UNIVERSITY OF TWENTE.

Faculty of Electrical Engineering,
Mathematics & Computer Science

Educating the UT Community on waste separation in a playful manner using a physical installation.

Johannes K. Nielen

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Supervisors:
dr. K. Zalewska
ir.ing. R.G.A. Bults

Faculty of Electrical Engineering,
Mathematics and Computer Science
University of Twente
P.O. Box 217
7500 AE Enschede
The Netherlands

Abstract

With sustainability becoming more and more important with constantly evolving rules and goals the University of Twente has to improve on this aspect as well. The specific area discussed in this report being waste separation. One of the biggest barriers to proper waste separation is a lack of education on subject and that is the issue this report tries to find a solution for. Thus the Research Question is: ”How can the UT community be educated on waste separation in a playful manner using a physical installation?” To answer this question the creative technology design process will be used. First background research is done and stakeholders requirements will be formed. These will be used in order to come up with concepts and of the final concepts, one will be built. The concept build was like an arcade type machine with a story and 2 mini-games. The installation was successful in educating the community and users enjoyed interacting with it. The 2 player aspect used was very much enjoyed by the users. For similar research would be wise to try and multiple iterations made throughout as this allows for more feedback and likely even better results.

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Chapter 1

Introduction

1.1 Situation

Sustainability is a big theme in today's society. Due to climate change and all different kinds of pollution, the demand for solutions to these and similar problems has increased. Proper disposal of trash is one of the challenges encountered by many different groups. When disposed and separated correctly, trash can largely be recycled, serve a second purpose, or be used for generating energy. When trash is not separated properly this can lead to it being burned as well as rendering parts of the waste stream that it polluted unusable for recycling. The University of Twente (UT), along with other institutions across the Netherlands needs to become more sustainable to keep up with the sustainability goals of the Netherlands. One of the goals the UT has set for itself is becoming waste free by 2030. This does not mean that no waste will be present on campus at all but that residual waste will be cut down to 10.5 kilograms per person per year, and that PMD waste is cut down to 2.5 kilograms per person per year. As aforementioned, PMD waste not separated properly cannot be recycled properly and if non-residual items get thrown into residual, this also unnecessarily increases the amount of residual waste which is not desired when trying to limit it. UT-CFM (University of Twente Campus Facility Management) has found that in 2020 [1], across 4 samples taken from different locations on the university campus, 77.8% of trash in the PMD bin was actual PMD and only 32% of trash in the residual bin was residual waste. For this research a waste island from the Waaier and it contents were analysed by the researchers on May 17th, 2023 A. This time it was found that in the PD waste stream, 35.9% of items were separated incorrectly, and in Residual 19.6% respectively. However, in the paper stream 100% of waste was separated incorrectly since it was all contaminated paper. To increase recycle rates proper separation needs to increase, especially considering the university its goal of a waste free campus by 2030.

1.2 Challenge

The hypothesis is that the UT community is not fully aware of how to recycle and what happens afters waste is thrown away. This is backed up by previous research from last year where Senna Claes & Younghun Rhee concluded that the UT community does not always know how to separate waste properly [2] [3]. The challenge therefor is educating the UT community about waste separation to make them care in a playful manner using a physical installation. The UT community needs to be taught what happens to waste after they throw it away. Why are there different waste streams, how are these waste streams filtered again to get the best recycling rates? What can be recycled, what can't? These questions should be answered to the UT community without losing their attention or their sympathy.

1.3 Research question

In order overcome these challenges the following research question has been proposed:
How can the UT community be educated on waste separation in a playful manner using a physical installation?

To answer the main research question two sub-research questions have to be answered using background research and the state of the art needs to be examined. The results of this research will then be used in order to ideate and design concepts which will in turn be used to develop a final prototype. The sub-research questions are:

1. What are the main barriers preventing proper waste separation and recycling?
2. What strategies are there to improve waste separation and recycling?

Chapter 2

Background Research

2.1 Literature Research

2.1.1 Barriers for waste separation and recycling

The current recycling system does not work optimally. But what are causes of this and what are factors that keep people from separating their waste correctly in general? And do these factors fit within the picture of the UT community? Deus et al [4] concluded that financial limitations are the main barrier when waste separation was researched in small municipalities in São Paulo, Brazil. The three other most prominent barriers were the lack of clear strategies in public policies, a low educational level on waste and the operational equipment being obsolete and insufficient. Considering the situation with the UT community, problems with operational equipment and financial limitations can be eliminated, leaving a lack of clear strategy and low educational level on waste. Ziqian et al. [5] suggest that perceived ease of use is a direct contributor of behaviour and that without proper incentive behaviour cannot be directly influenced. Previous research from students last year has found through surveying that the waste islands on the UT campus can still be confusing which in turn could demotivate the UT community in the waste separation task. A proper incentive is also a plausible issue, since it is expected that the UT community is aware of why they should separate their waste but still fail to do so with the desired accuracy. Haksevenler et al. [6] had similar findings mainly pointing out knowledge and awareness were limiting factors in solid waste collection as well as a lack of incentives and basic education. This further backs up the claims previously discussed. Nguyen and Aramaki [7] found that newer parts of a demographic can easily be excluded from the residential community dynamic, which includes waste management aspects. They then suggest two factors which cause the main problem, an insufficient sense of community and a lack of trust in authority. Though the UT community is constantly changing so the largest part of the demographic is always relatively new, waste management schemes are communicated through the waste islands themselves, however apparently not well enough to ensure the wanted separation rates. An insufficient sense of community seems unlikely since there are very little people that fully study or work alone within the UT community. However, a lack of trust in authority is something that can be recognised. Rumours of waste being thrown back together after having been separated by the community seem to be widely believed lowering the incentive to separate since it is believed to yield no results.

2.1.2 Improving waste separation and recycling

Strategies for behavioural change

In order to achieve the UT its goals it is necessary to stimulate proper separation in the UT community, this means that pro-environmental behaviour must be induced. Pro-environmental behaviour is defined as behaviour that causes a positive impact on the environment. In order to change behaviour different strategies and tools can be used. Wallen et al. [8] propose the following categorisation of strategies: Education and Awareness (EAA), Social Influence (SI), Outreach and Relationship building (ORB), Incentives and Nudges. EAA is based around educating and raising awareness through materials and resources that provide information. Wallen et al suggest that these are most effective when consumers already are motivated to engage in the wanted behaviour. SI strategies work through the perception of a group or an individual their believes. ORB strategies rely on building a bond and trust with the user or consumer, the goal of these strategies usually is to turn behaviour more sustainable or beneficial to individuals or communities. Incentives are also described by Grilli et al [9], non-monetary incentives as material compensations for individuals that engage in the desired behaviour, monetary incentives as direct payments, discount fees or lottery tickets. The use of nudges is discussed by Carlsson et al [10] , where they define green nudges as behavioural interventions aimed at reducing negative externalities. In their paper, pure and moral nudges are described as well. Pure nudges as a behavioural intervention that aims to make it easier for an individual to “do the right thing”and Moral nudges as a way to reward “doing the right thing” by provoking a psychological reaction to trigger behaviour change.

Since mistrust and a lack of knowledge and awareness were identified as key issues with waste separation in communities, it is important to educate and raise awareness within the UT community without tricking them or withholding information. Persuasive design as described by Tromp et al. [11] therefore seems to be required. It is described as weak and explicit, similar to EAA, meaning that it does require additional motivation in order to cause behavioural change, however the method is pure in the sense that it is fairly obvious to the once being influenced and does not force one into certain behaviour. Seductive design shares these qualities except it is more hidden as opposed to apparent or obvious. It allows for a sense of independent decision making instead of a blatant addressing of one their behaviour. A downside in the context of waste separation is that the quantity of required knowledge might be hard to pass on without it clearly trying to influence.

Gamification

Gamification, the practice of making something that normally would not be a game into a game, might be able to motivate students to learn better [12]. De-Marcos et al. [13] found that social gamification, a combination between gamification and social networking, works best out of four types of gamification and is also the most immediate. It does so by harnessing the motivational aspects of gamification in order to stimulate participation and engagement with learning contents. The social aspects allow participants to cooperate and have meaningful conversation in learning interactions. It also ties together with the before mentioned SI, convincing and educating individuals in a group setting through their believes and opinions about the subject. Bandyopadhyay and Dalvi [14] found that interactive installations have potential to bring out behaviour change. Since interactive installations bond with gamification well due to their similar nature this seems like a design choice with a lot of potential.

2.2 State of The Art

By inspecting technology or different techniques used in the past, new perspectives and insights can be obtained about the problem at hand and how to solve this. The results of previous work are especially precious because they allow for identifying possible pitfalls without a need to experience them firsthand. Campaigns and other actions performed by the CFM-UT and GreenHub will be considered as well.

2.2.1 Waste Separation Installation at the UT

The same problem considered in this report was also proposed last year to other University of Twente students, Senna Claes [2] & Younghun Rhee [3]. These students came up with a system that helped guiding the user in their waste separation as can be seen in Figure 2.1. The installation would be in an idle state when it did not sense any people closely around it using ultrasonic sensors. When in this idle state, the installation would show statistics on how much the individual waste streams had been used to separate that day as well as statistics on if the waste that had been thrown away was thrown away unsurely, incorrectly or correctly. When someone approaches the installation, it would come out of idle state and a selection screen would be initiated. Here the user could go through multiple menus in order to select the item that they wanted to throw away and find out in which waste stream it belonged. The installation would then check by infrared sensors if waste was disposed in the right waste stream in order to update its statistics and thank the user for separating if they did so correctly. When people did not use the selection menus, the installation would ask them if they separated correctly, incorrectly or if they were unsure, using this data as well to update the idle screen.

Figure 2.1: Last year's final prototype

2.2.2 Automatic Waste Sorting Machine

Zemerart Asani together with others managed to make an automatic waste sorting machine [15] as shown in figure 2.2. The project was done as part of a mechatronics course. Their machine was able to automatically separate glass, metal and plastic. They used an inductive sensor, a capacitive sensor and a ultrasonic sensor in order to determine the material the waste objects were made out of. Using an moisture sensor the machine should also be able to detect organic waste and would be able to separate that as well. Although there is no real educational aspect for the user in this machine, the technology could be included in possible solutions and the educational aspect could be added by including active feedback on the user their separation.

Figure 2.2: Automatic Waste Sorting Machine found by Zemerart Asani

2.2.3 Green Hub Waste Segragation Project

Beginning of February 2023 the Green Hub launched a project hoping to improve waste separation on campus. They did so by installing visual aides to already existing waste islands at busy spots in buildings on campus. The visual aides in one location were see-through plastic boxes hanging above the individual waste stream bins that showed examples of the waste that belongs within that stream. In the other locations the aides were boards with either descriptions or depictions of waste on them. The idea being that users of the waste islands would look to the aide whenever they would be confused on how to separate, in order to find out or be able to reason where their particular item of waste should go. Green Hub posted on Instagram alongside this, showing the installations as well as promoting their use as can been seen in figure 2.3.

