoming, USA. They explain that while it may be an expensive endeavor now, the different machinations are slowly costing less. They recycle the air that the plants transpire by condensing it and sending it back through their roots. They are also able to change the flavor profile of the produce by using LEDs; different coloured LEDs produce a biological change in the plants. Vertical farming may be great for the future, but it will also drastically change the lives of farmers and their identity in the produce industry.

Publication 4 *[4*] - Awareness:
Raising awareness of climate change for the public and companies is an important task, since it affects us all. There are many organizations around the world to tackle the problem, such as the Kyoto Protocol which is a foundational framework of an initiative that commits countries to reduce their CO_2 emissions over time. As carbon pricing around the world evolves and the consumers become more aware of climate change, it becomes increasingly beneficial to cut down on emissions. Already back in 2007, a study conducted by The Climate Group showed that 27 companies such as BP and HBOS reported to have direct cost savings for taking actions to reduce carbon emissions.

Publication 5 *[5]* - Awareness:

Waste is a big problem today and will be in the future. The high-income class is responsible for 34% of the total waste generation, whilst the low-income class only produces 5% of the total waste. In this video, a CNBC reporter describes how Singapore has fixed its waste problem, mainly focusing on reducing the waste, by creating awareness for the problem, but also, by establishing a well-designed waste management system. As the video describes, the waste problem cannot be solved by just creating more innovative ways of disposing of waste. The problem needs to be addressed at the source, the consumers and companies. Therefore, creating awareness of the problem is a way to reduce total waste production.

Publication 6 *[6]* - Awareness:

Thanks to the Paris Agreement, more fossil fuel companies have to change their operations and products to be more sustainable and environmentally friendly. However, it is clear that they are subtly hinting at the consumer for making the change happen slowe, being more fixated on consumer energy demand instead of the demand of fossil fuel products. This "greenwashing" changes the way that is thought about climate change.

Publication 7 *[7]* - Education:

Education surrounding climate change removes the fear of the subject, and helps people be more aware and active in preventing it. This company focuses on STEM subjects to bring a more dynamical shift towards sustainable development. Children are then better equipped to understand more complex concepts and are able to carry these into adulthood. Education helps people be important climate advocates and strengthens climate resilience, both on a local and global level.

Publication 8 *[8]* - Education:

Education empowers people and especially motivates the young. This company aims to help people understand the impact of climate change. Education is incredibly important in reducing fear for the future and encouraging change so that young people can make informed decisions and take action where necessary. This company works with children all over the world, as climate change is not an issue for just one place, it is an issue for us all to tackle. The way in which we educate young people is very important, which is why this company has created a series of videos to demonstrate what the future will hold if nothing is done.

Publication 9 *[9]* - Awareness:

Being more aware of the issues related to climate change helps to facilitate change. Talking about the near and long-term gains of a zero-carbon economy, including health benefits, will encourage behavioural change within society. It is important to keep tackling climate change even during the covid-19 pandemic. Having a global health crisis does not reduce the global climate crisis. By using campaigns and multimedia products, guidance and training can be provided to everyone.

Publication 10 *[10]* - Vertical Farming:

Vertical farming increases the crop yield per square meter. By growing food in layers one on top of the other in controlled environments, we can better guarantee the level and quality of production year round, regardless of weather conditions. These controlled conditions mean that no pesticides would have to be used and only 2-4 litres of water per kilo of vegetables would be needed. As well as this, vertical farms can be set up in disused buildings, such as office blocks. This reduces the amount of land needed by 10-20 times. As the world moves towards a majority working from home, more and more office blocks will be empty and useless. By turning these into farms, we can reuse this space rather than letting it go to waste.

Publication 11 *[11]* - Awareness:

Climate change is one of the most important challenges of today and the effects are already visible. Ice is melting causing the sea to rise, the weather is changing and animal populations are shifting. Climate change has been identified as one of the greatest health risks. This challenge can only be solved by making people aware of the problem and changing their beliefs and attitudes. Virtual reality is one of the ways to make people more aware of climate change. VR can be used to show, for example, the melting of a glacier in 100 years in just a few minutes of video. This will make the invisible effects of climate change visible and people can experience it themselves.

Publication 12 *[12]* - Education:

Since 2007, public care about climate change has dropped. Among other programmes, the United Nations Decade of Education for Sustainable Development has asked for more education about climate change. This created a demand for tools that could be used to teach this. Games about climate change are one of those tools. With these games people learn about climate change by doing and being instead of reading about it. Science has shown that this is way better because of the emotional pathway that the games create.

