# Improving Waste Separation at the UT Campus

Senna Claes – Creative Technology Bachelor Thesis

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# Abstract

The University of Twente has aims to become more sustainable, and therefore wants to reduce the amounts of waste produced and disposed. Therefore, the waste currently disposed has to be recycled more. However, since the UT community has a lack of waste separation knowledge this goal is hard to reach. The waste is incorrectly separated, and can therefore not be properly recycled. For this reason the client of this research, CFM-UT, reached out to find a solution. Thus, the aim for this research was to find a solution for the incorrect separation of waste at the University of Twente.

To find out why people do not dispose their waste correctly, and how their behavior can be changed, research was conducted. Additionally, a possible solution has been found, designed, and created. The intervention created is the Interactive Waste Island, which strives to positively change waste disposal behavior and educate its users about correct disposal.

An evaluation conducted through user testing with UT community members showed that the interactive waste island is a promising, and successful, concept. waste separation behavior of the participants using the product significantly increased in comparison with the participants who did not. In addition, the participants found the product to be attractive, informative, educating, and that it gave good feedback about their waste separation behavior. However, to use it in a realistic setting some further development is needed.

The client, CFM-UT, positively received the product created during this research and has shown interest to use it for their own future research as well.

# Acknowledgements

During this project, I received a lot of help from different sources, and for all of them I'm extremely thankful. First I would like to thank my co-researcher Younghun Rhee for the pleasant cooperation, and the support we have both given each other during the 2 modules of working on this project. Second, I would like to express my sincere gratitude to my two supervisors of this graduation project, Kasia Zalewska and Richard Bults. Without them this research would have not come as far. Thank you for the help in brainstorming, feedback, comments, guidance, and the (very) fun guidance sessions with helpful discussions. Additionally, I would like to thank my client for this project, Birgit Dragtstra. Thank you for your constant enthusiasm and support during this project, and the opportunities you have given. Third I want to extend my special thanks to one of my best friends Robert, thank you for helping me figure out how to work with Python and how to add my code to the system. Finally, a big thanks to my other friends, housemates, boyfriend, and family for your constant support, and openness to discuss my project.

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# 1. Introduction

## 1.1. Context

Waste is something that people produce and dispose of on a daily basis. To dispose all of this waste in an efficient and convenient way, the Dutch government introduced four waste streams: Paper, Organic, Plastic/Metal/Drink packages (PMD), and Residual [https://www.milieucentraal.nl/minder-afval/afval-scheiden/welk-afval-waar/]. The goal of these four streams is to make waste separation an easier and more straightforward procedure for the general public, but to also facilitate the process that happens after the waste is disposed; recycling and re-using of the waste.

Each of the four streams is given their own color (blue, green, orange, and grey respectively) to guide people in waste separation and disposal. In addition to this, signs are introduced on each bin to increase correct waste disposal. Despite the already existing interventions to clarify the process of waste separation, it can still prove to be more difficult than it initially seems; especially in very internationally-based settings like the University of Twente (UT), as the UT community has some difficulties understanding what the colors on the trash bins are supposed to mean. For the UT specifically, they tried to battle the issue of waste separation difficulty by introducing waste islands at specific spots on campus.

Each waste island has four bins that correlate to the nationally determined four waste streams, with each bin having the specific color that correlates to the waste that should be disposed in that specific bin. However, to make sure that everyone can understand what trash should be disposed in which specific bin, they added imagery and text-explanations next to the already existing signs. Next to general improvement of waste separation, these waste islands are one of the ways in which the UT has worked towards their sustainability oriented goals.

## 1.2. Challenge

Starting in 2020, the University of Twente adopted a new strategy for increased sustainability. This strategy “Shaping 2030” (Dragtstra, 2020) states that the carbon footprint of the UT should be reduced by 15% in 2023 through (sustainable) solutions. Especially for the topic of waste, the following goals have been set:

1. A (single-use) plastic free campus by end of 2022;
2. A waste free campus by end of 2030;
3. A circular campus by end of 2050.

The main goal of this strategy plan is to prevent, reduce and improve waste by means of recycling. The focus of this goal will fit the “circular campus by 2050” goal and be mostly directed at the waste separation at the UT campus.

Following a waste analysis done at the University, it was found that, though the waste islands are supposed to give people all the information they need to separate their waste properly, they do not succeed to the fullest. UT community members do not dispose their waste properly, which results in the residual waste consisting out of 32% PMD, 18% organic, and 18% paper waste. All this waste then ends up in the waste processing incineration installation, since residual waste cannot be used for recycling. However, the 32% PMD and 18% paper waste *can* be recycled, but due to improper waste separation ends up incinerated. This does not conform to the sustainability and recycling goals that the UT has set.

## 1.3. Research Goal

There is still a lack of education regarding the use of the different waste bins. This means that the people at the UT do not know in which bin to throw which trash, resulting in wrong trash separation. However, it could also arise out of laziness. Due to the distinct waste islands, there are no trash bins in e.g. lecture halls and study spaces anymore, which means that people collect their trash together and throw it away in one go. Since throwing away trash should be a short activity that people do not want to spend too much time on, and thus should be as short as an action as possible, the waste islands have

the resulted effect that people throw all their trash together in one bin. Defeating the purpose of having separate bins.

This project's goal is to design an intervention that will influence the UT community's behavior in a subtle way, so that waste separation will not be time consuming and difficult. The research question is the following: "How can interactive media be used to influence the UT community members' behavior of waste separation at the UT campus?".

## 1.4. Structure

The report is structured in different chapters to explain the development process of the intervention to improve waste separation. The second chapter, following this introduction, will go into the background of the waste islands that are placed at the UT, but also look into various ways that behavior can be influenced, with a literature review regarding the best ways that waste separation behavior can be positively influenced. Observational research at the UT will also be conducted and described, where the general behavior of the UT community regarding waste disposal is observed and compared to the ideal situation. In the third chapter the methods and techniques of the research will be discussed, followed by the ideation description in chapter 4. Thereafter the specification of the research will be highlighted in chapter 5. Following the ideation, the realization and evaluation of the project are described in chapter 6 and 7. Chapter 8 will go into possible adaptions for future work regarding this specific topic, and will discuss the limits & constraints, and possible improvements that could be made regarding this project.

# 2. Background research

## 2.1. Literature research

### 2.1.1. Separation of trash

The correct separation of trash has been made mandatory by the Dutch government since the first of July in 2020. This means that municipalities are obliged by law to collect the different waste streams separately (*Gescheiden inzameling afvalstromen verplicht per 1 juli 2020*, 2020). The goal of this plan is to increase the percentage of separated waste to 75% (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2019). If the municipalities do not follow the agreement, they have to pay a fine. Therefore, the municipalities try to motivate households to separate their waste as properly as possible. The University of Twente also has to conform to these rules. However, research by Dragtstra performed in 2020 at the UT proves that separation of waste is still a great difficulty under the UT community members.

#### *2.1.1.1. Issues separating trash*

According to scientific literature, three possible reasons for incorrect separation of trash are feasible. Firstly, people are too lazy to check their waste and dispose of it correctly. The placement of the waste islands at the UT campus, in accordance to the waste plan, means that people have to walk a longer distance from their lecture halls/study locations to throw away their waste. This results in them adding all waste together, and throwing it away in one bunch without separating each part separately; it is too big of a 'difficulty' to spend a few seconds more separating their gathered waste (Dragtstra, 2020). Ámadóttir et al (2018) proves that laziness is an issue with regards to waste separation. Participants in the study demonstrated waste separation behavior, but did not correctly separate the waste into the correct waste streams since they collected their waste together in one pile. Quite some students disposed of the waste while it was not fully separated according to the specifics that had been set for each waste stream. Their conclusion was that waste separation is determined by the waste holder's perceived value of the action. If the waste holder's perceived value is low, they will not separate the waste properly. Laziness in separating waste is thus a big influence in the performance of desired disposal behavior.