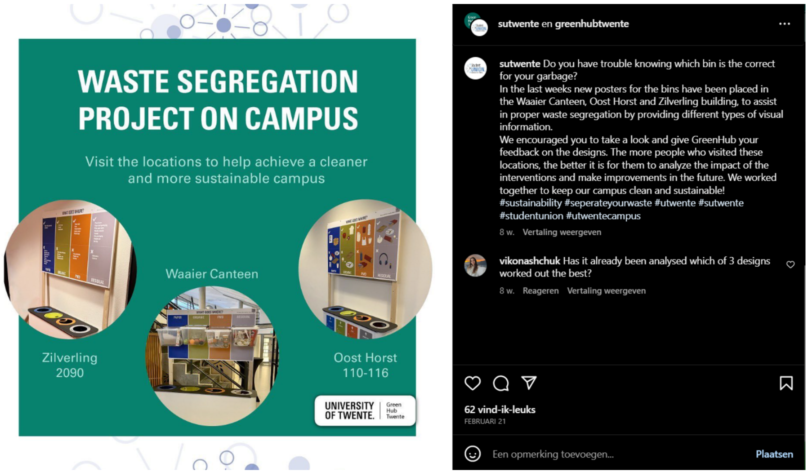

Figure 2.3: Green Hub's promotional campaign as posted on their instagram

2.2.4 The Fun Theory

The Fun Theory (thefuntheory.com) is an initiative from Volkswagen where fun is used in order to make the public do tasks like throwing away trash, fastening your seat belt or taking the stairs instead of the escalator. Making mundane tasks fun allows the public to improve their behaviour while enjoying it. This idea fits perfectly to our research, since we want to make learning about waste separation fun. In figure 2.5 and 2.4 respectively, the piano staircase and world's deepest bin can be seen. The piano staircase makes use of playing piano sounds triggered by specific stairs to make walking up the stairs fun. The world's deepest bin plays a long falling sound followed by something hitting the bottom of a well in order to give users the idea of a long fall. This also intrigues users making them use the bin more.

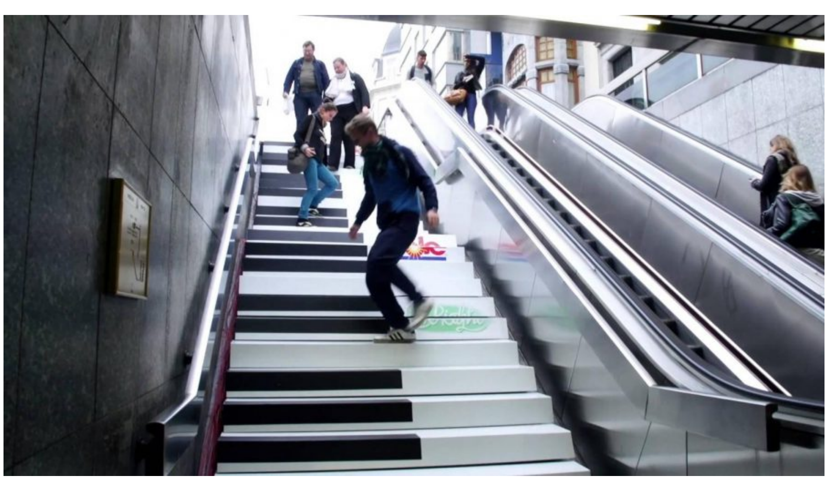

Figure 2.4: The Fun Theory project (thefuntheory.com) Piano staircase

Figure 2.5: The Fun Theory project (thefuntheory.com) world's deepest bin (bottom)

2.3 Conclusion

The goal of the background research is to find ways in which the University of Twente can improve the waste separation within its community, doing so by finding barriers and exploring strategies to overcome these barriers. Knowledge of common barriers regarding waste separation, and strategies to counter them could be useful when designing in order to improve waste separation or recycling rates. The main barriers applicable to the University and its community are: lack of education regarding waste separation, ease of use, no proper incentive and a lack of trust. Examples of these barriers in practice are: measurements of trash separated into the incorrect waste streams and the existing rumours on campus of all waste being thrown together after it has been separated by the community. These issues should be addressed when considering possible solutions, and it makes sense to do so using behaviour changing strategies since the desired outcome involves the UT community changing their separation behaviour. From the discussed strategies, EEA and SI, possibly combined with incentive and nudging seem the most fitting to the situation. As a possible solution, an interactive installation could be considered, combining social gamification and persuasive design this could be a promising solution allowing peers to come to sustainable conclusions together.

Chapter 3

Method & Techniques

3.1 Design Method

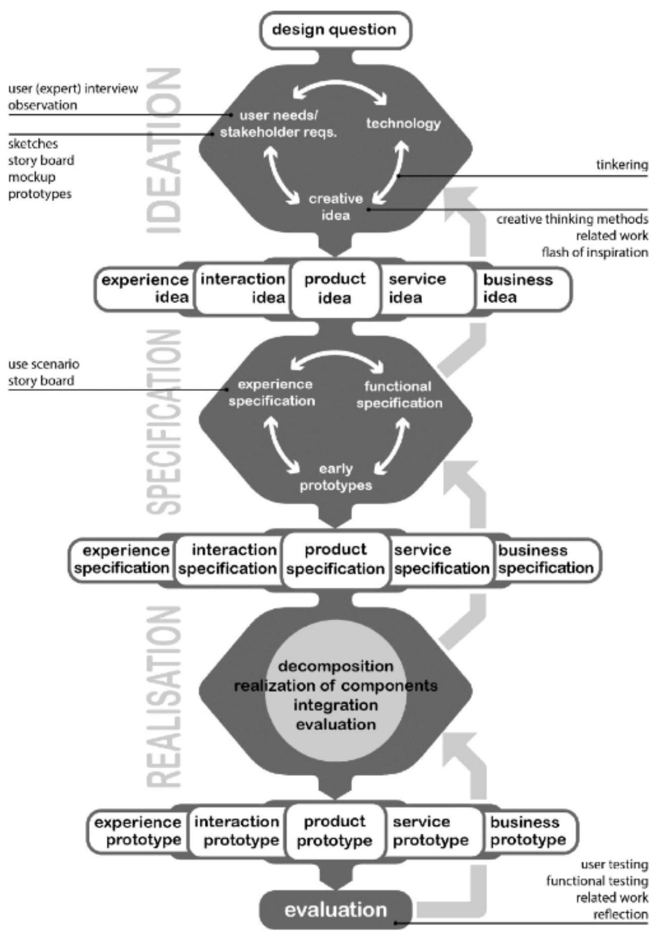

Figure 3.1: Creative Technology Design Method

The Creative Technology Design Method as developed by Mader and Eggink [16] as depicted in figure 3.1 is the design method used throughout this research. This design method was used as it allows for a dynamic design process, evaluating throughout and always allowing for changes while still ensuring all needs are identified and met. The Creative Technology Design Method Consists of four stages and their respective processes:

- Ideation
- Specification
- Realisation
- Evaluation

3.1.1 Ideation

The Ideation stage begins with a design question. What are we designing for whom and for what scenario? By going back and forward between thinking about possible technologies, user needs and stakeholder requirements and creative ideas concepts are found. In the specific case of this research this would be a mix between the experience, interaction and product idea as shown in Figure 3.1. The stakeholders will be identified by brainstorming about which people would be affected by the solution to the set problem. For stakeholder analysis a power/interest matrix as described by Olander & Landin [17] will be used as can be seen in figure 4.1. This matrix allows for researchers to discover where their stakeholders lie within it and how they should handle contact with those stakeholders. It does so by separating them into four groups, which all have their respective actions. As the name implies the factors deciding in which group the stakeholders fall are power and interest, both ranging from high to low. After the stakeholders have been identified and analysed, requirements will be formed.

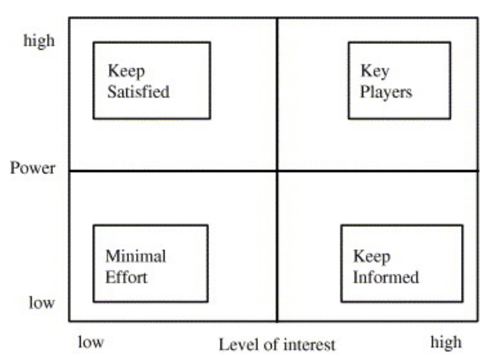

Figure 3.2: Power/Interest Matrix for stakeholder mapping [17]

3.1.2 Specification

In the Specification stage concepts are elaborated upon, experience specifications and functional specifications are established and early prototypes can be made. Within the specification stage there is possibility to evaluate or add on to the results of the ideation stage as new ideas might come to mind as well user needs, stakeholder requirements or the need for different technologies. The early prototypes and experience and functional specifications lead to more complete overall specifications of the design. Once the specification phase is reached one concept has been chosen, but in order to realise it, everything concerning the concept has to be worked out. As the goal is to have a certain experience with the concept, first the experience specification needs to happen. In order to get a better view of the different experience aspects of the concept, user scenarios will be used. These allow for an insight of all the things a user might encounter while making use of the concept. Once it is known what exactly the experience should look like and what possible downfalls might be, it is time to look at functional specifications. Functional specifications are what allow experience specifications to be achieved. In order to tailor a certain experience, the concept needs to function in a way that ensures the wanted experience. Functional specifications are more measurable, whereas experience specifications tend to be more vague or subjective. With all of the specifications identified, the concept can be divided into parts for realisation.

3.1.3 Realisation

After the specifications for the design have been set it will be realised in the Realisation stage by making a prototype. The design of the prototype will be split into different components and should fulfill all the specifications from the previous phase. These will then be realised separately in order to later integrate them. The fully realised design is then evaluated on functionality, appearance and educational aspects . After the evaluation, when the outcome is not as desired, it is possible to go back to the specification stage or fully back to the ideation stage, depending of the results. When doing so, the undesired outcomes can be addressed in the idea or the specifications. When the results of the evaluation are positive the design can be made into a prototype.

3.1.4 Evaluation

When a functioning prototype has been developed, it is ready for further evaluation. In the Evaluation stage, the prototype is tested by users for its functionality. It is compared to related work in order to see if improvements have been made or not and reflection of the entire process and design will be conducted. This reflection can then be used by moving back in the stages in order to make design changes for a better results or giving recommendations to anyone trying to design to solve the same or similar problems.

3.2 Techniques

3.2.1 Requirements Elicitation and Prioritisation

In order to discover (preliminary) stakeholder requirements an interview with the client will be held. Requirements from other stakeholders will follow after identifying the stakeholders by questioning them as well as brainstorming and role-playing (pretending one is the client in order to think of specification that might be convenient or necessary). Once these requirements are found, they will be ordered by priority using the MoSCoW method as described by Haughey [18]. This method works on the principle that requirements in a certain process either: must, should, could or would. The requirements that must be met are essential for a successful project. Requirements that should be met would have a large impact if they are realised, however they can be dropped if there would be a lack of time. ”Could” requirements could be implemented if there is enough time and they do not affect anything else in the project. Lastly, ”would” requirements cannot be implemented at this time, however, it would be nice to have it implemented in the future.

3.2.2 Concept Ideation

In order to generate concepts, brainstorming will be used. Brainstorming is a practice where the goal is to try to come with as many ideas as possible, good or bad, in order to get a view of how a certain problem or task could be handled. After a large quantity of ideas has been generated they are evaluated using the requirements that were established beforehand. The ideas that do not pass the evaluation are disregarded. After disregarding the least probable and considerably worst solutions, a selection of 5 concepts is made. The selected concepts will then get worked out in order to find the full potential. After re-evaluating all of the worked out ideas with the requirements in mind, the best concept is chosen.

3.2.3 Evaluation Method

In the evaluation stage, the prototype will be evaluated based on how well it does the task it was designed for: educating the UT community and changing their behaviour.

The stakeholder requirements will also be evaluated. In order to evaluate the prototype for these goals, user testing needs to be done. In order to do user testing ethical approval by the UT EEMCS (Electrical Engineering, Mathematics and Computer Science) ethics committee is needed. The user test will be executed on members of the target group: UT community members, which are primarily students. They will be interviewed briefly before and after using the prototype about their knowledge prior to the experience compared to after and the experience overall. The interview will question if they learned anything from the installation, if they enjoyed the interaction and if they believe an installation like this could help improve waste separation. Results from the user test will be statistically analysed to find their power. There will also be a trash count to measure if the installation actually did improve waste separation compared to previous counts. After gathering all the results from the evaluation there will be reflection on the project in order to give recommendations to similar research in the future.

Chapter 4

Ideation

In this chapter, stakeholders, preliminary requirements, initial concepts and the final concept will be discussed. The stakeholders will first be identified and analysed. Based on the stakeholders, the preliminary requirements will be introduced and discussed based on importance. Using the preliminary requirements, the initial concepts are worked out and evaluated in order to select the final concept which will then be further developed.