Publication 13 *[13]* - Education:

Education makes the biggest difference in what our future will look like, since each generation will shape the world in some way. Studies have shown that if only as little as 16% of high school students in high- and middle- income countries received education about climate change, around 19 gigatons of CO_2 could be reduced by 2050. Students not only need knowledge about the causes of climate change, but also a set of skills which lets them apply that knowledge to solve real world problems. Educating children about climate change can also have an impact on their parents, since when it comes to controversial topics, children can bypass the adults' political ideologies which may have blinded them towards the issue. This effect increases the concern of climate change and also changes behaviours in the environment such as reducing energy consumption or waste production.

Publication 14 *[14]* - Agriculture:

Climate change has effects on agriculture. 14% (and another 17% when land use and conversion are included) of the global CO2 emissions is emitted by agricultural activity. Technology will determine if farmers are going to mitigate and adapt and how well. The adaptation and mitigation potential is greatest in developing countries where there is not as much agricultural productivity yet. These countries are also the most vulnerable to climate change because they do not have enough capital to adapt innovatively. The core of the challenge is producing more food with less resources. Innovative technologies are needed to change the speed of climate change.

Publication 15 *[15]* - Green Internet of Things (GIoT): Applications, Practices, Awareness, and Challenges:

The article discusses possible usages of IoT applications and how these can be environmentally friendly as well as challenges coming up with these. Problems like the amount of E-waste for example are discussed. Also, the different possibilities of where data is processed are discussed, taking into account the great need for bandwidth when it comes to cloud computing for example whereas fog computing needs less bandwidth but also means less efficient processing/ storing of data. The paper gives a good overview of problems people are faced with when it comes to the implementation of IoT and shows which technologies might be helpful in different cases.

Publication 16 *[16]* - GREENIFY: A Real-World Action Game for Climate Change Education:

Greenify is a real-world action game that is supposed to educate players about climate change relevant actions. Players can challenge each other with self-created missions, share their knowledge and try to empathize with positive peer pressure amongst its players. The paper found out in a small scale study of new yorker students and PhD attendants that GREENIFY makes most of the participants think about climate change and even take action. Some also started to create missions to challenge their peer participants. Some stated they did play the game to achieve scores but also the willingness of learning about climate change motivated them. This article might be useful when it comes to developing a game to educate about climate change as it involves many important points that could help a game to be successful.

Publication 17 *[17]* - IoT based Smart Agriculture:

The present paper aims to show possibilities for optimization of agricultural processes, especially farm work, using IoT based nodes. A robot and a monitoring system and a sensor. Due to a lot of spontaneous events that might happen on a farm e.g., wild animals, a system supervising the whole farm and locating possible problems could help increase earnings. The first node describes a robot using GPS for its orientation. It can spray plants, cutting and scaring off animals. Furthermore, it is used to keep vigilance. The second node describes a warehouse using different sensors to check if everything is alright within the warehouse and alarming the farmer in case of any circumstances. The third node is used to control e.g., the water pump, based on real-time field data sent by the robot. The whole system might be connected to the internet, giving the farmer the possibility to supervise the farm as well as control machinery.

Publication 18 *[18]* - Vertical Farming:

Vertical farming is a key point in reducing the impact on agriculture from climate change. This method of growing plants requires less water but, mainly it uses a lot less land. Additionally it is more effective at producing larger amounts of food without the use of chemicals and pesticides. There is no need to enrich the water with minerals when using this method. Though this process seems ideal, there are some factors that affect the environment, such as, the manufacturing of the electronic devices used in setting up a well-functioning vertical farm.

Publication 19 *[19]* - Education:

The problem needs to be addressed at the source, meaning everyone worldwide should be educated about climate change. It is an urgent priority to deliver environmental education in schools as it is as important as reducing greenhouse gas emissions and formulating government regulations. Raising awareness regarding the changes that need to happen in order to control our environment the best we can.

Publication 20 *[20]* - Awareness:

With our current knowledge we can predict some changes that are going to happen to our environment, to our way of living and to the world as we now know it. The CO_2 in the atmosphere has increased to approximately 380 parts per million today, after the industrial revolution. There will be a direct impact on companies, for example the use of the Kyoto protocol, which is an initiative for countries to reduce their carbon dioxide emissions. In addition increasing public awareness concerning climate change, will create opportunities for consumer companies.

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Chapter 2: Identification of General Problems and Challenges

In the previous chapter, the publications that were discussed had overlapping themes and problems. These problems can be seen below.