Secondly, there is not enough accessibility to the waste bins which reduces the amount of convenience trash disposal takes. Accessibility plays a huge role in combination with laziness. If the option to separate waste is not easily accessible, people will not go the extra mile to make sure their waste is thrown away separately. For this reason, trash cans should firstly not be placed more than 75 meters from each other to limit littering and to improve waste separation rates (City Trash & Recycling & Gumtow, 2016; Sheau-Ting et al., 2016). If placed further away, it is too long of a walk. Secondly, the option to separate waste should be clearly indicated, and convenient of use, since people will otherwise ignore the option and just throw the trash away without separating (Bernstad, 2014).

Thirdly, and most importantly, there is too little knowledge regarding waste disposal. When Zhang & Wang (2020) implemented different waste streams in distinct parts of China, they discovered that knowledge is a highly important part of waste separation. If the people do not know what each waste stream is supposed to contain, they are not able to separate properly. Árnadóttir et al. (2018) proved that most people have high intentions with regards to waste separation ,with a positive viewpoint about the fact, but just lack the education to know the specific differences between each waste stream. Intention is often a good predictor of wished-for behavior, but not when there is a lack of knowledge/skill to perform the behavior in the correct way (Chaerunnissa et al., 2020). This lacking also impacts the encouragement of waste separation; with people not knowing how-, or not knowing that it is possible, to separate waste, it is a difficult process to encourage them to differentiate between the waste streams that they do not even understand/know that exist (Sheau-Ting et al., 2016). Therefore, knowledge and proper education with regards to waste separation plays a big, if not the most important, role in the separation of waste. For this reason, this research is mostly going to focus on how to educate the UT community next to influencing them with regards to the separation of waste.

## 2.1.2. CFM-UT background

Since the end of 2017, a new waste collector started at the University of Twente and waste islands were introduced at central locations in the buildings at the UT to try and collect more waste streams separately (Dragtstra & Marechal, 2020). These waste collectors are also called the 'waste islands' that are distributed all around the UT. The waste islands have the four distinct waste streams (paper, organic, PMD, residual) that should motivate waste separation. Due to the fact that there are now specific 'islands' where the waste is disposed, there are no longer any waste bins near lecture theatres and desks; everyone needs to walk some distance to dispose their waste.

### *2.1.2.1. Design*

The design of the waste bins is influenced by the coloring scheme that the Dutch government implemented nationally, and is meant to influence people to separate their waste correctly. This color scheme being: Blue for paper, green for organic, orange for PMD and grey for residual waste. Each of the colors is represented on top of the waste island, as on the sides, for extra visibility and recognition. The 'names' of each waste streams are represented within the colors. In each color block presented on the side, the icons of the trash that should be disposed in that specific waste stream are presented (see figure 1). In the PMD waste stream part, an extra area specifically for cups is added to motivate people to thrown away their cups in the correct bin, but also to save space in the rest of the bin.

**Figure 1**
*UT waste island*


*Note*. By the Univeristy of Twente, 2022.

### *2.1.2.2. Placement*

According to one of the key members of the CFM-UT, M. Elferink-Drewes, the locations of the waste islands were carefully chosen by a team of approximately 20 people. As a group, they walked around the buildings on campus to determine the perfect placements. Each waste disposal island should have a distance of maximum 75 metres from the previous one. Per building they checked for the most optimal location for a waste island, and for this they had some criteria:

1. The location should be a key point in the building, e.g. close to a lecture hall/study spot;
2. The location should be easily accessible, so not behind pillars/in weird corners;
3. The waste bin should be clearly visible from all angles at the location.

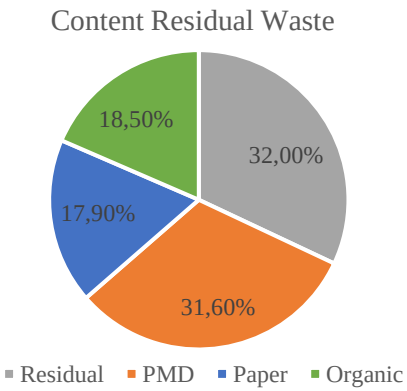
Using these criteria they selected each location thoughtfully. The location placement was first tested in the Vrijhof, building before placing the waste islands in the other buildings distributed around the campus. The Vrijhof building was selected for its broad variance in use. It has the UT library, classrooms, study spots, office space, but also theater rooms; everything that the other buildings have separately, but then contained in one building. The testing procedure took around a week, and after the placement decisions were granted as successful, they implemented the strategy of location-picking in the other buildings as well.

If they noticed later on that a specific waste island in one of the UT buildings was not used as much, specifically because of the location choice, they would move it and go against their own rules for 'the greater good' of motivating correct waste disposal behavior.

#### *2.1.2.3. Sampling of the waste*

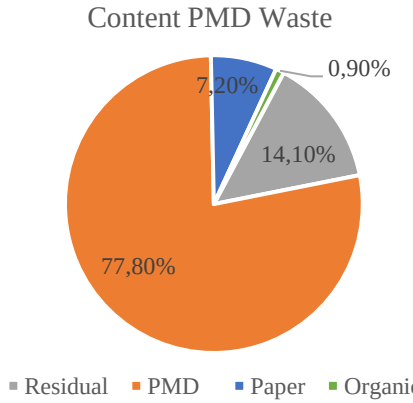
CFM-UT has executed research (Dragtstra & Marechal, 2020) on the subject of waste separation at the University of Twente in January 2020. They analysed the collected waste, residual and PMD specifically, on 4 different locations at the UT. The waste analysed were Residual and PMD, and it turned out that especially the residual waste stream consisted out of a lot of other waste (figure 2), a 68% percentage. It shows that the residual waste bin is being used for all of the waste streams, you could even say that many people from the UT community consider it to be a mixed waste bin, which is a shame because paper & PMD waste can be properly recycled instead of being ignited like the organic & residual waste (Dragtstra & Marechal, 2020). The content of the PMD waste bins (figure 3) contained 77,8% PMD, which seems like a high level. However, PMD waste can only be recycled if the amount of 'other' waste is very low (Dragtstra & Marechal, 2020). Too much 'other' waste results in the trash bag being rejected, and ultimately ignited instead of recycled. The PMD waste is the responsibility of Groenbeheer at the UT, and they check if the clear PMD bags have too much of other waste in it. This control is very strict.

**Figure 2**
*Pie chart residual waste content*




*Note.* Information from Dragtstra & Marechal (2020) put into a pie chart via Microsoft Excel.

**Figure 3**
*Pie chart PMD waste content*




*Note.* Information from Dragtstra & Marechal (2020) put into a pie chart via Microsoft Excel.

Because the control of the PMD waste stream is very rigorous, it is important that mainly this waste type is separated as perfectly as possible. A few mistakes too many can cause a lot of waste to be unnecessarily ignited. If this happens too often, it goes against the sustainability goals that the UT has set, especially the ones with regards to becoming a circular campus (where the waste is recycled, re-used, and then recycled again continuously).