4.1 Stakeholders

4.1.1 Stakeholder Identification

The following stakeholders were Identified:

- UT-CFM
- Project Supervisors
- Project Researchers
- Waste Separation Company
- UT Community Members

4.1.2 Stakeholder Analysis

UT-CFM

The UT-CFM is the client for this research. They manage the entire University of Twente Campus and implement sustainable policies on campus as well. Their goal is to achieve the sustainability goals set by the UT, in order to do so improving waste separation is a vital aspect. Since they are the client, it means they are decision makers and have high influence as well as interest in the project as depicted in figure 4.1. They are an important key stakeholder and should be managed closely.

Project Supervisors

The project supervisors are important stakeholders as well. The supervisors are Kasia Zalewska and Richard Bults. They get to advise what the project researchers pursue and what they should not. Through weekly meetings with the project researchers they keep a close overview of what is actually done and provide feedback and guidance on this. Since they supervise the project they have a high interest as well as high influence.

Project Researchers & Designers, Hans & Victoria

The project researchers are essentially the heart of the project. However, the influence held by the researches is limited by the influence of the client and their supervisors. They do make vital decision for the direction of the project. In this research the researchers work as a duo, however this report will focus on the physical installation and that of Victoria will focus on the use of interactive media.

Waste Separation Company

Since this project is about proper waste separation, the deciding institution with regards to how to separate properly is an important stakeholder with high influence as well. For the UT its waste, that is the waste processing company, Pre-Zero. Even though they have low interest in the specific ways waste is separated, it is in their interest to have higher separation rates overall.

UT Community Members

The UT community members are the actual users of the final installation. Since it needs to keep them engaged and interested, they have a high influence as well. However, they do not have a high incentive for better general waste separation, so they have low interest.

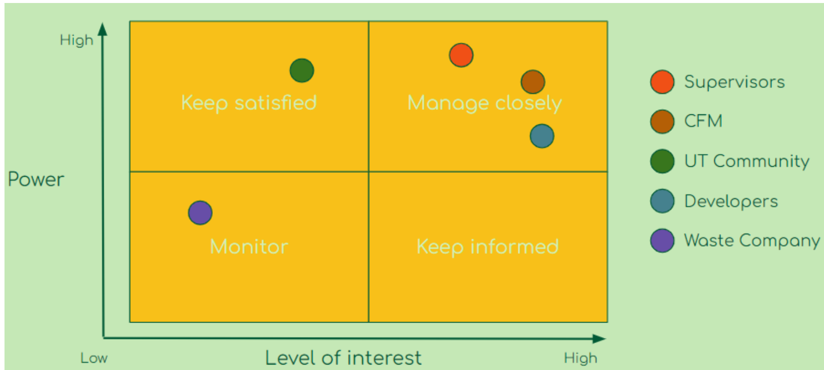

Figure 4.1: Stakeholder Matrix, visualising the power and interest in the project

4.2 Initial concepts

Through brainstorming and conceptualising concepts were generated, by voting a selection was made leaving 5 concepts. These concepts were then worked out in order to gain more insight to how they would work and to what level they corresponded to the project.

4.2.1 Waste Arcade Machine

The waste arcade machine, as shown in figure 4.2 would be an arcade machine functioning like any of its kind. The twist however, would be in the games. By the use of extra story narrative in the games with woven in information about waste separation and/or general sustainability, classic games like Gold Miner, Pac-Man, Snake or Tetris could be transformed into informational games. Using special inputs like the pedal on a pedal-bin the games could be made more waste-related as well.

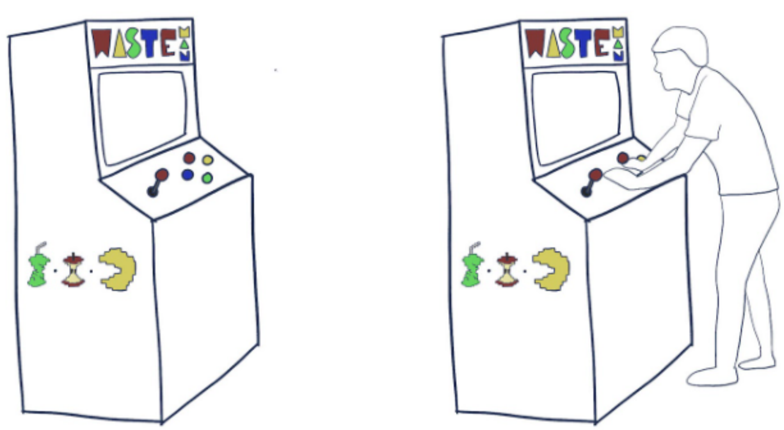

Figure 4.2: Waste Arcade Machine

4.2.2 Waste Game Pillar

The waste game pillar, as shown in figure 4.3 was ideated to be a 3D installation which could be approached from any angle. It would have arcade-like animated lights than when the installation would be idle would light up in order to quickly show by-passers that it is an interactive installation meant to be used. The screens would serve as an explanatory tool telling the user what to do when the game started. When the user would start the game, the pillar would drop items (likely 3D printed) representing items from the four waste streams which would be NFC tagged, the tag storing specific information about the items. It would then be the task of the user to correctly separate the waste as fast as possible in the four bins mounted around the pillar. The bins would have stickers to indicate their waste stream but would also have flashing lights in the colour representing their waste stream, increasing the game-like element of the installation and the urge to be fast and thus learn quickly. By reading the NFC tags of the items in the bins they were put in individualised feedback could be given to the user telling them which items they should correct their separating behaviour on.

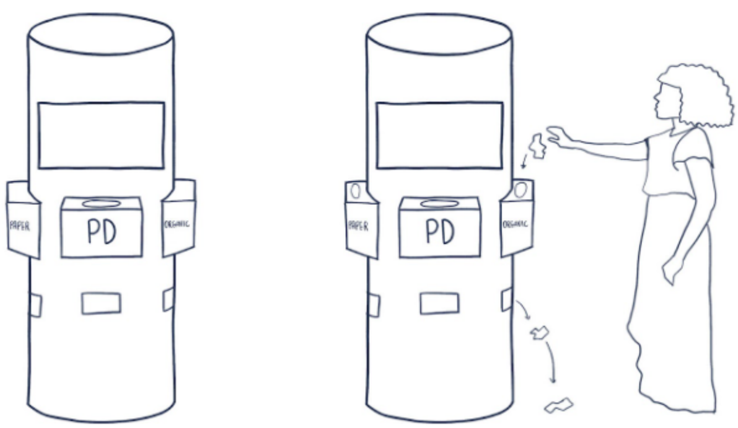

Figure 4.3: Waste Game Pillar

4.2.3 Waste Separation Whack-A-Mole

Waste separation Whack-A-Mole, as shown in figure 4.4 would have an arcade-like, similar appearance to its original. It would also have some similar aspects to the aforementioned waste game pillar. Again, using a screen to explain the game to the user and NFC tagged items representing waste, this installation could also provide personal feedback. This game dispenses items one by one in order for the user to also separate them one by one. Like Whack-A-Mole, the correct hole representing the right waste stream would change per item, thus engaging the users cognitive load. To indicate which hole is which waste stream LEDs would be used switching colours matching the those of respective waste streams.

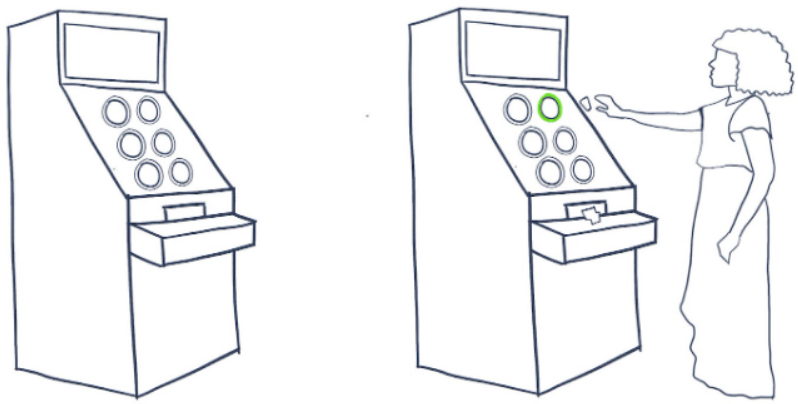

Figure 4.4: Waste Separation Whack-A-Mole

4.2.4 Waste Separation Story Game

The waste separation story game would as the name implies, be a story game. For the installation, a big screen, preferably touchscreen would be used as can be seen in Figure 4.5. The installation would use a story with information about waste separation and sustainability, in order to make the user make certain choices which would then influence the outcome. By making these choices incorporate the theme of waste separation and sustainability the user would be educated on these issues. The big screen would allow for an easy overview, making it easy for users to interact with each other and to make the choices together. This increases the social aspect which as mentioned before in Chapter 2 also enhances the education.

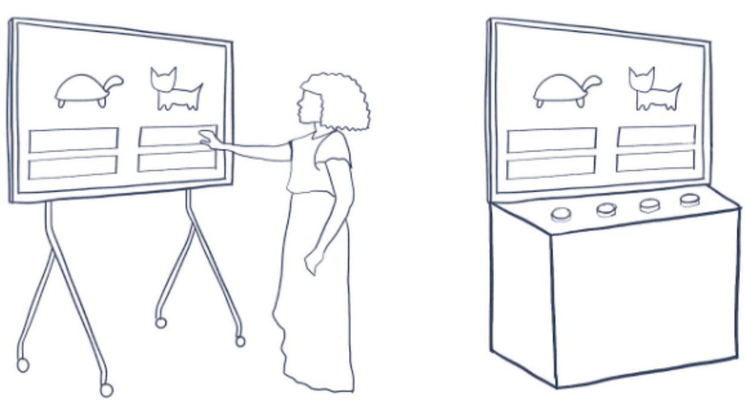

Figure 4.5: Waste Separation Story Game

4.2.5 Waste Separation Hybrid Board Game

The hybrid board game combines digital and physical aspects in one installation. As seen in figure 4.6, the installation would be a table with a screen in the middle. The horizontal form of a table allows the installation to be approached from all angles. It also allows for multiple people interacting with the installation at the same time which is beneficial as mentioned before. The board game would be accompanied by visuals from the screen and audio, guiding the user through the game. It would make the user perform tasks using the physical objects on the table in order to learn about waste separation and the processes behind is as well as the consequences. The game could be played by multiple people at the same time and they could work together in order to get a better result or outcome.

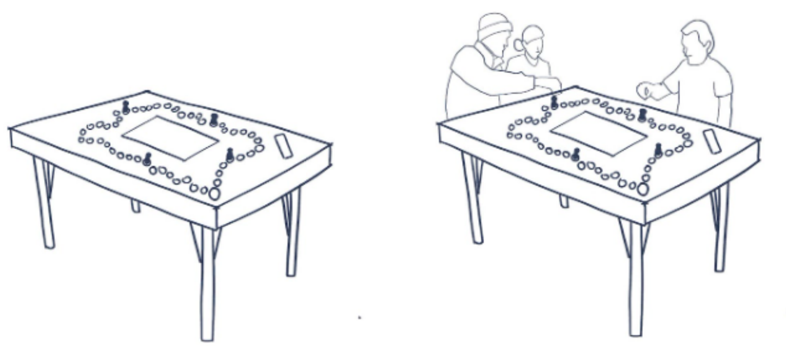

Figure 4.6: Waste Separation Hybrid Board Game

4.3 Selected & Improved Concepts

Considering the key factors and preliminary requirements the final concept was chosen, the hybrid board game. Since it allows for social interaction, a fun environment and a larger number of ways to provide educational information this concept incorporates most of aspects that were found to enhance the educational purpose. After having presented this concept as the selected concept, some feedback was received by the project supervisors, which was then incorporated into the design.