1. *Global food shortage*
2. *Trash problem*
3. *Overpopulation*
4. *Lack of awareness for climate change*
5. *E-waste problem*
6. *Fossil fuel companies, lack of participation against climate change*
7. *Forgetting the climate to focus on covid*
8. *Agricultural energy consumption*
9. *Create social engagement*
10. *Agricultural phosphate problem*

Global food shortage
There is a global shortage of food, or more specifically, the distribution of food across the world is very uneven, as many people in developing countries cannot either afford it or simply don't have access to it. Global warming has also made agriculture more difficult, as more land has become infertile.

Trash problem
Improper waste management plays a significant role in climate change, as it affects the living conditions of every living being on the planet. This goes for the massive amounts of waste that is thrown into the ocean as well as littering on a smaller individual scale. People don't often pay attention to where they throw their trash.

Overpopulation
The population of our planet is growing rapidly with each coming year, which means more resources are required to uphold society. Resources such as food, medicine, fuel, and also land, because every person needs space to live as well. The planet's resources can only handle that many people, especially if said resources are not evenly distributed.

Lack of awareness for climate change
Climate change is still quite a controversial topic, as there are many who would argue against it, which makes finding and funding solutions much more difficult. Education is one of the most important aspects of our development, which also greatly affects the awareness of climate change. Other than education, there is also not enough campaigning for climate change awareness.

E-waste problem
With trash itself being a problem already, the use of more electronic devices leads to more electronic waste too. Compared to general trash, electronic waste may contain chemicals which are toxic to humans, which makes this type of waste especially dangerous and the management of it very important.

Fossil fuel companies, lack of participation against climate change

The burning of fossil fuels is one of the biggest causes for climate change, but the lack of cooperation from the fossil fuel companies with the climate change cause is concerning. The companies see climate change awareness activities as hostile activities that could potentially lower their profits, which makes it difficult to settle on agreements.

Forgetting the climate to focus on covid

Although the Covid-19 pandemic is very much an issue and should definitely be focused on, it has taken quite a lot of focus out from the ongrowing issues of climate change. It may seem as if climate change was a problem of the past, as now there is a new problem which everyone is focusing on, but that couldn't be further from the truth, because climate change is very much still here and should be focused on as well.

Agricultural energy consumption

As the population grows, so does the demand for agricultural products, which uses up a lot of energy. With technology becoming smarter as time goes on, this would become less of an issue, but new technologies are expensive and in most countries in the world, especially in developing ones, access to these technologies is scarce or nonexistent.

Create social engagement

There are lots of challenges when it comes to making the public enthusiastic over climate change. Often, simple graphic representations of facts don't really do much and because people like to interact with things, the best way to move about this would be to create meaningful engagements with said facts in forms of games or other similar types of media.

Agricultural phosphate problem

The loss of soil phosphorus causes problems in the agricultural department, as it limits food production. The depletion of it has caused high scarcity as well as high need for it, where many developing countries cannot afford to fertilize their soil anymore and food production becomes much more expensive.

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Chapter 3: Identification of Relevant Problems

Aside from the previously mentioned problems, the problems below were found during research and deemed as relevant and urgent issues:

1. *Deforestation*
2. *Loss in biodiversity*
3. *Plastic pollution*
4. *Rising sea level*
5. *Overconsumption*

Deforestation cannot be blamed for one individual cause alone, rather the problem comes from many places, all of which have different reasons behind them. Some of these reasons may be because of the need for more agriculture space, fire, and resources such as palm oil. It can be very hard to combat deforestation, as planting trees may feel like the most obvious solution, due to how long they grow, it is not exactly the most optimal one. One way to combat this would be to do our best to curb it instead, but that would require a lot of planning and talking between many industries and governments.

Loss in biodiversity may seem like a problem which doesn't affect us that much, but that couldn't be further from the truth, as humans rely on nature to solve many of our individual problems such as health and food. Loss in biodiversity is a problem that is caused by many of the other climate threatening problems (such as deforestation and plastic pollution) and threats to this will lead to resource scarcity. One of the things we can still do, is the preservation of endangered species, to keep the ecosystem diverse.

Plastic pollution has become quite a problem in recent times, as the use of it has risen substantially within the past half a century. The problem with plastic is that it's just too convenient, which makes it easy to use it too much. Another problem is that usually plastic tends to be the cheaper option which means that companies are more likely to use that over other alternatives. Due to poor garbage management, a lot of plastic can end up in the ocean, which then can end up in the food circle of many sea creatures, which can be a part of our own food circle. This is one example of how plastic can have a direct impact on our own health.