According to Dragtstra & Marechal (2020), the main reason for improper disposal of waste in the PMD stream is a lack of education. Though the waste islands show the most important information with regards of what trash should go into which bin, there can still be a lot of confusion regarding e.g. wrappers that are different kinds of plastic, cups that still have a little residue, or plastic cups that are wrapped in a type of paper. If the UT community is properly informed about the right waste separation behavior, mistakes with regard to these confusing waste types can be prevented.

### 2.1.3. Influencing behaviour

There are many theories that attempt to demonstrate why behavior is influenced and might change. These theories mention personal, environmental, and behavioral attributes as major aspects of behavioral determination.

Firstly, the Fogg Behavior Model (FBM) states that human behavior is a concoction of three main factors: motivation, ability, and triggers, of which each has subcomponents. The theory proclaims that, for a person to act out preferred behavior, they must be adequately motivated, have the ability to perform the behavior, and be prompted to perform the behavior. All three of the factors must be present at the same time for the favored behavior to take place. Persuasive technology often sees behavior as something that we cause to occur; activation of behavior is often the goal. However, there is another aspect of behavior change: preventing behavior from happening. FBM gives insight into this. One can stop a certain behavior by taking away one of the three factors (Fogg, 2009).

Secondly, according to the Social Learning Theory, environmental, personal, and behavioral factors all influence behavioral change. Each factor influences the others. For example, in accordance with self-efficacy principles, an individual's thoughts influence their behavior, and an individual's characteristics elicit specific responses from the social environment. Similarly, an individual's environment affects the advancement of personal traits as well as the person's behavior, and an individual's behavior can change their environment as well as how they feel or think. The mutual interactions between these factors, which are believed to cause behavioral change, are the center of social learning theory (Bandura, 1974).

Finally, the Transtheoretical Model of Behavior Change implies that there are six stages of change with regards to behavior change: precontemplation, contemplation, preparation, action, maintenance, and termination. Individuals transition between these stages, before they achieve a complete behavior change. In the first two stages, the person begins thinking of changing their behavior, and in the preparation stage starts planning for it. During the action stage they begin to act out the changes behavior consistently, and they finally enter the maintenance stage once they consistently show their changed behavior for at least six months. In addition to the six stages of change, ten processes of change have been identified. These ten process come with self-efficacy, temptations, and decisional balance (Prochaska & DiClemente, 1983; Prochaska & Velicer, 1997) .

#### *2.1.3.1. Nudging theory*

Nudging theory explains a technique used to influence behavior without actually limiting the choices of the person influenced, nor significantly changing their economic incentives. They should not be mandates, and the intervention must be easy and should not cost a person money (Thaler & Sunstein, 2008). Thus, social influence and some small & simple adjustments to decision-making settings could influence pro-waste separation behavior choices. For the rest of this paper we will go with the definition:

*"Nudging is an alteration in the choice environment of the person, without forbidding any options nor changing economic incentives (p. 9)".*

Nudging specifically works by influencing people's behavior with them ultimately choosing the 'better' and desired option out of free will because of outside influences that might be big or small in size. Some examples of a 'nudge' are the graphic warnings on cigarette packages, automatic payment systems for credit cards, default rules for programs, but also an alarm clock could be seen as a nudge (Sunstein, 2014). Nudges can be applied in the six main domains of influence: family planning, land management, meat consumption, transportation choices, water use, and waste behavior (Byerly et al., 2018). There are 10 important nudges: Default rules, Simplification, Use of Social Norms, Increases in Ease and Convenience, Disclosure, Warnings, Precommitment Strategies, Reminders, Eliciting Implementation Intentions, Informing People (Sunstein, 2014) that can then be applied to these domains, and used for influencing people to do a preferred action. A fully worked out list of the definitions can be found in Appendix I.

#### *2.1.3.2 Education*

As discussed in various headings above, knowledge is a critical aspect in behavior change, and therefore education is an important aspect in the theory of changing behavior as well. If a person does not know how, they will be less likely to act out the preferred behavior. That is why it is important that the UT community knows exactly how the waste is supposed to be separated, what challenges might

arise, and how these challenges can be resolved. Education is able to clearly communicate both the risks of not taking action and the advantages of taking action to confront behavior (Chewning, 2022). According to research by Liu et al. (2019), proper education had a significant positive effect on the willingness of residents to separate household waste. Therefore, improving education can increase the compliance of people to separate their waste. Education can come in the form of posters, interactive games, educational videos, and trainings.

## 2.2. State of the art

To properly assess the solution for the lack of knowledge, an assessment should be made of already existing solutions and technologies, but also the actions that the CFM-UT has undertaken/is planning to take with regards to waste separation.

### 2.2.1. CFM-UT actions

During an interview with B. Dragtstra, it was mentioned that the people from CFM-UT have already started with executing actions targeting correct waste separation. In collaboration with Greenhub they have created a poster which shows the different waste streams and what happens after disposal to raise awareness (see Appendix II for the poster). This poster is published on the UT website, but not distributed anywhere else.

In addition to the poster, they worked together with a team of students for a serious gaming app. This app will be released during the kick-in, and used during the kick-in as an activity, to teach new students in a fun way how to dispose waste correctly. The game will work as a type of scavenger hunt where you can scan the waste islands and individual waste streams around the campus to educate yourself about the correct separation of waste.

Finally, CFM-UT decided to create some improvements for the waste islands. They limit the amount of text and increase the amount of images, since text proved to be less attractive and helpful. They are also planning to improve the imagery used, and are creating more functional stickers to place on the waste islands in the future. They are also planning to add slots for paper dispensing on every wase island at the UT since this was not feasible when they initially placed the waste islands due to a lack of budget.

### 2.2.3. Existing Campaigns and Technology

Next to the actions that CFM-UT is planning, there are already existing technologies on the market that should help with the waste separation issue. For this state of the art the focus was mainly laid on (1) existing technologies that improve waste separation, (2) campaigns that focus on improving waste separation.

#### *2.2.3.1. Bin-E the smart waste bin*

The Bin-E smart waste bin (figure 4) is a customizable IOT device that sorts and compresses the waste you dispose immediately. This means that you do not have to separate your waste yourself. It even offers an app that can let you control the bin from a distance, and provides you real time data like the contents level, technical status, and advanced reports. It can be modified to personal preferences in terms of housing color, flap type, and graphical imagery. Its mission is “to revolutionize the recycling chain by creating a systematic solution that fully automizes waste management” (Luboński & Otysz, 2022).

**Figure 4**
*Bin-E the smart waste bin*

### *2.2.3.2. SEGD Smart bin*

The SEGD smart bin (figure 5) is an interactive waste system that has three separate bins for compost, recycle, and landfill. Each of these bins is connected to a digital scale, microcomputer and digital screen. The digital screen displays an animation of the waste that should be disposed in the correlating bin falling down. Next to the imagery, short texts regarding the waste types is also presented on the screen. As soon as a person throws away their trash into one of the bins, it is weighed. After weighing, the person can see how much money could be saved if everyone recycled or composted that same amount of trash. This way the person is educated about how to separate their trash, but also how much money could be saved which gives a bigger impact (Smart Bins | SEGD, 2014).