4.3.1 First Iteration

The first iteration can be seen in figure 4.7. The board was switched from horizontally to vertically in order to be more visible from a distance and to people passing by. To this design, LEDs with an idle animation will also be added in order to highlight that the installation can be interacted with and to show its game-like nature. The interaction with the installation needs to be designed so it will not take more than 5 minutes, and in order to make it more fun, players should be able to influence each other whilst playing the game. When asked, UT Community members told us that the social aspect was a major reason for them to play board games or games in general, thus user interaction was also expended. The game will now have to option to either assist or bother other players to increase engagement.

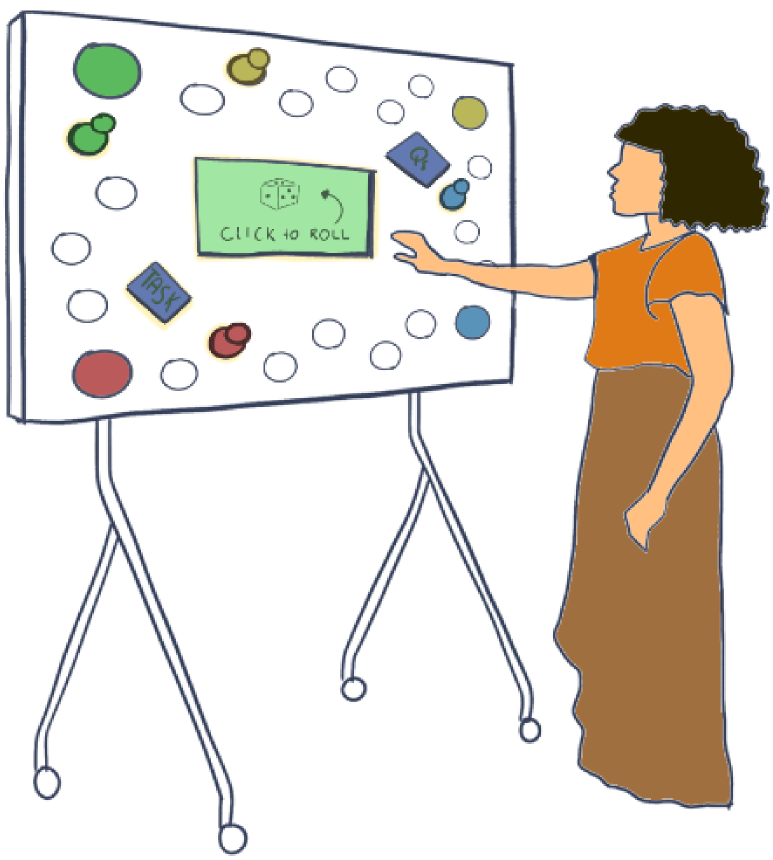

Figure 4.7: First Iteration Of The Improved Hybrid Board Game

4.3.2 Second Iteration

After extra consideration, a second iteration of the selected concept was made as can be seen in 4.8. Like the first iteration, it utilises a more vertical design for better visibility, is operated while standing and still has a screen and board game map. However, in order to increase its intuitiveness, the screen was made bigger and the board map was made smaller and a panel for more intuitive controls was added. A more arcade-like design was chosen for a more obvious game-like appearance.

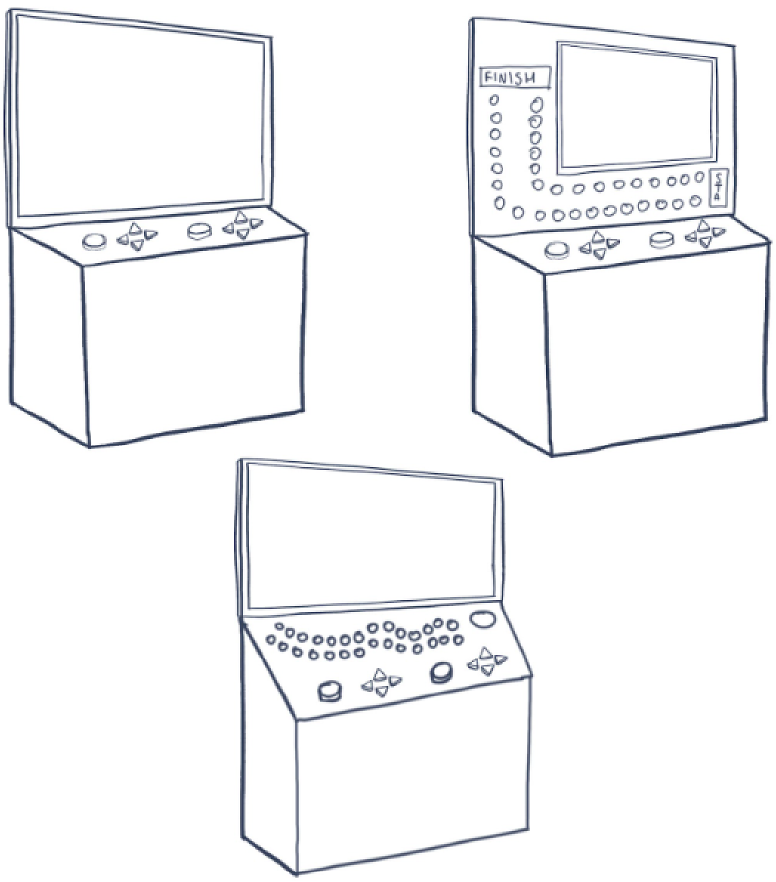

Figure 4.8: Second Iteration Of The Improved Hybrid Board Game

4.3.3 Third Iteration

A third iteration of the concept was made considering sustainability for the materials as well as taking other things into account, like the size of the touchscreen monitor. This led to the design as seen in 4.9. This design allowed for a smaller amount of wood needed and used the stand which the touchscreen monitors are normally mounted on. As can be seen on the image, the workload was divided between researchers. Victoria was in charge of the game design, story and presenting the information. My part was the physical installation: inputs (buttons, touchscreen & distance), physical appearance and communication between input and output subsystems.

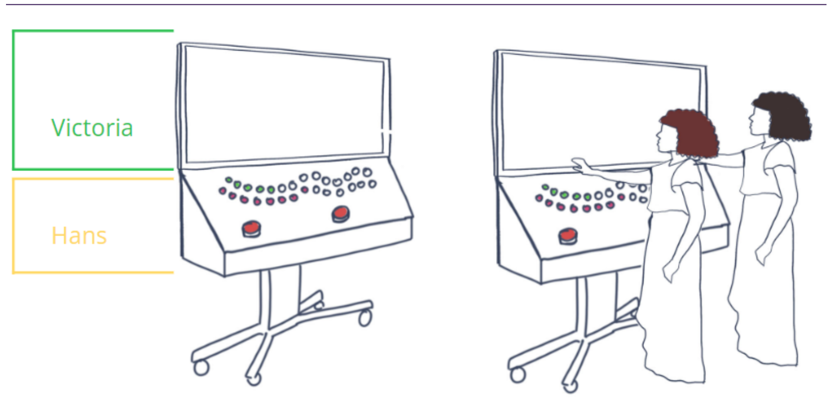

Figure 4.9: Third Iteration Of The Improved Hybrid Board Game

Chapter 5

Specification

Within this chapter the specification phase shall be described. The goals of this phase is developing the improved concept even more and defining it through functional requirements. This is done by first developing a persona to then base an interaction scenario on them. The interaction scenario walks through an entire interaction with the realised concept. In the next section, the system requirements will then be given in order to make sure the final product achieves the experience as set in the interaction scenario. The system requirements will be split into functional and non-functional requirements.

5.1 Persona

Using templates provided by Canva.com a persona was made. Cody is a Creative Technology student studying full-time in Enschede. They mainly care about enjoying life while still passing their courses. Although they try to act sustainably they struggle to do so from time to time due to inconvenience and a lack of knowledge. On University, they use the waste islands to separate their trash but when unsure they throw their trash in the residual bin since they have heard that the residual waste stream gets separated later again anyway.

5.2 Interaction Scenario

5.2.1 Scene 1: Installation Idle

Cody and a friend just finished having lunch at the Waaier. When they go to put away their used dishes, their attention is caught by an arcade like machine with a screen and flashing LED lights. After they put away their dishes they decide to go take a closer look.

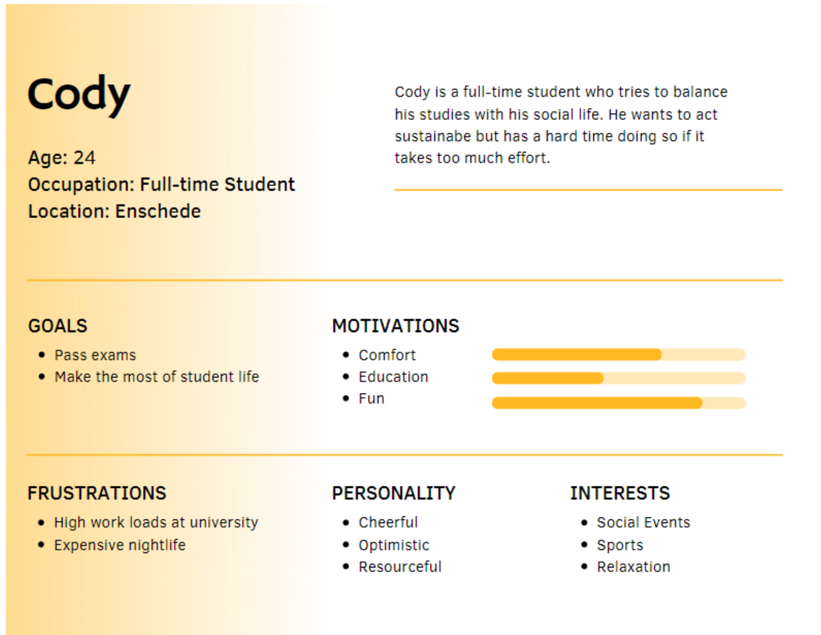

Figure 5.1: User Persona

5.2.2 Scene 2: Approaching

When they walk up to the machine, they first see a text on the screen inviting two players to come and play ”Trashpocalypse”. On further inspection, the installation has a board-game-like road map with LED lights as well as two sets of big buttons. When they get closer a meter to the installation the screen changes. They are now invited to press a button to start the game by a graphic on the screen.

5.2.3 Scene 3: Start of the Game

Curious about the game, Cody and their friend initiate the game by pressing the buttons. The screen changes again and they are shown a scenario in which the UT in the future has been polluted by trash. The narrative tells them the UT has been caught in the trashpocalypse, they are part of the few survivors and can help restore order. Intrigued by the story Cody and their friend keep playing.

5.2.4 Scene 4: First Mini-game

After showing them the after-effects of bad waste separation they see the introduction screen to the first mini-game. Here they have to memorise what waste streams certain trash items belong to, in order to separate them again after an antagonistic character messes the waste streams up. They are told that they can reorder the waste by dragging the items over the screen using the touchscreen. They then are told that they have 30 seconds to reorder the waste and that Cody is responsible for two streams and their friend is responsible for the other two. Depending on how many items of their waste streams have been placed in the correct stream they get points awarded to them.

5.2.5 Scene 5: Scoreboard 1

In accordance to the awarded points, their LED progress bar updates to show their current position in the game. As the physical LEDs light up indicating their positions, Cody and their friend feel progression. The game then tells them that their actions are helping to bring the UT campus back to its former glory, its cleaner appearance.

5.2.6 Scene 6: Mini-game 2

After seeing the positive consequences they are then thrown into a new issue occurring within waste separation. The non-residual waste streams have been polluted and now the items that do not belong in there need to be fished out. They are presented with a Gold Miner-like game where they both have to fish out the residual trash from in between the rest, while everything is moving on conveyor belts. They control this game by timing when they press a button with the swinging of the hook in the game. Based on the amount of residual items they caught they again are awarded points.

5.2.7 Scene 7: Scoreboard 2

The points awarded in the previous scene get added to the points awarded before which lets their progress bars ignite further again. Since Cody scored less than their friend, they realise that some of the things they had assumed about waste separation were wrong.