As global warming gets worse over time, it threatens the arctic, since as the climate gets warmer, the more the ice in the arctic melts, causing the sea levels to rise. This threatens us because it causes more frequent flooding and storms, which can damage our infrastructure. It also threatens the survivability of the animals living in the arctic (such as polar bears).

Overconsumption is caused by the uneven distribution of resources across our planet. The wealthier countries consume more than double the amount that many developing countries consume. This also affects the developed states, as it raises health concerns amongst the public and issues such as obesity have become more widespread than ever in history. There is no direct solution, as it is the mentality of people which has to be changed. The most important thing to focus on with this problem is to raise awareness and mandate regulations.

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Chapter 4: Problem Selection and Motivation

Team 4: McLaren has chosen to tackle '*Plastic Pollution*'.

The reason this was chosen is that plastic pollution is an accessible problem in which a difference can be made. The world around us uses too much plastic. Many items that could be made with more sustainable materials are instead being manufactured in a way that is cheaper and easier. This may be beneficial to large companies, but it is detrimental to the environment. Modern society has come to rely too heavily on the use of plastics, rather than using natural and sustainable methods that have been around for thousands of years.
The overuse of plastics has led to an unhealthy level of plastic pollution in the world. This is harming the ecosystem. People are directly contributing to plastic ending up in the food that they eat. Plastic in the oceans will end up being consumed by fish and eventually work its way back up the food chain to our own plates. This plastic does not decompose. Once it has entered a landfill or been washed out to sea, it will break down into smaller and smaller pieces, poisoning the environment.
As well as this, the creation of plastic requires a substantial amount of energy which is usually supplied by burning fossil fuels. This further adds to the enormous carbon footprint left behind by the use of plastics.
There is room for plastics in our future, but we need to eradicate the use of single-use plastics, and only use plastics in items that are meant to last a very long time.

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Chapter 5: Potential Solutions

Potential solutions to plastic pollution:

1. Trash can that motivates recycling
   > The trash can will scan the product, using a barcode or a camera to recognize the material, and indicate where to throw it away. A point system could be implemented to further encourage recycling. Everytime someone recycles and puts the trash in the right receptacle, they could earn a point. This scoreboard could be placed on a screen near the bins or on a website.
2. Plastic replacements (e.g. bioplastic, glass, tins)
   > By using less plastic, less plastic is produced. Therefore lowering the chance of plastic being deposited into the environment. Replacing plastic bottles with either glass or (resealable) aluminium cans that are recyclable would drastically reduce the use of plastic.
3. Allowance of own cups for the coffee machines on campus
   > At the time of writing, you cannot bring your own cup to the coffee machines around the campus. Using your own coffee cups would be easier and would reduce the amount of waste that is produced when using the disposable cups.
4. Create awareness for the damage that plastic creates to the environment
   > By creating awareness for the plastic pollution problem, people might think differently, this could lead to people trying to avoid, or trying to recycle Plastic. This could be done with an installation or a game.
5. New use for recycled plastic
6. Reusable cups around campus
   > If the cafe's and vending machines all used reusable cups that could be dispensed and collected throughout the campus, tons of waste would be reduced. These cups could be linked to student IDs, granting students a discount for every 10th cup of coffee. If it were expanded to off campus, there would be even less waste.

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Chapter 6: Solution Selection

Smart bin that motivates recycling:

Smart bins would be a useful and interesting addition to campus life. The possibility for students to scan their items if they're unsure of the correct bin can increase the level of correctly recycled materials. This choice is something accessible for the team and it is possible to make a change with. This project could also lead to some interesting data. The change from the current system to the new system will hopefully provide many people on campus with information on what to recycle and when, as it is believed that it is common for people to either not know, or not care, about recycling. The data gathered from recycling the cups could also be used as motivation for the students to keep on doing it, as people tend to get attached to numbers.

Modules	Role given to:
Documentation	Nate, Alyson and Martin
Box design	Julian
Scanner-Arduino-ESP communication	Jildan
Programming LED strips	Jildan
Building the unit	Joris
ESP-Database-Website communication	Joris
Logo/Icon Design	Alyson and Nate
Managing/Organizing tasks	Martin and Julian
Validation and testing of the system	Alyson and Nate

Division of tasks during the project:

The project can be divided into different modules. Julian and Martin managed the group work and organized a bin from the facility management for example. The documentation was mostly written by Nate, Alyson and Martin. Furthermore Alyson and Nate presented and documented a day of testing the system in the Smart XP. Joris was responsible for building the unit and making the esp module communicating with a server that stores the values in a database. He also created a website that dynamically changes based on the last scanned item. Jildan figured out how to realize the communication between the Arduino as well as the communication between the esp and the arduino. Besides that, he wrote the script for making the different LED strips light up, depending on the scanned object.