**Figure 5**
*The interactive SEGD smart bin*

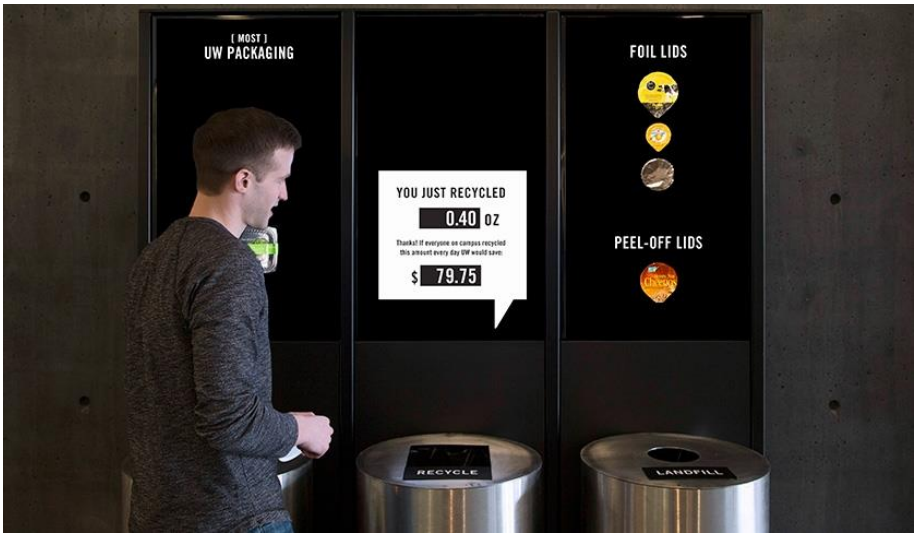
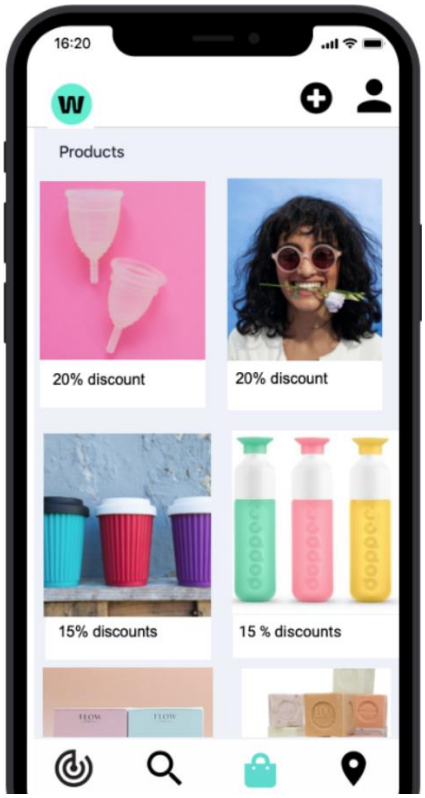



**Figure 6**
*The Wasted App homescreen*




### *2.2.3.3. The Wasted App*

The Wasted App (figure 6) is a start-up based in Amsterdam with two female founders. The app rewards their users for recycling plastic and helps them with removing plastic from their daily life and environment. It lets the user track their progress in limiting plastic use with each step they take, and also give out rewards like getting exclusive discounts from sustainable brands. The app works with environmentally-focussed brands that offer sustainable products only. By using the rewards, and buying a new sustainable product, the user can then see their growth in positive impact rise again which promotes more wanted behavior. The app has a step-by-step realistic guiding process that shows the steps the user can take for a more sustainable lifestyle; small steps at the beginning to bigger steps near the end (WASTED, 2021).

### *2.2.3.4. Trade cans for Burgers*

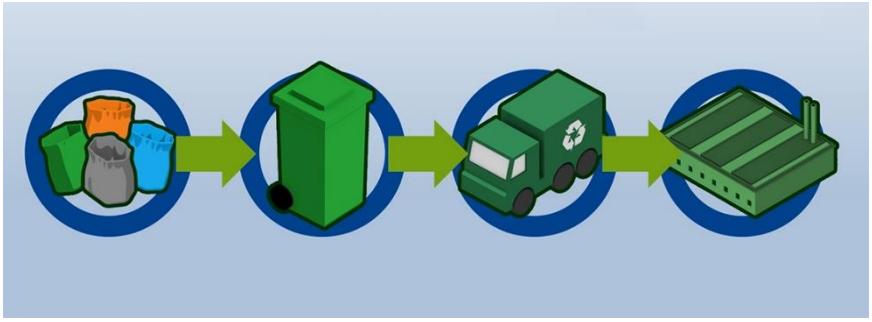
The McDonald's in Stockholm created a new environmentally friendly campaign together with advertising agency DDB in 2014 where they let people collect cans and exchange them for a burger, instead of having them pay for the food (see figure 7). During the festival-prone times in the city, the McDonald's figured that all kids would have spent their money on tickets, food, drinks and merchandise with no money left to fill their hungry bodies at the end of an intense day of partying. Therefore, the campaigns not only consist out of a smart promotional text, people can actually pull out trash bags from the poster display to gather their cans. This way the festival goers clean up the massive amounts of beer and soda cans left around the city due to the festivals without knowing, and get a stomach filling reward in return. However, next to helping with cleaning the area, the campaign could also immensely help people in the low income neighborhoods (Zimmer, 2014).

**Figure 7**
*McDonalds campaign – trade cans for burgers*


### *2.2.3.5. The Optibag system*

The Optibag system (figure 8) is a system developed in Norway which aims to optimize household waste separation by making it as easy as possible. The trash is disposed into different colored hermetical bags and then disposed into a single bin, which is emptied in a standard waste assembling truck. When the truck reaches the optical sorting plant, the bags are then sorted by color to the correct container to be recycled. The system makes it easy for households to separate their waste since the colors are easily recognizable and the bags of good quality and not difficult to use, but it also optimizes the process for the municipalities as no bins or waste collection trucks need to be replaced or changed for this system to work (T., 2018).

**Figure 8**
*The Optibag Separation System*



### *2.2.3.6. Rethink Waste Game*

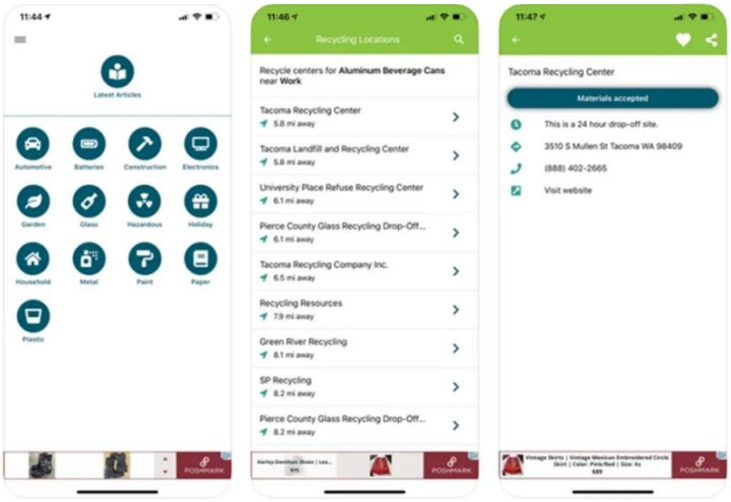
The waste sorting game ‘Rethink Waste’ developed by the city of Surrey (figure 9) is designed to be a fun resource for children, teachers, families and adults looking for information on the aspect of recycling. The game is useable via an internet browser, but is also downloadable as an app. In the game, the user is presented a single type of waste (e.g. apple core, plastic packaging, a broken toy) that changes after each ‘disposal’. They are supposed to drag the single waste type into the correct bin. The waste type will not disappear until disposed correctly. When 5 to 6 waste types have been disposed of correctly the level is finished and the user can choose an item to put in their own city park. After this they can continue to the next level. In the end, the user finishes with a beautiful park, and is able to download their very own ‘trash separation’ certificate which is especially fun to use in a primary school setting (Waste Sorting Game, 2020).