5.2.8 Scene 8: Ending

Cody and their friend watch the ending animation on the screen. The animation shows that Cody's friend has won and ends the story saying that the university is now a cleaner place but the trashpocalypse is not yet over. Cody and their friend obtained new information about waste separation which they can now use while throwing trash away. When walking away from the installation it turns back to idle mode as they leave its 1 meter proximity.

5.3 System Requirements

5.3.1 Functional Requirements

Functional Requirements	**MoSCoW Priority**
The installation must be able to be used by two users at the same time.	must
The installation must sense users when they are 1 or less meters removed from the installation.	must
The installation must allow for at least 3 manners of input per user. These are: Distance, butto presses & touchscreen touches.	must
The installation must sense when people leave the 1 meter proximity after the game has ended.	must
The installation must have arcade-like LED's with an idle animation.	must
The installation must have at least 2 minigames.	must
The installation should incorporate a touchscreen as input.	should
The installation should go back to idle state after it has not been interacted with for over 45 seconds.	should
The installation should have a LED roadmap which shows the progress in the game.	should
The installation could support single player use.	could
The installation could keep a high-score ranking.	could

5.3.2 Non-Functional Requirements

Non-Functional Requirements	**MoSCoW Priority**
The installation must clearly show the installation is a game meant to be interacted with when idle.	must
The installation must be easy to interact with.	must
The entire interaction with the installation must be at most 5 minutes.	must
The controls for installation must be easy to use	must
The controls for the installation should be intuitive.	should
The input from the users should be processed & communicated to the game without clear delays.	must
The installation should provide feedback after input is given.	should
The installation should induce conversation about waste separation.	should
The user should be able to see their process in the game on the control panel.	should
The installation could be easily movable.	could

5.4 Functional Architecture

5.4.1 Level 0 Decomposition

The level 0 decomposition of the system can be seen depicted in figure 5.2. This is the black box model as perceived be the user. When they come close to the installation it goes out of idle mode, updating the screen. When they press buttons this affects the game as well, resulting in the screen as well as the LED progress bar updating. When the touchscreen is being touched, this passes the locations of the touches and their IDs to the game, for the user the gameplay screen just updates.

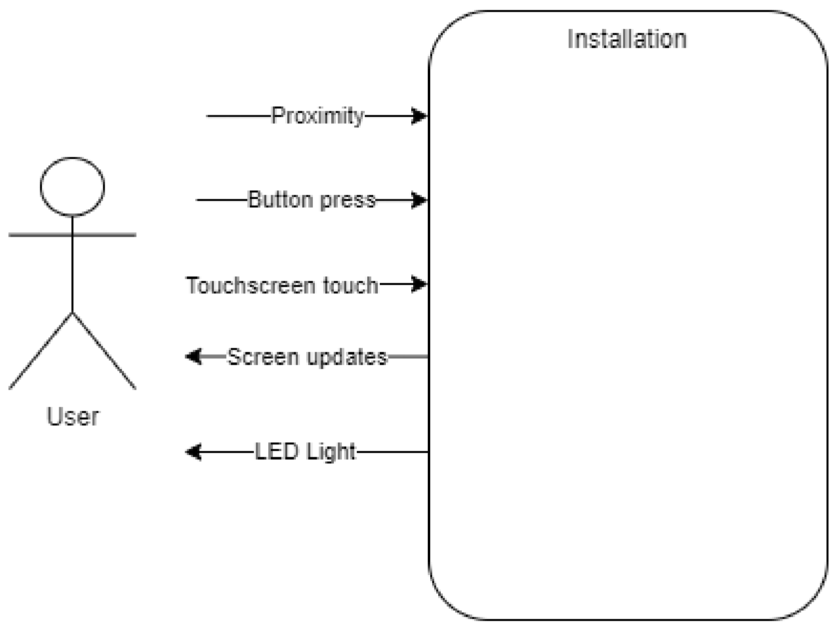

Figure 5.2: Level 0 Decomposition

5.4.2 Level 1 Decomposition

The level 1 decomposition of the system can be seen depicted in figure 5.3. All major inputs are provided by the user. Button presses and proximity are passed to the Arduino micro-controller which then passes them to the game on a computer, touches are passed to the touchscreen, which then does the same. The game then uses the proximity to go from idle to start mode and the button presses and touchscreen touches as controls for the game.

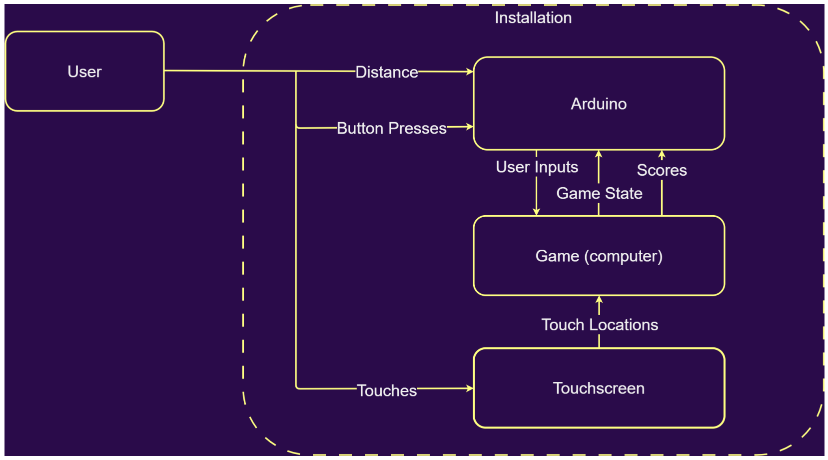

Figure 5.3: Level 1 Decomposition

5.5 Time Sequence Diagram

The interaction with the system can be depicted as the following time sequence diagram.

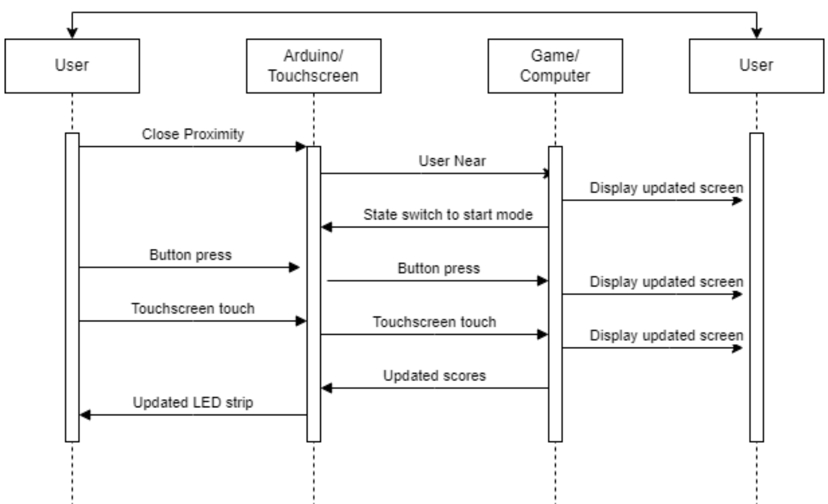

Figure 5.4: Time Sequence Diagram

Chapter 6

Realisation

Following the ”Design Process for Creative Technology”, the next phase in the design process is Realisation. In this step, the prototype is realised. The realised system is an arcade inspired game, consisting of a control panel and a touchscreen. The game will awaken from its idle state when approached by a user. It will then be controlled by the buttons on the panel and the touchscreen, dependent of the stage of the game. My part of this project can be split into multiple subsystems:

- Serial Communication
- Control Panel Physical Input
- Control Panel LED Progress bar
- Control Panel Build
- Control Panel Idle
- Touch Control Unity

6.1 Serial Communication

6.1.1 Arduino to Unity

Using tutorials by Erika Agostellini on erikaagostinelli.com, a simple serial communication between Unity and the Arduino Uno was first set up. The tutorials used simple sketches and circuits in order to show how the serial communication works. Unity is coded with C# which has a serial library, so it was relatively simple to set up. For communication from Arduino to Unity, bytes were used since only three control inputs were connected to the Arduino: the distance sensor and the two buttons.

6.1.2 Unity to Arduino

Communication from unity back to the Arduino was a bit more complex. The Arduino needed to be able to interpret different kinds of incoming info. It needed to set the panel to active mode and reset it to its idle mode on command, and it needed to be able to receive two scores at the same time, in order to update the LED progress bar connected to the panel. To achieve this, strings were used to send information. When users started the game from the start screen ”g” for go would be sent to the Arduino and when it needed to be reset after a full game was finished, ”r” for reset would be sent. In Unity, the score updates would be send throughout or after the mini-games in a string consisting of the scores in numbers separated by a comma. To update the scores on the progress bar, the Arduino would first check if the incoming string was ”g” or ”r” and then afterwards, now knowing it would be a score update, it would separate the incoming string at the comma and the convert the text before and after into integers. These would then be added onto the existing score.

6.2 Control Panel Physical Input

The controls of the game include multiple inputs from the control panel.

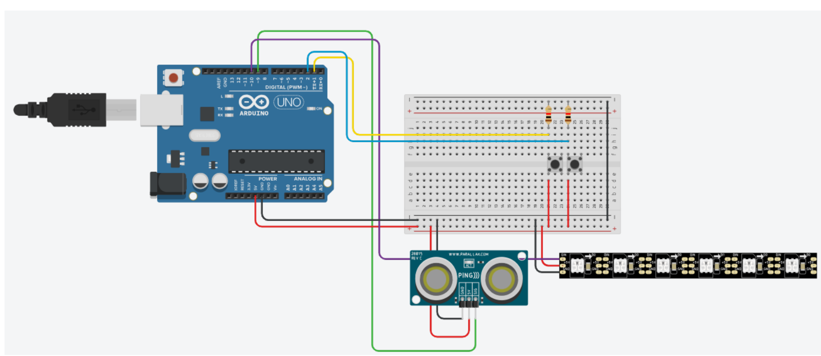

Figure 6.1: Circuit diagram (LED strip depicted shortened to fit image)

6.2.1 Ultra Sonic Distance Sensor

In order to sense users or potential users approaching, an ultra sonic distance sensor was used. This sensor is used by sending out a ultrasonic pulse and then waiting until this pulse bounces back to the microphone mounted on the sensor. The distance between the sensor and the object the sound has hit can then be calculated according to the time it took to travel back and forward between the sensor and the object. This is done by dividing by two due to the sound traveling back and forward and then dividing by 29 since the time is measured in milliseconds and the desired unit of distance is centimeter. These distance sensors however are not the most stable, so in order to ensure some more reliability an if-loop was added in the code where the calculated distance had to be less then 1 meter, six times in a row. After calibrating, six times seemed to be the limit where the Arduino did not falsely send an indication of an object in front of the installation often. Using a higher number could have resulted in even more stable behaviour, however this would result in a longer wait time before the installation switched out of idle. And since a key factor of attracting interest is surprise, the installation going into the start screen out of the idle screen is essential for the purpose of the installation.