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Chapter 7: Methodology

Equipment we have to buy:
- Camera (for QR code scanning)   link   ~ 50 euros
- LED strips (for indicating where to throw trash)   link   ~ 15 euros
- 5x RGB strip connector   link   ~ 5 euros
- Sticker paper (putting QR codes on products)   link   ~ 5 euros

Total: ~ 80 euros

Other equipment needed:
- Wires
- Arduino uno
- Power supply
- Tools from designlab
- Wood
- Laptop

Data collection*:

Compare the percentage of the correctly recycled trash of the normal (without smart system) bin to the percentage of the correctly recycled trash of the smart bin. The data of the smart bin is collected a week later than the normal bin but on the same day and at the same location.

By comparing the data, we can make a conclusion regarding the effectiveness of our project and the way it influences recycling.

**Revised data collection plan due to corona measures:*

It was not possible to collect data due to all cafeterias being closed and students to work from home.

Data will be collected from people in SmartXP, who will be surveyed on the spot to ask them what their experience of using the trash bin was, as well as to get their feedback on it.

Technical Description:

The QR code scanner communicates via serial communication with the Arduino Uno. The Arduino then lets the different LED strips turn on, based on the scanned item. It also sends data to the ESP32 module via serial communication. Both modules were used, as the ESP32 module is only capable of 3.3V serial communication, which did not work with the QR code scanner. The ESP32 then redirects the information to a SQL database using an HTTP request [22]. A website was created to give the user further information depending on the scanned item. It dynamically changes to show a page of the type of what waste the last scanned item was. AJAX protocollation was used to realize this. The system can easily be expanded with more units showing data and values of scanned items around the campus.