**Figure 9**
*Rethink Waste game homescreen*


### *2.2.3.7. iRecycle*

iRecycle is an app developed by Earth911.com that helps you find local recycling spots for when you are travelling, on the road, or at home (figure 10). It grants access to more than 1,600,000 ways to recycle more than 350 materials all around the United States. It has a minimalist interface that uses pictograms and selection screens that are easy to use. The app lets you select your material, searches for the best recycle spot, and then maps out the route to the location. It also contains daily articles, podcasts and how-to guides targeted at sustainable living (Earth911.com, 2019).

**Figure 10**
*iRecycle app tabs*



### *2.2.3.8. Improving accuracy of waste sorting through behavioral nudges*

Student associates from Harvard University researched students' waste separation behavior and came to the conclusion that it was not up to standards. To improve the waste separation behavior they came up with a nudging-based solution to hang in the school cafeteria (see figure 11). Around the separation bins in one of the main areas they applied three nudging techniques. (1) Loss aversion by highlighting the disadvantages of not correctly separating, (2) social norms by positioning the nudge in an area where students can watch each other's behavior, and (3) simplification by using physical showcasing of trash for each waste stream. Using these nudges they reworked the waste separation information boards, and it resulted in an increase of correctly recycled waste (Xu et al., 2019).

**Figure 11**
*The reworked signs above the trash bins at Harvard University*


### *2.2.3.9. Eugene Smart Bin*

A local startup called Uzer, located in France, realized that the bad recycling habits of the country's population was something that could be solved by encouraging better habits. Therefore they developed the Eugene smart bin (figure 12) that can tell users what they can recycle, and what cannot be recycled. In essence, the smart bin is a pedal bin that has a barcode scanner on top which scans the user's product and shows what part of the product can be recycled (and thus put into the recycle part of the bin) and what part of the product cannot be recycled (and thus put into the non-recycle part of the bin). This smart system should teach the French population which products can, and which cannot, be recycled in hopes of improving the recycle rates of the country (Cooper, 2016).

**Figure 12**
*The Eugene smart bin barcode scanner*

## 2.3. Interviews & observations

### 2.3.1. Interview CFM-UT

During the introductory meeting with the client of this research, B. Dragtstra, from the CFM-UT we talked about the most important aspects of the issue of waste separation, the biggest issues as defined by B. Dragtstra, and possible solutions that are introduced/will be introduced in the future. According to them, the main important aspect of waste is to 'rethink' it. Which means that people need to think about waste in another way than that they do now, and most preferably think about it as something they can reduce in their life.

The trouble that arises most since the introduction of waste islands is the difficulty of understanding the intervention. Especially international members of the UT community are not familiar with the Dutch ways of separation and since the waste islands are based on them, it is important that they are educated. PMD seems to be the hardest waste stream, but most throw their waste into the residual stream. Since the waste islands replaced all other waste bins in the UT buildings people need to surpass a longer distance to throw away their waste. The distance results in people hoarding their waste together and not separating it when arrived at the waste island, but throwing the whole collection into the residual stream.

To stimulate waste separation the waste islands were placed at carefully selected places. Four team leaders were responsible, and checked for the most optimal locations where a lot of waste was produced. Even the design was thought about. Because people read from left to right, the residual stream was placed at the far right of the waste island. The paper waste stream has a slot which is reminiscent of a piece of office paper. There are stickers and explanatory texts placed on the waste islands to know where to disposed which waste type. The colors are inspired by the national colors, but international members of the UT community do not recognize or know this.

B. Dragtstra also specifically highlighted the fact that there are strict controls on the content of the PMD waste stream. The company 'Groenbeheer' checks each bag meticulously, and if the amount of other waste in the PMD stream is too high, the bag gets rejected. However, the UT community thinks the entire container is rejected, instead of it being one bag at a time. It is a BIG issue that the UT community does not now this information, because they might put more care in separating when they know that their effort is not useless in the end.

To battle the lack of waste separation, Greenhub created a poster with each waste stream and what happens with the waste after disposal to raise awareness. However, CFM-UT found that it is hard to reach a large target audience, and therefore they would like to try out the nudging technique. Examples of how to apply nudging would be to show what products are created from the recycled waste as some sort of showcase in a central location of the UT. One aspect that was emphasized is that you have to limit the extra actions that a person should act out, and that imagery works noticeably better than text.

### 2.3.2. Informal interview with peers

Three informal interviews were conducted with peers where their trash habits and waste separation knowledge was discussed in a light-hearted session (see the full answers in Appendix III). According to the participants of the informal interviews, they found the waste separation method present at the UT (the waste islands) to be not as understandable as they would wish it to be. It turned out that for the international participant of the informal interviews, the Dutch separation method was hard to understand since it was distinctly different from the one used in their home country. The explanation used on the waste islands to showcase the correct waste disposal behavior did not give them enough information, and especially PMD is a confusing waste stream. They also noted that they thought used paper cups could be thrown away in the paper waste stream, but they actually have to disposed used cups in the residual stream since the paper is not clean anymore after usage.

The two other Dutch participants mentioned that the waste islands were hard to understand as well. They added that the waste islands have too much text, as quoted "They were confusing because there were pretty big lists of what could go in each bin". In addition, the imagery used on the bins is presented quite low, this means that, mainly tall, people have to bend down to see the pictures properly which in turn makes it hard to check if they separated their waste correctly.

On average, the three participants in the informal interviews gave themselves a 6.5 waste separation knowledge rating, which is a number that could be improved. Therefore it can be concluded that the waste islands are not adequately efficient in informing people about correct waste separation, and that the knowledge of the UT community is not sufficiently high enough to separate their waste correctly at this point in time.

## 2.4. Conclusion & Discussion

The available literature analysed, the observations and interviews undertaken, and the state of the art techniques, applications, and solutions, all add to the overview of important elements that need to be taken into consideration when designing an intervention that targets behaviour influencing. At this moment there are a lot of possible techniques that can be applied, of which the biggest one is the behavioural technique nudging. Its ten default applications can be recognized in almost all solutions that the State of the Art campaigns and technologies present. Mainly the aspects of simplicity, default rules, increases in convenience, reminders, and informing people about the consequences of their choices come back in the state of the art research. For this reason, it is a technique that this project should definitely take into consideration to apply in the final intervention that will be created. It must be said that the other three techniques could be applied as well, since they also give proper insights in people's behaviour, and ways of influencing that.

This background research also proves that education and knowledge are key aspects in the execution of (wished for) behavior of people. Resulting from the (informal) interviews and the at the UT, it can be said that both the concepts education and knowledge are things that are lacking at this moment with regards to the waste islands placed in the University buildings at the UT and especially under the international community that is part of the bigger community. It is important that the UT community knows exactly how the waste is supposed to be separated, how the waste islands work, what challenges might arise, and how the challenges can be resolved to improve the general waste separation behavior. For that reason, the final intervention should not only influence the behavior, but should also increase the knowledge of the UT community.

The State of the Art shows that there is a wide range of existing solutions that should definitely be taken into consideration. A lot of inspiration can be taken from the existing interventions, as each operates in a different way and targets a different audience. Especially since this project aims its solution on the whole UT community which has a wide range of age, nationalities, and backgrounds which means that it is hard to direct the eventual solution to a specific group of people.