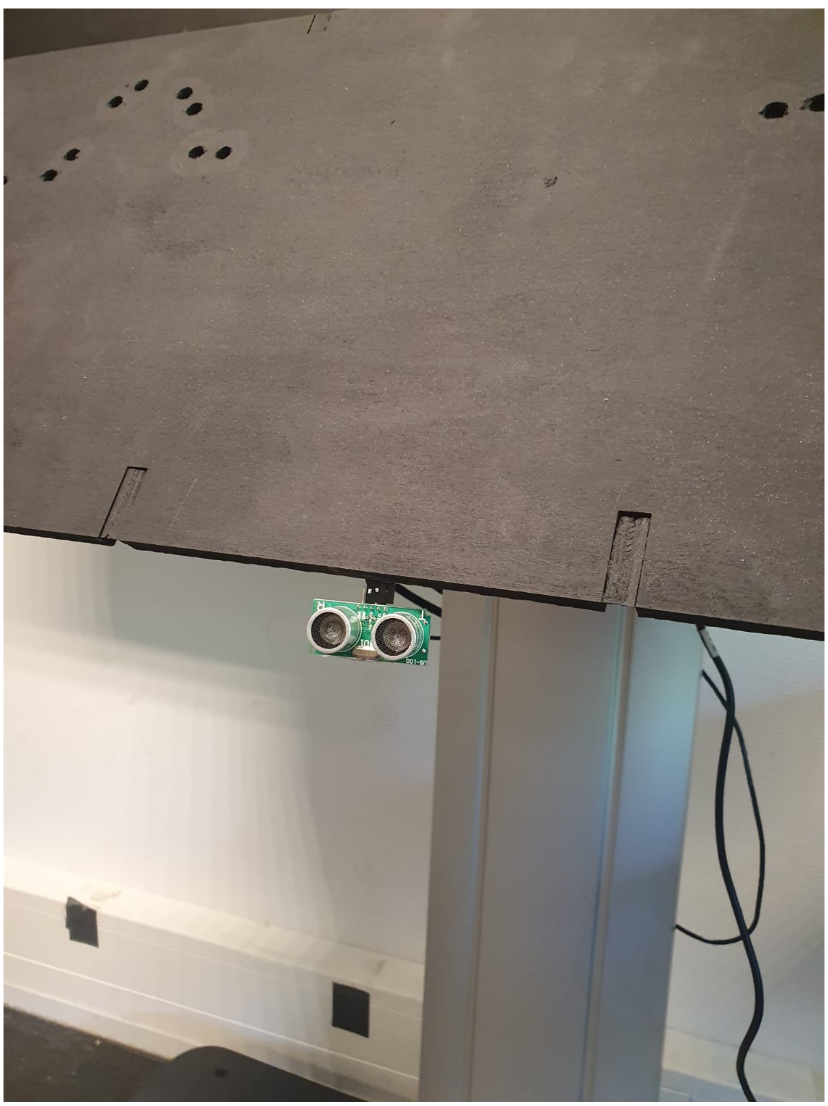

Figure 6.2: Ultra Sonic Distance Sensor

6.2.2 Button Switches

The button input from the panel was made using button switches, multiple were installed in parallel underneath the entirety of the button so it would not get stuck easily. In order to prevent ”floating”, pull-down resistors were used for the button inputs. Floating is a phenomenon that occurs due to high impedance where because an input pin is not connected to the ground it is not pulled to a high or low logic state. Because of this micro-controllers can interpret the value as high or low at random. By connecting the input pin through the ground through a pull-down resistor its default input (without button press) is set to the low state, since the pin measures the voltage over the resistor. When the button is pressed the input pin will go to a high state.

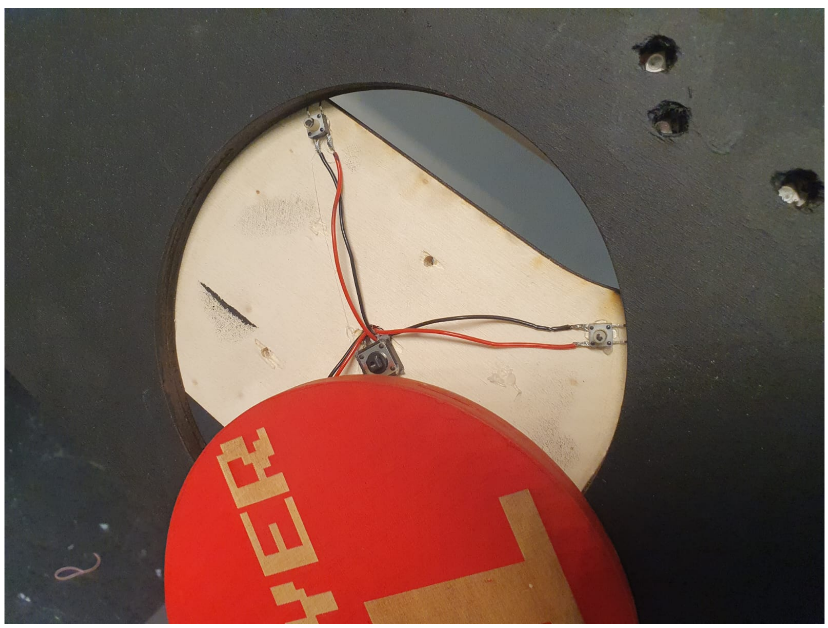

Figure 6.3: Button switches

6.3 Control Panel Build

6.3.1 Laser Cutting And Engraving

The panel was build using laser-cut plywood. The mapping used for the laser-cutting was created in Adobe Illustrator. The dimensions were chosen to fit the CTouch touchscreen and the colours the panel was painted in were chosen in order to match the CTouch as well. The buttons were made with leftover wood from the panel in order waste as little wood as possible and were painted first to be engraved after to make the text look nice.

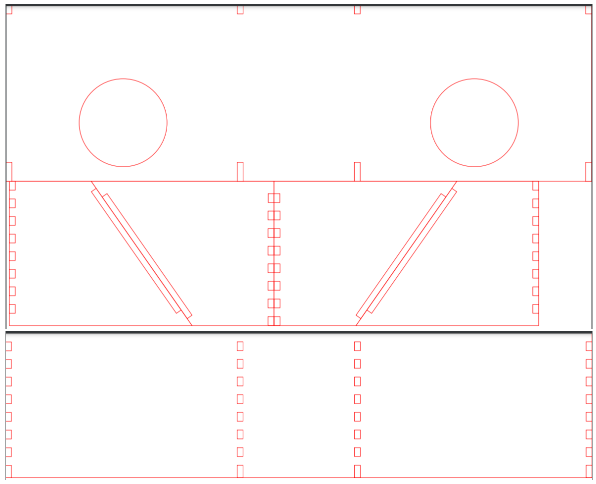

Figure 6.4: front side of panel (top), back side of panel (bottom)

6.3.2 Button Mechanics

The buttons had multiple button switches underneath, in order for the buttons not to get stuck in the panel these button switches were spaced out as much as possible. The direction of the button moving while being pressed was guided using nails. These nails would go through the back plate into the button. The back plates were made with left-over wood from laser cutting as well.

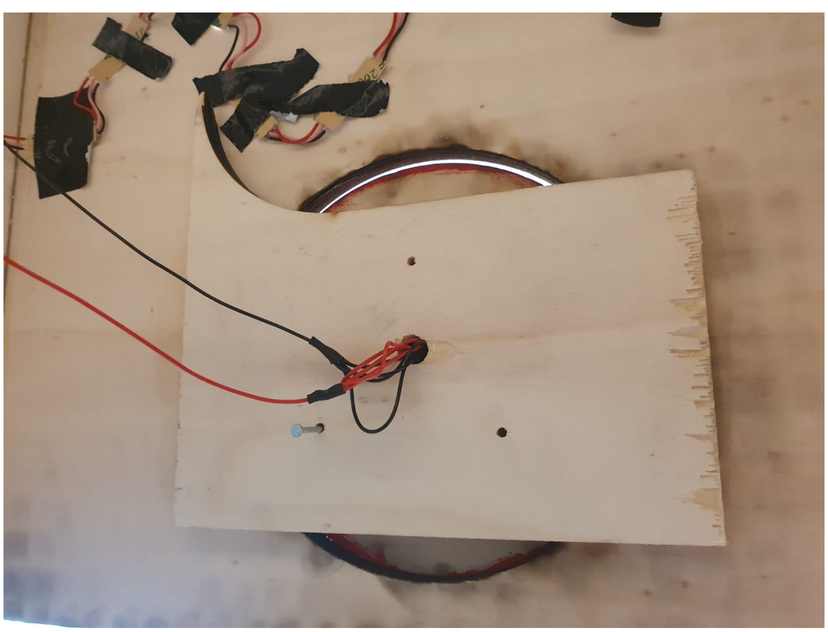

Figure 6.5: Bottom side of the button

6.3.3 Connection To Television Mount

In order to mount the control panel underneath the touchscreen a television mount was used. The panel needed to be connected to this mount thus mounting extensions were made using bolts, nuts and washers.

Figure 6.6: Panel Mounted on TV stand mount

6.4 Control Panel LED Progress Bar

6.4.1 LED Progress bar

Since the progress bar was supposed to represent a route, an LED strip with individually addressable LEDs had to be separated and soldered back together with wires in between LEDs. These new LED strips with wires in between were then used to draw the path of the progress bar on an A4 paper. This paper was then used to line up the spots where holes needed to be drilled for the LEDs to shine through. The paper was flipped for the different sides to make the progress bars symmetrical. The LEDs were then stuck through the holes from underneath as can be seen in figure 6.7.

Figure 6.7: Bottom LED progress bar

6.4.2 LED code

The LED strip code needed to be written in a way where the LEDs would progress symmetrically as well. For this 2 separate for-loops were used which can be found in Appendix C. In figure 6.8 both the idle and active LED animations can be seen.

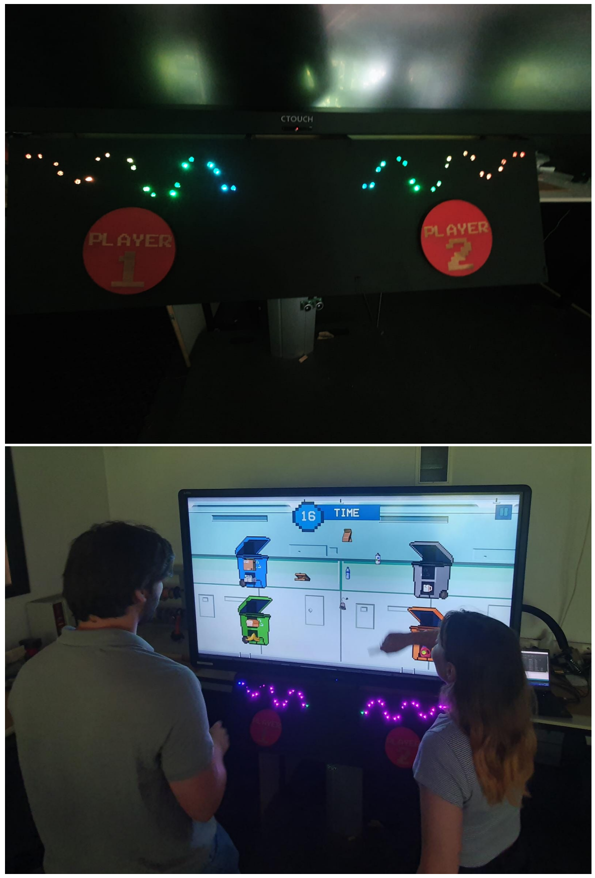

Figure 6.8: LEDs in idle mode (top), LEDs in active mode (bottom)

6.5 Touch Control Unity

CTouch touchscreens allow for up to 40 individual touches at the same time. For this to work with the program, the Unity input Library was used. The ids of the individual touches were stored in the touchable game objects so they could keep track of the fingers dragging on screen and which touch belonged to which object.

6.6 Integration

6.6.1 Arduino Integration

In the Arduino program, a division between idle and active was made. In the idle state, the Idle LED animation runs, button and distance input get checked as well as incoming serial data. Whilst in active state, the arduino does not check distance anymore, the LEDs have a separate active animation and the button input and serial data are still checked the same.

6.6.2 Unity Integration

In Unity, the serial data code was implemented in all different scenes in order to check the button presses or distance sensor. When scores or the game state get updated in the game, unity sends serial data to the arduino to update it as well. The touchscreen code was added to one of the games where the script for the individual would check if they were being touched or dragged on the touchscreen.

6.7 Functional System Test

6.7.1 Procedure

In order to test the functionality of the system a procedure had to be set up. The testing was done by putting the installation in idle mode and then walk through the game to see if everything was behaving as desired. The checklist being: does the installation sense it when someone is close by, does the screen then change, do the buttons work properly, does the touchscreen work properly, does the system go back into idle mode after the game has been finished.