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The box design was made with Fusion360 and lasercut in the Design Lab, as well as the soldering of an Arduino shield, which connected all the parts.
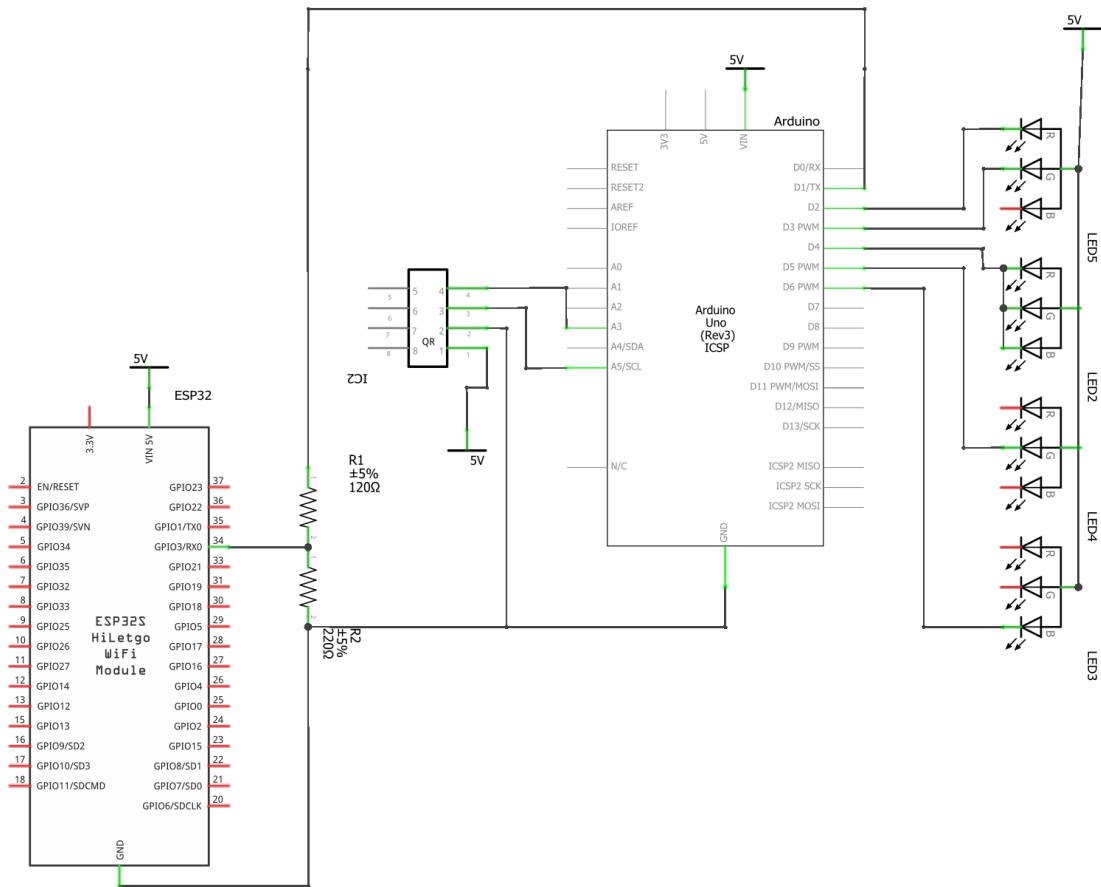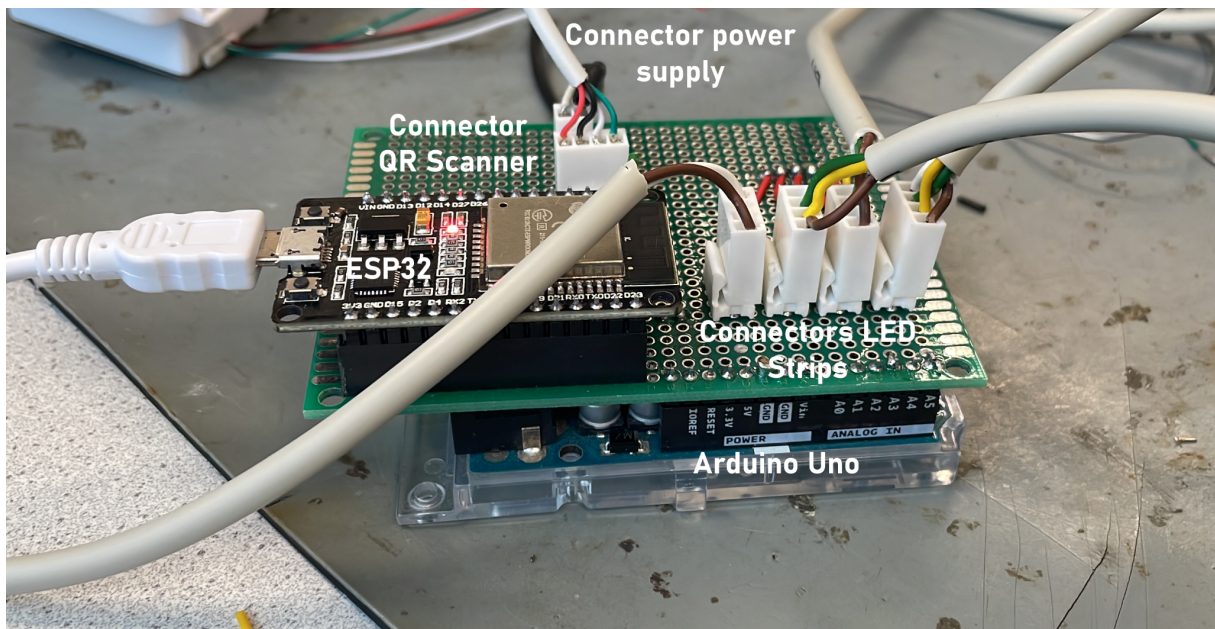