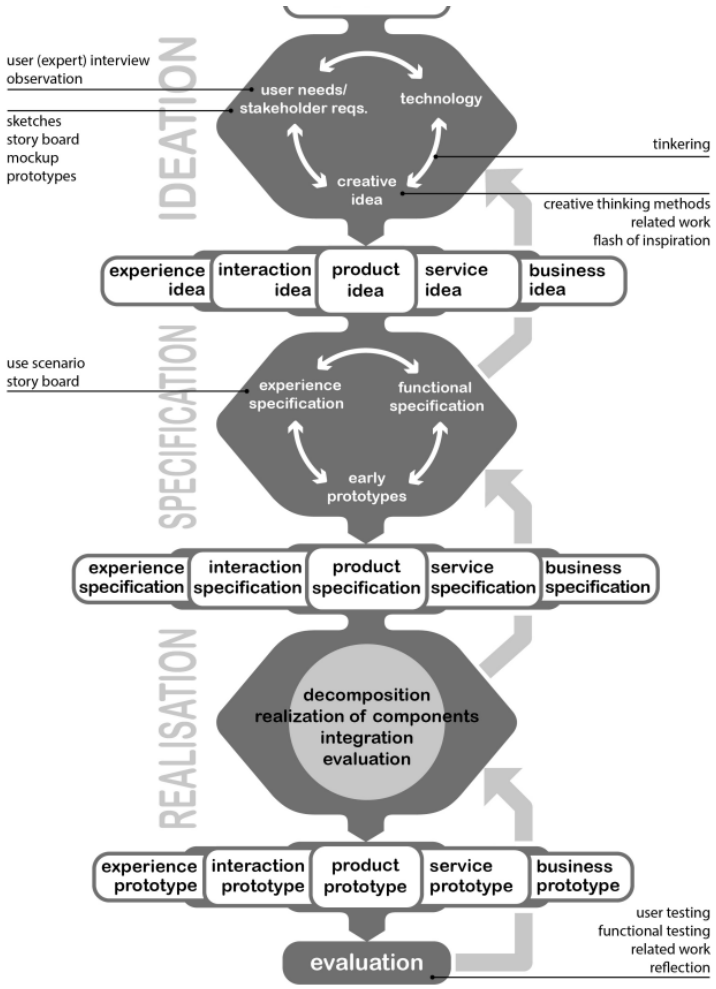
To close the gap between the situation at hand (where waste is not correctly separated though a lot of actions are taken) and the desired situation (where waste is correctly separated due to the intervention), this research will focus on finding a solution that considers the diversity of the UT community and the behavioral techniques that could be applied. All this while being interactive, providing enough information regarding waste separation, and being educational so that the community can learn about waste separation next to motivating correct separation behavior.

Especially the need for simplicity and behavioral control are aspects that will be taken with into the brainstorm phase of ideation. Nudging can be applied in simple, yet effective ways, and is therefore a feasible option to include in a possible final solution.

# 3. Methods & Techniques

The design process of the interactive waste separation intervention follows the Creative Technology Design Process designed by Mader and Eggink (2014). The process consists out of divergence and convergence, forming a spiral model as can be seen in figure 13 that defines four different stages of a design process: ideation, specification, realization and ending with evaluation. The process is flexible, and moves through each stage multiple times to rework and refine the design and prototype of a product/service. It combines research, feedback and prototyping to create a functional prototype that fits the user needs and stakeholder requirements.

**Figure 13**
*The Creative Technology Design Process*




The type of design that will be used during this project is User Centered Design (Ferris, 2004). This means that the user is at the center of the design process, and will have impactful influence over the interaction and the final design choices with regards to the product. The product will be made with the user in mind during each phase of the process, and when the final prototype is created it will be tested with members of the final end-user group. This is the moment they will be directly involved. During this testing phase, the participants of the study can remark on the prototype and give feedback for improvement and/or change.

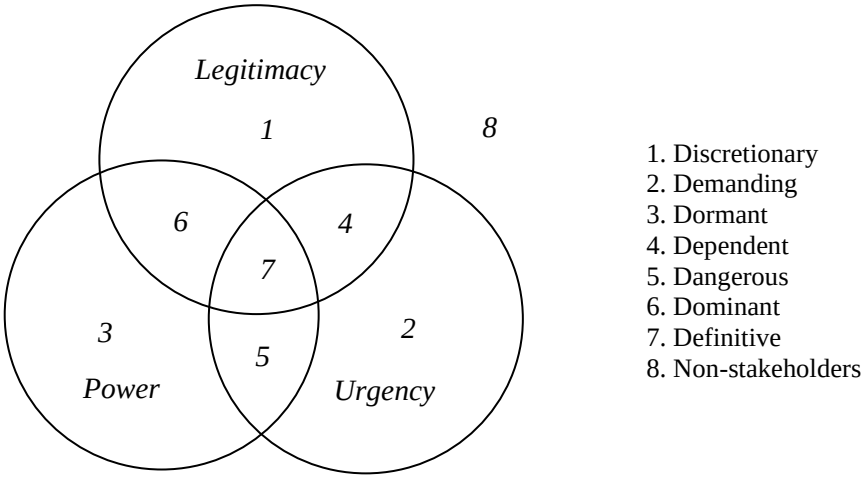
## 3.1. Ideation

The ideation phase is the first phase in the design process which starts with a design question, which in the case of this research is the main research question. It has three possible start positions: user needs/stakeholder requirements, technologies, or a creative idea.

The client of this project tells us what can be changed and altered about the waste islands, and what interventions can be taken with regards to the waste islands, whereas the end-users show us how the intervention can be implemented best with regards to succeeding in their change of behavior. Therefore, since for this project the end users and client play key roles in the development and design of the solution, the ideation starting point was "user needs and stakeholder requirements".

This starting point is executed by first identifying the main stakeholders of this project. There are various ways to do this, but for this project the Stakeholder Salience Model, SMM, (Mitchell et al., 1997) will be used. The model divides each stakeholder over three dimensions: legitimacy, power, and urgency, which are presented in a Venn diagram with overlapping regions (see figure 14). In total there are eight regions associated with a specific stakeholder type based on their location within the Venn diagram. These are depicted in figure 14 as numbers within the diagram, with their meanings described on the right side.

**Figure 14**
*The Stakeholder Salience Model Venn diagram*




After the identification of the stakeholders and their requirements through the background research, the next step is to order the requirements from most to least important. To do this, the MoSCoW method (Haughey, 2011) will be used. This method states that though all requirements are important, some of them must be prioritized to make sure the design can be finished within the timescale. The categories of order are the following: Must have, Should have, Could have, and Won't have. All the requirements defined following the stakeholder analysis will be ordered within these categories.

The next step in the ideation phase is to make sure that we know which technologies can be used according to the stakeholder requirements. For this step, the State of the Art from chapter 2 and close contact with our client is needed to find out what exactly can be done with the waste islands, and if they can be adapted or changed in any way. As soon as these requirements are defined, a brainstorming session about the technologies can be conducted. This brainstorm will happen, first individually with use of a mind-map (The University of Adelaide, 2021), and after that in collaboration with co-researcher Younghun Rhee. It is most important that the brainstorm (Paulus & Kenworthy, 2018) session should make use of creativity-inducing options, e.g. a whiteboard/mind maps/paper and pen. Giving the option to draw things out and scratch out words/add them flexibly creates a more creative ideation flow.