6.7.2 Results

All the ”must” requirements from the functional requirements have been met. Same as all the ”should” functional requirements. However, from the ”could” functional requirements we failed to make a 1 player game and implement a high score system. After running through the test procedure, a number of times it was found that the buttons could get stuck from time to time, the buttons had some delay in them for one of the games and the active LED animation differed between the first time it got initiated and the times after. The delay on the buttons was fixed by changing delays in the Arduino code. The LED animation was fixed by changing the code to be symmetrical. To alter the button design to prevent them from getting stuck there was not enough time before the user testing, so this was left while evaluating the prototype.

Chapter 7

Evaluation

7.1 User Testing

In order to evaluate if the research question could be answered or not, results were needed. These results were obtained through user testing. 33 participants, recruited through WhatsApp messages in groups, and mainly students, observed and used the installation (mostly) together with other participants and were asked to fill in a survey and answer questions afterwards.

7.2 Survey

In figure 7.1 the survey questions and results are displayed. We asked the user testers to rate the installation from 1-5 on different categories immediately after they finished playing the game.

Figure 7.1: Bar Graph results

7.2.1 Open Questions

After the user testers had filled in the survey they were interviewed and asked the following open questions to go more in-depth:

- Did you encounter any technical issues or glitches while playing?
- How did this game make you feel about the concept of recycling?
- Were there any specific aspects of the game that you found particularly enjoyable or engaging? Why?
- What challenges or difficulties did you encounter while playing the recycling arcade game?
- Did you feel that the game adequately educated or raised awareness about recycling? Why or why not?
- How did the multiplayer mode enhance or affect your experience of playing the recycling arcade game?
- Were there any moments in the game where you felt unsure or confused about what you needed to do? Can you describe those moments?
- Did the recycling game inspire you to think differently about recycling or consider taking action in your own life? If yes, how?
- How would you describe the overall atmosphere or mood of the game? Did it match your expectations for a recycling-themed game? Why or why not?
- Would you like to play this game again if you saw it in a public space (such as a hallway)?
- Can you suggest any specific improvements or additions that would make the recycling arcade game more enjoyable, educational, or impactful?
- Any general remarks?

7.2.2 Results

The main goal of the user evaluation is to evaluate if the research question, ”How can the UT community be educated on waste separation in a playful manner using a physical installation?”, can be answered using the conducted research. The main points to be evaluated are education and playfulness as well as the attractiveness of the installation, since users otherwise would not interact with it.

Education

As can be seen in figure 7.1, the question ”How much did you learn about waste separation form interacting with the installation?” on average scored about a 2.9, where 5 would mean that they learned a lot and 1 that they learned nothing at all. After being asked the question: ”Did you feel that the game adequately educated or raised awareness about recycling? Why or why not?” Participants largely responded positively but gave comments saying that they were already interseted in separating and recycling waste, so they already knew a lot. They wanted more information additional to the games to find out where certain items should go and said that they needed more time in the game or multiple run-throughs before they could know everything.

Playfulness

As can be seen in figure 7.1, the overall experience, enjoyment, motivation to keep playing and enjoyment of multiplayer were on average all rated above a 4. 5 would mean that they really appreciated the overall experience, really enjoyed the the installation, were very motivated to keep playing or really enjoyed the multiplayer, respectively, and 1 that they did not at all. After being asked about the overall theme/vibe of the game, the multiplayer aspect and replaying the game, most users again responded positively, saying that they would play it again, they liked the style of the game and the story and they like the multiplayer aspect although some users reported that it did make them rush from time to time, possibly making them miss information.

Attractiveness

As can be seen in figure 7.1, the question: ”How much did the installation grab your attention before interacting with it?” on average scored higher than a 4, where 5 would mean that they could not miss it and 1 that they would not notice at all. After being asked if they would play the game again, one user reported that the installation was attractive and intriguing with a big screen and two big red buttons, however another reported that the installation needed more attention-grabbing features to lure them in.

Other feedback

When asked for specific improvements for the game users mentioned the following options: More feedback, more prominent LEDs, an extra mini-game, more educational information on waste separation and the process afterwards and clearer instructions on the mini-games helping them to learn about waste separation as well.

7.2.3 Discussion

Based on the results, the research questions can be answered. Although a 2.9 on average does not seem high for the educational aspect, it does show that most users did feel like they have learned about waste separation through the installation.
Since the installation got rated above a 4 on average for enjoyment of the installation, being playful can be considered a success.
The average score for attractiveness of the installation was also above a 4, indicating interest from users before even interacting. This can be interpreted as potential users wanting to interact with the installation which then leads to them being educated. Thus the attractiveness aspect can be considered successful as well. Something that could be done in future research is asking participants for what their role in the UT community is, and perhaps their gender and age to see if this data could be used to draw conclusions as well. An extra question that could be added could ask about their prior waste separation education and motivation. Since people who are already motivated to separate their waste correctly, might already know about the information that the game teaches, they likely would not learn as much from an installation like this. and would need to be addressed in a different manner. However, this group of people is also not the focus of the project as they contribute the least to the identified problem of inadequeate waste separation on campus.

Chapter 8

Discussion & Future Work

In this chapter the performance and limitations of the installation will be discussed. Based on these findings, recommendations for future work will be given.

8.1 Appearance

During user testing it was found that the LED progress bar on the control panel was often not seen by users whilst they were playing the game. In order to make the progress bar more prominent multiple options are possible. The touchscreen used was very big, by using a smaller touchscreen the panel would be bigger in comparison making the overview for users easier. Users also reported adding more LEDs to the installation would also increase the appeal, these could then also be used as actuators to events in the game.

8.2 Control

As found before user testing the buttons had some issues. The main problem being that they could get stuck sometimes. This could be fixed by adding a couple button switches underneath so the button could not sink into the socket as far in some spots. Users also reported their buttons not working while being pressed during the story scenes of the game, however button pressing is blocked for the initial 5 seconds per scene so users cannot skip them accidentally and have to read about waste separation more. This could be communicated to them by adding a loading or waiting animation in the story scenes. While working on the serial communication the game sometimes seemed to lag, this was fixed by decreasing the readout time for the serial port in C#.

8.3 Design Process

During user testing some issues regarding the game and installation were found, as well as additions that could be added to the game in order to get closer to having the desired result. If more time would have been left for realisation it would have been possible to test multiple iterations which could lead to better results.

8.4 Future Works

For anyone in the future doing similar research the main advice to be taken would be to start in time with realising a concept so there is time to evaluate multiple iterations. Since the key stakeholders are the end users it is important to tailor the product to them and by going through multiple iterations this is possible.

A second matter to be considered when repeating or doing similar research is how to add even more information into the game without it disrupting the experience . Adding another mini-game seems obvious, but picking a game that fits the theme and makes it easy to intuitively add waste separation aspects into it might prove a challenge. Especially aspects such as the processing of waste once it is separated and the parameters that are involved or an additional larger overview of what waste items go where and why would be good additions.

The last matter to consider is how sustainable you want your work to be in comparison to how convenient it is. The buttons used in this installation were made using the same wood as the panel, this way reducing the waste generated. However, the buttons did cause a large part of installation malfunctions. If the installation will be more permanent it might be worth considering buying proper buttons so the installation might function better.

Chapter 9

Conclusion

The Main Research Question of this project states: ”How can the UT community be educated on waste separation in a playful manner using a physical installation?” In order to answer this research question, two sub-research questions were formulated.

Sub-Research Question 1: What are the main barriers preventing proper waste separation and recycling?

Through background research it was found that a lack of education is likely the main reason for improper separation. Other reasons for poor waste separation include lack of incentive, lack of trust and too little ease of use.

Sub-Research Question 2: What strategies can be used to improve waste separation and recycling?

Through background research it was found that in order to change behaviour in a moral and educational fashion persuasive design should be used. Education and Awareness (EAA) should be raised, Social Influence (SI) can be used in order to change behaviour in this specific case through social gamification which allows peers to teach each other and to be more engaged, and a proper incentive should be provided. All of these can be combined in an interactive installation.

Actualised installation

Through the findings in the background research the requirements for the installation were found. Using these requirements the concept in figure 4.9 was realised. The installation was made for a two player experience in order to use social gamification and social incentive to help the users learn about waste separation. Through mini-games guided by a story the players are taught about which waste goes where and where other waste should not go. The players get immediate feedback in the mini-games to see if they separated correctly educating them further. By pinning the players up against each other they are given more incentive to perform better so they outperform their opponent. The controls for the game were chosen to be simple to make it so anyone can play the game. The design was picked to give the installation a game-like feel to make users want to interact with it.

Evaluation of the actualised installation

With the use of the answers to both sub-research questions the installation was built. The installation was evaluated by user-testing. Users rated how much they had learned by using the installation with a 2.88 on a scale of 1-5, meaning they had learned from it but they were already aware of some of the information too. They rated the installation a 4.18 for attention grabbing and gave the overall experience a 4.12 (both on a scale from 1-5). From these numbers it can be concluded that users enjoyed the game. Users noted that if they would spend more time with the game they could perform better, showing a desire to play the game more and to learn more as well. Combining this with the user feedback saying it would be beneficial having a third game with another aspect of waste processing and an additional information section added to the game would allow for the installation to perform even better at educating the UT community.

Using these answers we can conclude that an interactive arcade style game-installation can be used in order to educate the UT community on waste separation.

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Appendix A

Waste Island Check Results

A.1 Waste Streams

PD			Residual		
items:	Amount:	Should be in:	items:	Amount:	Should be in:
paper cups	43		paper napkins	73	
bubble wrap	1		wooden cutlery	60	
PET bottles	9		paper cups	15	pd
6 cans	6	res	plastic bags	6	pd
wooden cutlery	9	res	paper food bags	13	
plastic contsiners	10		paper bowls	4	
paper napkins	17	res	paper food containers	9	
plastic container lids	2		paper trays	15	
aluminium container lids	4	res	condiment packets empty	3	pd
paper tray	5	res	salt&pepper packages	16	
paper bags	2	res	aluminium foil	1	
paper bowls	1	res	metal key chain lock thingy	1	
condiment packets	6	res	plastic containers	2	pd
condiment packets empty	3		plastic lids	3	pd
drinking cartons	4		aluminium container lids	9	
metal bottle cap	1	res			
plastic food bags	15				
aluminium foil	1	res			
snack wrappers	5				
caprisun	1				
	Total amount:			Total amount:	
	145			230	
	Total good:	%:		Total good:	%:
	93	0.6413793103		185	0.8043478261
	Total faulty:			Total faulty:	
	52	0.3586206897		45	0.1956521739

Paper			GFT		
items:	Amount:	Should be in:	items:	Amount:	Should be in:
paper napkin	139	res	wooden cutlerty	4	res
paper cups	20	res	napkins	3	res
wooden cutlery	28	res	paper food bags	1	res
paper food bags	16	res	portions of rice	2	
plastic wrapper	3	res	banana peels	3	
sandwich bag	1	res	tangirines	3	
paper food containers (waaier	3	res	apples	2	
paper tray	7	res	egg shells	2	
cigaret bud	1	res	ginger slices	10	
			grape vine	1	
	Total amount:			Total amount:	
	218			31	
	Total good:	%:		Total good:	%:
	0	0		23	0.7419354839
	Total faulty:			Total faulty:	
	218	1		8	0.2580645161

A.2 Analysis of Whole Waste Island

Overall total:	
624	
Overall good:	%:
301	0.4823717949
Overall faulty:	
323	0.5176282051

Appendix B

Information Letter and Consent Form

Information letter

In this document, we would like to inform you about the research you have agreed to participate in. In the proposed research, entitled "Improving waste separation on the UT campus", you will be required as a user, to give feedback on a prototype. For this research you will be asked to play a game. This game was designed in order to stimulate proper waste separation through fun and education. Participating in the research will hopefully improve general understanding of the waste separation process. During the playing of the game observations will be made about how you interact with the installation. Afterwards you will be interviewed on your experience and asked if you learned anything. The information gathered by the observations and interview will be anonymous and will only be used to draw general conclusions about the project. Participation in this research is voluntary, and consists of no monetary reward. You can withdraw from this research at any point before and during the observations or interview by telling a researcher you do not want to participate anymore or do not want your data in the research. An overview of the anonymised data will be published in the appendices of our theses in the Creative Technology Thesis repository after the full reports have been finalised.