Schematic of connections
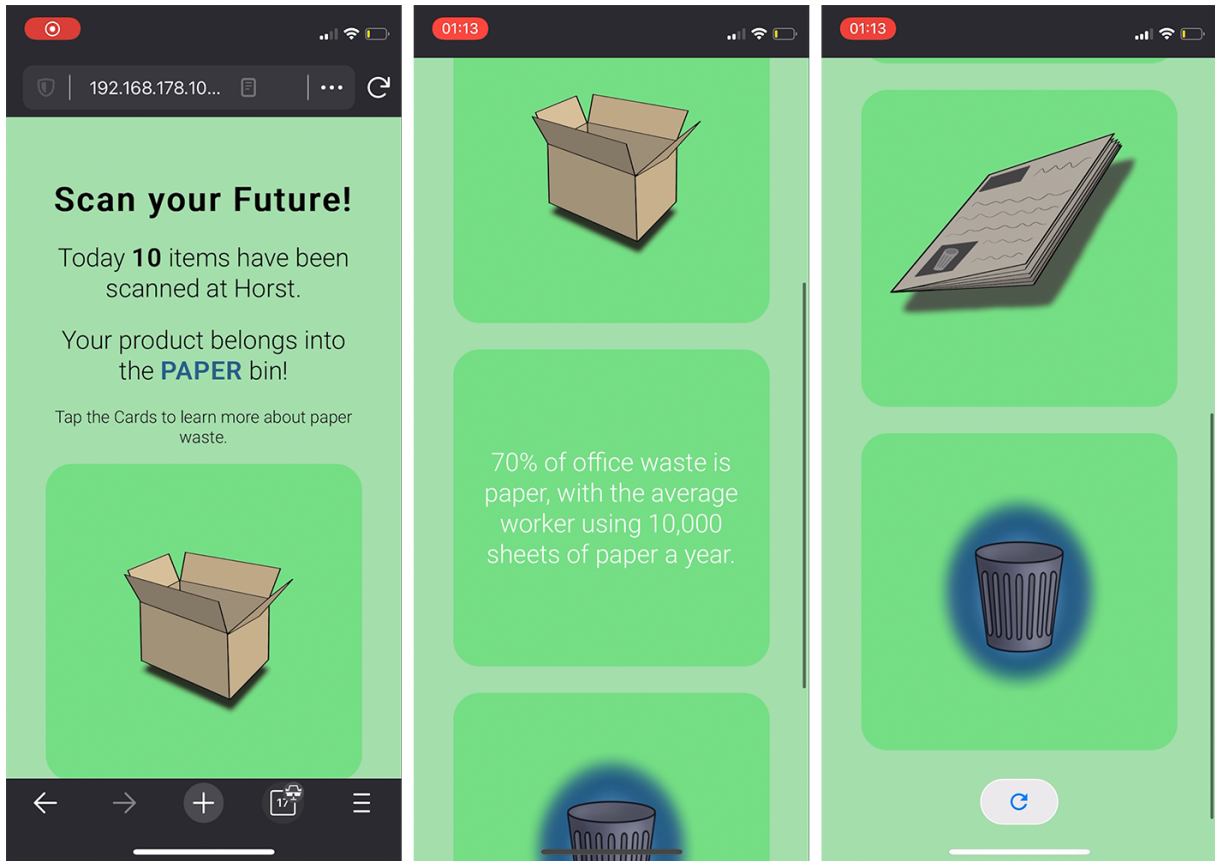
Screenshots of the website, showing the flipcards, and the refresh button on the bottom.

The Arduino shield, connecting all the components.

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Chapter 8: Validation

For validation we spent a day in SmartXP to ask users about their opinions on the experience of using a trash bin implemented with our system. The users were asked to provide feedback as well as general comments about the idea.

Some of these comments include:

"Amazing images, very nice lights."

"I love the QR code and the beep when scanning something. It would be useful to make the LEDs more visible. I like the facts and the website."

"I think it's very cool, nice light indication. Using a screen could work as well, but lights are better."

"I expected the paper cup to be in paper, and it looks good."

"It works surprisingly well, I would actually use it, especially with pmd and residual. Putting the website icons next to each other on a computer would aesthetically look more pleasing. It looks great for a prototype."

The general consensus was that people liked our idea and design. The LEDs were a good idea, but we should've placed them differently to make them more visible. Implementing a screen could help to further indicate where waste should go, but isn't necessary. And finally, people definitely learned something about recycling, which was apparent when they were surprised that paper cups go into "Residual" and not "Paper".

Research done on correct recycling of products:

Many testers were unsure about the correct recycling of, specifically, single use paper cups such as those dispensed by the campus coffee machines. To ensure our advice was correct, more research was done.

Paper cups cannot yet be recycled widely within the EU. This is due to the cups being lined with a thin layer of plastic that prevents them from being processed at a paper recycling facility. There has been a lot of research, testing, and development in recent years to make recycling possible on a large scale [23]. So far, the UK is able to recycle a large amount of paper cups through the four facilities able to process them. Unfortunately, as of January 2021, this is not possible throughout the rest of Europe [24].

Some paper cups are lined with a wax-based waterproofing and as such would be accepted by paper recycling companies. However, as these are the minority of cases and it is almost impossible to distinguish between the two types, all paper cups will be sent for incineration.

This case is a great example of testers believing they are recycling correctly but unfortunately do not know all the facts. Our system will help to educate and inform users at the point of recycling to prevent material being sent to the wrong place.

Leiden University has produced a useful series of posters to aid in correct recycling [25].