After the technologies are thought of, another brainstorm session will be conducted, this time about the last point within the ideation phase of the creative design process: "creative idea". For this brainstorm session sketches will be made to visualize what the ideas will look like physically. The brainstorm starts individually, but later again in collaboration with co-researcher Rhee, where we will put our idea sketches together to come up with a final collection of possible concepts. Feasibility is a

key selection point in finding the final collection, since the solution should be made in time. In the end, the ideation phase ends with an interaction and product idea where a single final concept is chosen.

## 3.2. Specification

The second phase, Specification, follows the Ideation phase. It starts with an experience specification, where a story board (Wikipedia contributors, 2022b) is created to show the experience the user has with the final concept. This story board is used to figure out what the interaction of the end-user with the design should entail. The storyboard is also translated in a Storyline with Personas to figure out each interaction with different types of end-users. The personas are created to reflect these types of end-users. As soon as all the interactions are determined, a Time Sequence Diagram (Wikipedia contributors, 2022) will be set up, depicting the interaction between the different parts of the product.

After the handlings are figured out, the functional specification phase can be conducted. This is where we look at the functional and non-functional requirements of the solution, and what technical functions are needed to make sure that the experience interactions work out properly. These functionalities will be ordered following the MoSCoW method (Haughey, 2011) When the experience and functional specifications are decided, the early prototypes can be created. These so called 'paper prototypes' are used to test if the specifications work according to the stakeholders and end-users. When, following this testing, they prove to be incomplete, the specifications can be reworked, and a new prototype can be created. This will go on in a circling type of way until the all specifications are complete, and a 'final' early prototype is set up. After this, the process can continue to the Realization phase.

## 3.3. Realization

During the realization phase the focus mostly lies on the decomposition, the realization of components, the integration, and evaluation of the prototype. The main goal is creating the realization of the envisioned product that was created during the specification phase. The requirements and functionalities that were found during the previous phases are taken as a starting point for the realization process. The envisioned product that followed from the specification phase is going to be separated into sub-parts, and then linked to fitting technological components that can be utilized to implement the functions that the product should carry out. If each sub-part works individually, they can be connected, and then analyzed to see if they work together properly as well. If that is the case, they can be properly implemented in the prototype. Ultimately, this phase ends with an interaction prototype, as conforms to the interactive media part of the design process that this research focusses on. Another aspect of this phase is conducting a functionality test, to find out if all functionalities of the prototype work well.

The functionality test is necessary, as the researcher needs to make sure all functionalities of the prototype work properly before testing it with the users in the evaluation phase. To do this, a functionality table will be constructed to test all functionality parts of the prototype, and to see which of these parts might fail such that they can be improved and/or changed. It is an important part of the realization phase, as a defective prototype breaks the user testing phase of the evaluation.

## 3.4. Evaluation

When the prototype has been created, it is important to check if it works as it should; does it influence the UT community members waste separation behavior, and educate them about waste separation? Or does it not carry out its base function of behavioral change and education? This will be tested during the user testing phase in the evaluation. For this testing phase, ethical approval by the Ethics Committee (Ethics Committee | Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS), 2022) of the UT is needed.

The user test is executed by members of the target group. The group should test this system as if they are using it outside the testing environment, and pretend that they are making use of it in a real-life setting. They should report if they felt that the intervention worked, and if their needs are met. In addition, they should give comments about the installation having unnecessary parts or if they miss

aspects in the installation. User needs that were not discovered can be found out during this stage. Following the testing, the participants of the user test will be asked to take part in a short, structured, interview about their interaction with the product, or fill in a short survey detailing their experiences with it. This way any underlying issues are still able to be discovered. The results from the user testing will then be analyzed using the software program SPSS (SPSS Statistics – Overview, 2021).

When both parts of the evaluation phase are conducted, the reflection can start. Within this phase, the researcher reflects on the results of the testing phases, and sees what must be improved to gain better results. With the results of the evaluation, a newer and improved prototype can be created.

# 4. Ideation

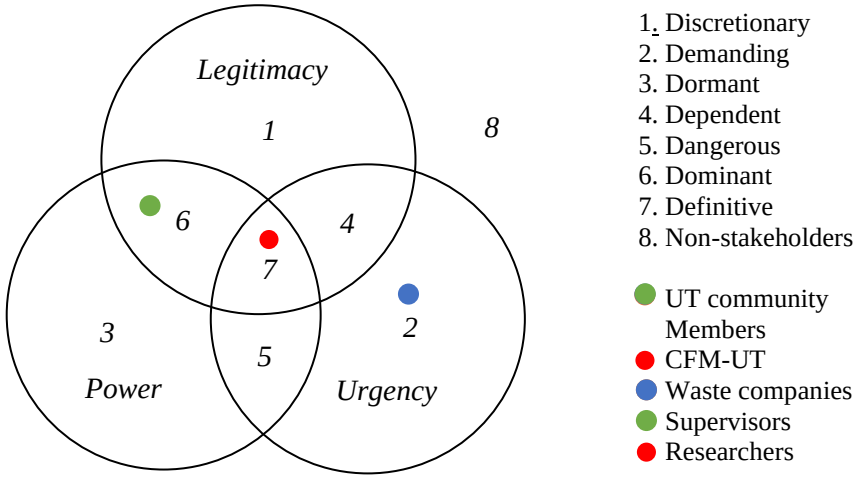
The ideation phase of this research focuses on the generation of concepts for proper/effective waste separation at the University of Twente. It starts with a stakeholder analysis to gain insight in the needs, wants, and requirements of the main stakeholders of this project. Thereafter the list of preliminary requirements is created, which should be taken into account while thinking of possible concepts.

After the list is created, the concept generation is explained which starts with brainstorming sessions and concept generating processes. Following that, all thought of concepts are individually discussed and analyzed after which a final concept is determined. It should be taken into consideration that a key aspect of the concept(s) should be interaction, and behavioral influencing, as these two aspects are main parts of the research question for this research.

## 4.1. Stakeholders

An intervention that should improve people's waste separation behavior is highly dependent on the stakeholders, they set the requirements that the intervention should follow. To identify the stakeholders in this project, the Stakeholder Salience Model (SMM) is used (Mitchell et al., 1997). This model applies three dimensions: legitimacy (appropriate involvement), power (ability to impose their own will), and urgency (need for immediate action). These three dimensions are represented in a Venn diagram (see figure 14) that has eight regions that are associated to a specific stakeholder type.

**Figure 15**
*The Stakeholder Salience Model Venn diagram*




Each of the eight regions linked with a particular stakeholder has a distinct meaning based off of their location in the Venn diagram, e.g. the dominant region has power and legitimacy but little urgency and therefore tend to have certain expectations that must be met at some point, whereas the dependent region have urgent and legitimate stakes in the project but little power so these stakeholders may lean on another stakeholder group to have their voices heard. The definitive stakeholders have power, legitimacy, and urgence and therefore the highest salience. Within this project there are multiple stakeholders from different regions involved, and these are analyzed via the Salience Stakeholders Model.

### 4.1.1. The UT community members

The waste separation intervention is directed at the target group of UT community members, making this group the focus of the design. This means that whilst the group is not constantly directly involved in the process of the intervention, they do have power over the design and functionalities of the intervention (high legitimacy). If the intervention does not work for them, the aspects that do not seem to work should be changed such that the intervention will be successful. The high amount of power comes with a lower amount of urgency. Found during the background research, the UT community members do not have enough knowledge to change their behavior. They would like to

improve, but there is no real haste behind it following the background research. The informal peer interviews conducted during the background research concluded that the UT community members would like to change their behavior, and separate their waste properly, yet cannot execute this behavior due to unclarity of the bins and a lack of education regarding how to separate waste.