For any further questions feel free to email Hans Nielen using the following email address: j.k.nielen@student.utwente.nl

Study contact details for further information: Kasia Zalewska, k.zalewska-kurek@utwente.nl

Contact Information for Questions about Your Rights as a Research Participant:
If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

Consent Form for Creative Technology

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	O	O
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	O	O
I understand that taking part in the study involves observations about my interaction with the installation as well as recording my answers to the interview questions.	O	O
Use of the information in the study		
I understand that information I provide will be used for Graduation Theses.	O	O
I agree that my information can be quoted anonymously in research outputs	O	O
Future use and reuse of the information by others		
I give permission for the data that I provide to be anonymously archived in the Creative Technology Thesis Repository so it can be used for future research and learning.	O	O

Signatures

______________________ ______________________ ________

Name of participant [printed] Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_________________________ ___________________ ________

Researcher name [printed] Signature Date

Study contact details for further information: Kasia Zalewska,

k.zalewska-kurek@utwente.nl

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Appendix C

Code

C.1 Arduino

```
#include <FastLED.h>

#define NUM_LEDS    40
#define BRIGHTNESS  100
#define LED_TYPE    WS2812B
#define COLOR_ORDER GRB
#define UPDATES_PER_SECOND 30

CRGBPalette16 currentPalette;
TBlendType    currentBlending;
extern CRGBPalette16 myRedWhiteBluePalette;
extern const TProgmemPalette16 myRedWhiteBluePalette_p PROGMEM;
CRGB leds[NUM_LEDS];
int start, timer, pos1, pos2, state;


String subString[2];
//String incoming;

const int trigPin = 5; // Trigger Pin of Ultrasonic Sensor
const int echoPin = 6; // Echo Pin of Ultrasonic Sensor
const int echoPin2 = 10;
//const int echoPin3 = 9;
const int LED_PIN = 11;
const int pin_button1 = 12; // yellow-left
const int pin_button2 = 8; // green-right
```

```
int pin_slider = A0;
long butTime1, butTime2 = 0;
long duration, duration2, duration3, cm, cm2, cm3; // distance variables
static uint8_t startIndex = 0;

void setup() {
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(echoPin2, INPUT);
  pinMode(pin_button1, INPUT_PULLUP);
  pinMode(pin_button2, INPUT_PULLUP);
  delay( 3000 ); // power-up safety delay
  FastLED.addLeds<LED_TYPE, LED_PIN, COLOR_ORDER>(leds,
  NUM_LEDS).setCorrection( TypicalLEDStrip );
  FastLED.setBrightness(  BRIGHTNESS );
  currentPalette = PartyColors_p;
  currentBlending = LINEARBLEND;
  start = millis();
  pos1 = pos2 = 1;
  timer, state = 0;   //state 0 = idle, 1 = active
  digitalWrite(trigPin, LOW);
  Serial.begin(9600);
}

void loop() {

  if (state == 0) {
    digitalWrite(trigPin, HIGH);
    delayMicroseconds(10);
    digitalWrite(trigPin, LOW);
    duration = pulseIn(echoPin, HIGH);
    delay(10);
    cm = duration / 29 / 2;
    Serial.print(cm);
    Serial.println("cm");
    if (cm < 90 ){
      timer++;
    }
    if (cm > 150 || cm == 0 ){
```

```
      timer = 0;
    }
    if (timer >=5){
      Serial.write(5);
      timer = 0;
    }
    if (Serial.available() > 0) {
      String incoming = Serial.readString();

      if (incoming == "g"){
        state = 1;
      }
    delay(10);
    }
    if (digitalRead(pin_button1) == HIGH) {
      Serial.write(1); // Unity will read this value
      Serial.flush();
      delay(20); // This delay is important - 20 should be enough for
      //a smooth transition.
    }
    if (digitalRead(pin_button2) == HIGH) {
      Serial.write(2); // Unity will read this value
      Serial.flush();
      delay(20);
    }
    startIndex = startIndex + 15;
    FillLEDsFromPaletteColors( startIndex);
    FastLED.show();
    FastLED.delay(100);
  }
  if (state == 1) {
    if (digitalRead(pin_button1) == HIGH && butTime1 <= millis() - 500) {
      butTime1 = millis();
      Serial.write(1); // Unity will read this value
      Serial.flush();
            //Serial.println("but1");
      delay(20); // This delay is important - 20 should be enough for
      //a smooth transition.
    }
```

```
    if (digitalRead(pin_button2) == HIGH && butTime2 <= millis() - 500) {
      butTime2 = millis();
      Serial.write(2); // Unity will read this value
      Serial.flush();
            //Serial.println("but2");
      delay(20);
    }
    if (Serial.available() > 0) {
      String incoming = Serial.readString();
      if (incoming == "r"){
        state = 0;
        pos1 = pos2 = 1;
      } else if(incoming == "p1"){pos2++;}
      else if(incoming == "p2"){pos1++;}
      else {
        int index = incoming.indexOf(',');
        subString[0]=incoming.substring(0,index);
        subString[1]=incoming.substring(index+1);
        pos1 += subString[1].toInt();
        pos2 += subString[0].toInt();
      }
    }
    displayLEDs();
  }
}

void displayLEDs() {
  for ( int i = 0; i < NUM_LEDS / 2; i++) {
    if (i < pos1) {
      leds[i] = CRGB::Red;
    }
    else if (i < NUM_LEDS/2 - 1) {
      leds[i] = CRGB::Purple;
    }
    else {
      leds[i] = CRGB::Green;
    }
  }
  for (int j = NUM_LEDS-1; j >= NUM_LEDS / 2; j--) {
```

```
    if (j > NUM_LEDS - pos2 -1) {
      leds[j] = CRGB::Blue;
    }
    else if (j >= NUM_LEDS / 2 + 1) {
      leds[j] = CRGB::Purple;
    }
    else {
      leds[j] = CRGB::Green;
    }
  }
  FastLED.show();
  FastLED.delay(5);
}

void FillLEDsFromPaletteColors( uint8_t colorIndex)
{
    uint8_t brightness = 255;
    uint8_t colorIndex2 = colorIndex;
    for( int i = 0; i < NUM_LEDS/2; ++i) {
        leds[i] = ColorFromPalette( currentPalette, colorIndex, brightness,
        currentBlending);
        colorIndex += 10;
    }
    for (int j = NUM_LEDS-1; j>=NUM_LEDS/2; j--) {
        leds[j] = ColorFromPalette( currentPalette, colorIndex2, brightness,
        currentBlending);
        colorIndex2 += 10;
    }
}
```

C.2 Unity

C.2.1 Touchscreen

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.EventSystems;
```

```
public enum TrashType
{
    PD,
    Residual,
    Glass,
    Paper
}
public class TrashPiece : MonoBehaviour
{
    [SerializeField] private AudioSource source;
    [SerializeField] private AudioClip pickupClip, dropClip;
    [SerializeField] private RecyclingBinSlot[] binSlots;
    public TrashType type;

    private bool dragging;

    private Vector2 offset, originalPosition;
    private Memory manager;
    private Vector2 endpoint;
    public bool reachedEndpoint = false;

    private float dist;
    private bool swipe = false;
    private int swipeId, touches;
    private Vector2 touchPos = new Vector2();
    private Transform toDrag;
    void Start() {
        manager = (Memory)FindObjectOfType(typeof(Memory));
    }

    void Update() {
        if (!IsStarted() || UnityEngine.Time.timeScale == 0) return;
        if (IsStarted() && !reachedEndpoint) transform.position =
        Vector2.Lerp(transform.position, endpoint, Time.deltaTime * manager.trashSpee
        if (!reachedEndpoint && Vector2.Distance(transform.position, endpoint)
        < 0.01) reachedEndpoint = true;
        touches = Input.touchCount;
        if (touches != 0)
        {
```

```
dragging = false;
int i = 0;
while (i < touches)
{
    Touch touch = Input.touches[i];
    Vector3 pos = touch.position;
    if (touch.phase == TouchPhase.Began)
    {

        Vector3 wp = Camera.main.ScreenToWorldPoint(pos);
        touchPos = new Vector2(wp.x, wp.y);
        if (GetComponent<Collider2D>() == Physics2D.OverlapPoint(touchPos))
        {
            Debug.Log("oof");//your code
            swipe = true;
            swipeId = touch.fingerId;
        }
    }
    if (swipe && touch.phase == TouchPhase.Moved && touch.fingerId ==
    swipeId)
    {
        Vector3 wp = Camera.main.ScreenToWorldPoint(pos);
        touchPos = new Vector2(wp.x, wp.y);
        transform.position = touchPos;
    }
    if (swipe && (touch.phase == TouchPhase.Ended || touch.phase ==
    TouchPhase.Canceled) && touch.fingerId == swipeId)
    {

        if (UnityEngine.Time.timeScale == 0 || !swipe) return;
        RecyclingBinSlot rbSlot = null;
        foreach (var binSlot in binSlots)
        {
            if (Vector2.Distance(transform.position,
            binSlot.transform.position) < 0.8)
            {
                rbSlot = binSlot;
            }
        }
```

```
                    swipe = false;
                    if (rbSlot == null)
                    {
                        // Return();
                    }
                    else
                    {
                        rbSlot.Place(this);
                    }
                    foreach (var binSlot in binSlots)
                    {
                        if (rbSlot != binSlot && binSlot.currentPiece == this)
                        {
                            binSlot.currentPiece = null;
                        }
                    }
                    source.PlayOneShot(dropClip);
                }
                i++;
            }
        }
    }
    }
    }

    public bool IsStarted() {
        return manager.isStarted;
    }

    public void Shuffle() {
        float x = Random.Range(-3f, 3f);
        float y = Random.Range(-3f, 3f);
        endpoint = new Vector2(x, y);
        originalPosition = endpoint;
    }
}
```

C.2.2 Example Serial connection

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;
using System.IO.Ports;

public class LoadAfterTime : MonoBehaviour
{
    SerialPort sp = new SerialPort("COM3", 9600);
    private float delayBeforeLoading = 5f;
    private float timeElapsed = 0f;
    public AudioClip pressButton;
    // toast and double click exit game
    bool doubleBackToExitPressedOnce = false;

    // Use this for initialization
    void Start()
    {
        UnityEngine.Time.timeScale = 1;
        sp.Open();
        sp.ReadTimeout = 100;
    }

    // Update is called once per frame
    void Update()
    {
        timeElapsed += Time.deltaTime;
        if (sp.IsOpen)
        {
            try
            {
                int received = sp.ReadByte();
                if ((received == 1 || received == 2) && timeElapsed >=
                delayBeforeLoading)
                {
                    //sp.Write("g");
                    if (SceneManager.GetActiveScene().name == "StartMenu 1")
                    {
```

```
                    sp.Write("g");
                    Debug.Log("g");
                    SceneManager.LoadScene(SceneManager.GetActiveScene().buildInd
                    + 1);

                }
                else if (SceneManager.GetActiveScene().name == "MemoryIntro")
                {
                    SceneManager.LoadScene("Memory");
                }
                else
                {
                    SceneManager.LoadScene(SceneManager.GetActiveScene().
                    buildIndex + 1);
                }

                sp.Close();
            }
            else if (received == 5 && SceneManager.GetActiveScene().name ==
            "1. Idle Screen 1")
            {
                SceneManager.LoadScene("StartMenu 1");
                //sp.Write("g");
                sp.Close();
            }
        }
        catch (System.Exception)
        {

        }
    }
    else
    {
        sp.Open();
    }

    if (Input.GetKeyDown(KeyCode.Escape))
    {
        if (doubleBackToExitPressedOnce)
```

```
            {
                Application.Quit();
            }
            doubleBackToExitPressedOnce = true;

            StartCoroutine(DoubleClickExit());

        }
}
```