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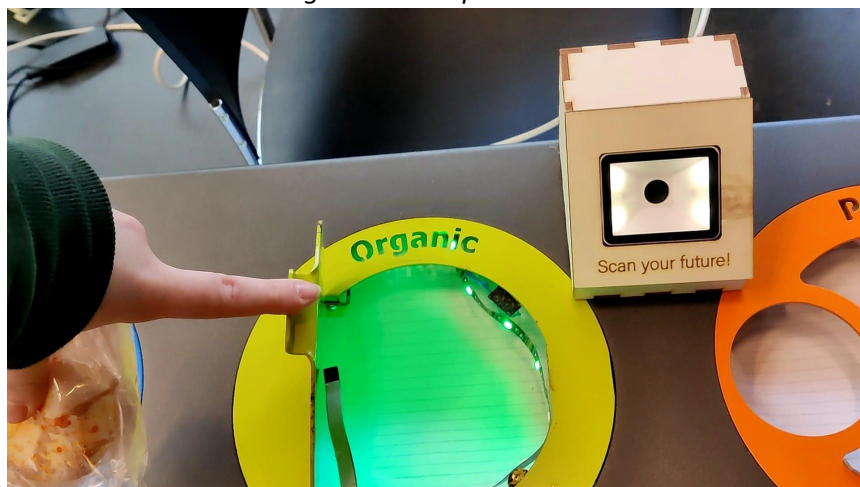
The following images show the system in use:

Approaching the system:
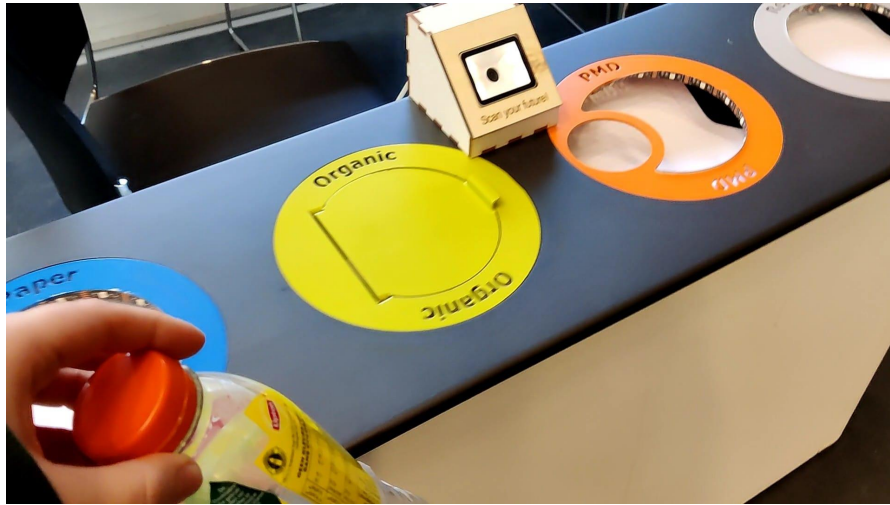
Scanning a product:

LEDs turning on when a product is scanned:

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Chapter 9: Results and Conclusion

There were some challenges faced, as due to Covid-19, there was no way to receive results from cafeterias in time, and the small sample of people isn't enough to prove how widely the system would be adored in more public spaces. Despite that it still gave a general feel for how a user might view the system.

The implementation of QR codes on the scannable products encountered no technical errors, as the camera picked them up quite well from a reasonable distance. Considering most of the positive feedback was directed towards the intuitiveness of the product scanning, it is safe to say that the camera is a success.

For this project QR codes were placed manually onto products to demonstrate the scanning. It is not realistic that industries would adopt this QR code system for recycling purposes, it's just a proof of concept, as our system also can recognize barcodes. When scanning barcodes, our system picks up the first number it recognizes, and processes that to light up the bin with the corresponding number. This means that making a small change to a barcode by adding additional numbers at the end to indicate the product material would make the implementation of our system plausible. As the barcode indicates what material it is, that opens up the possibility for countries to sort the products in their own way for recycling. This proves that this could be a potential solution for better waste management across the world.

To conclude, after surveying users, it was shown that people liked the general idea of scanning an item and placing it where the lights turned on. It also showed that not everyone knew how to sort all types of trash, as the placement of 'PMD' and 'Residual' surprised some users, which proved that our system created more awareness than simply reading the placement of trash from a list. The intuitiveness of the camera also made scanning items easy and some of our initial fears of users finding it more of a nuance than improvement were lifted.

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Euripides Christofides helped with this project for the first few weeks

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