The UT community members therefore mostly have power and legitimacy in this project, making them a *dominant* stakeholder group.

### 4.1.2. CFM-UT

The second important stakeholder is CFM-UT, as they are the client of this project and are aiming to improve the waste separation quality of the UT community members. The organization has a legit stake in the project as they are directly involved and will most likely apply the intervention if it proves to be effective. Their main goal is to see the quality of waste separation increase, to reach their set sustainability goals for the upcoming years. Since their sustainability goals are set to be concluded in the upcoming few years there is a sense of urgency in the waste separation improvement, as the deadlines of the goals are getting nearer (the earliest being due at the end of 2022). As a client of this project the organization is a powerful stakeholder as well, and can have a lot of influence over the design, functionalities and placement of the intervention. They play a big role in the image of the University of Twente in general as well. Therefore making them an important key in the whole waste separation operation giving them a place in the *definitive* stakeholder group.

### 4.1.3. The waste companies

A stakeholder group that is placed outside the center of the project are the waste companies involved at the University of Twente. They are appropriately involved by having the responsibility of checking the individual waste bags of paper and PMD waste, and disposing them in the residual container when the bags contain too much ‘other’ waste. They also feel urgency with regards to waste separation improvements, as it would make their job way easier. However, the intervention is not designed for them but for the UT community. They will like the idea of better waste separation, but will not be the end-users of the product, nor the client or experts, which gives them little power over the design and functionalities of the intervention, yet high urgency. Therefore making them a *demanding* stakeholder.

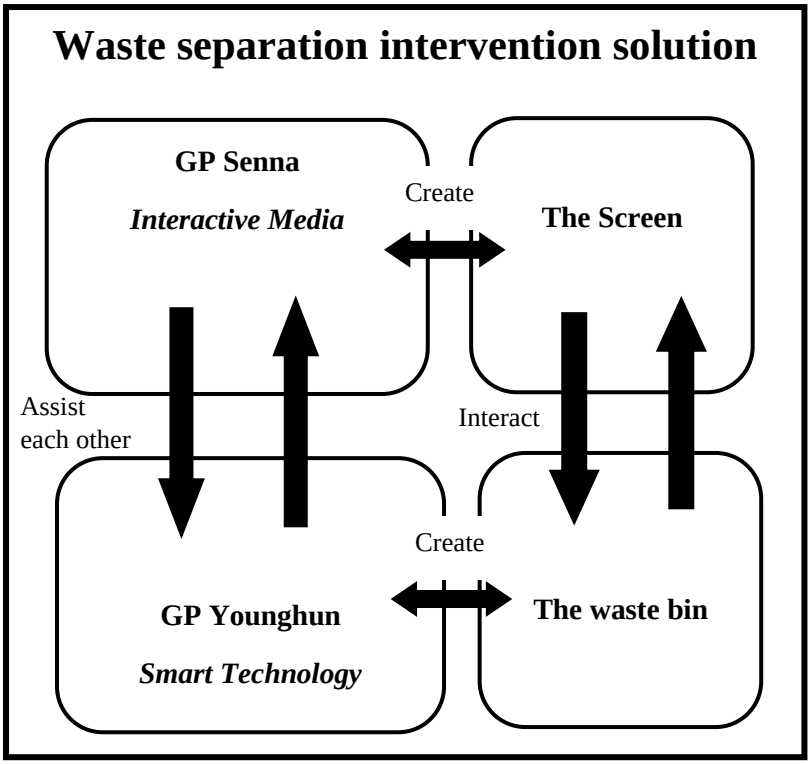
### 4.1.4. The Project supervisors

The supervisors of this project are key stakeholders as well. They are the stakeholders that are in charge of legislation; they decide what the researchers can or cannot do in terms of the project. Each week there is an informative advisory meeting with the supervisors to talk about the project and get approval/disapproval for certain ideas. This means that they have a high stake, and are directly involved, giving them a high legitimacy. In addition, they have a big amount of power whilst this project is in process, as they make or break the decisions taken. The urgency level for this stakeholder group is lower, they help solving the problem by assisting the researchers in real time but they do not have the sense of urgency that the researchers and the client may have. Therefore, this stakeholder group is *dominant*.

### 4.1.5. Researchers/developers

Within the project, the work of Younghun Rhee and myself influences each other. In the end, the final intervention of this project will be a collaboration of both our projects. However, within the final interventions, and therefore also the project, there are two distinctly different parts, which separate our work though we have an influencing role in each other’s part of the project. This mutual influence can be seen in figure 16. It shows that while both of us are working together on the same topic, we go into different directions and work on different aspects of the final intervention. There might be some overlapping areas within collaboration, as shown by the vertical arrows connecting our two graduation projects and the horizontal arrows connecting our individual projects to the whole topic, but we have our own separate sub-topics within the main topic, designing to improve waste separation at the UT campus.

**Figure 16**
*Collaboration visualisation graduation project*




Due to the fact that Younghun Rhee and myself are working separately, yet collaborating at certain points during the project, we both have a high stake within this research. Since we create the final solution together by combining our different parts, and provide all the research within this document, we have the biggest amount of power, urgency and legitimacy. This is why ourselves as a stakeholder group are also *definitive*.

## 4.2. Preliminary requirements

The needs and requirements of the stakeholders have to be taken into consideration when designing a product. The stakeholders' perspective can evoke specific requirements that the designers should keep in mind during the design of the tool. After a meeting with the client, undertaking informal interviews under peers that are part of the UT community, and the background research as present in chapter 2, a list of preliminary requirements was established. These can be found in table 1.

**Table 1**
*The preliminary requirements set by the stakeholders and background research*

| Number | Requirement | Where from? |
|---|---|---|
| 1. | MUST not change the waste island in any way: no adapting the stickers, size, nor waste dispensing holes in any way. | CFM-UT. |
| 2. | MUST not move the waste islands in any way, they have to stay at the location they are now. | CFM-UT. |
| 3. | MUST be easy to interact with. | Background research. |
| 4. | MUST give awareness about waste separation in a limited timeframe. | Background research. |
| 5. | MUST provide an educational aspect such that the next time people know where to put the waste. | Background research. |
| 6. | MUST take a limited amount of actions. | CFM-UT & background research. |
| 7. | MUST provide an educational aspect such that the next time | Supervisors, CFM-UT |

| | | |
|---|---|---|
| | people know where to put their waste. | |
| 8. | MUST be installed close to the waste island. | Supervisors, CFM-UT, Researchers. |
| 9. | SHOULD show the benefits of recycling. | Supervisors, CFM-UT, Researchers & background research |
| 10. | SHOULD check if waste is disposed of in the right waste bin. | Researcher, Supervisors |
| 11. | SHOULD prevent the waste from being disposed of in the wrong waste bin. | CFM-UT |
| 12. | COULD prevent technological discrimination. | Background research |
| 13. | COULD work with positive reinforcement instead of negative. | CFM-UT, background research |

The preliminary requirements are ordered according to the MoSCoW method (Haughey, 2011). This means that each requirement is ordered by Must, Should, Could, and Won't. The idea is that, to deliver the greatest and fastest business benefits, the requirements must be prioritized early.

'Must Have' requirements are crucial within the timebox of the project. Without these requirements the project fails. The 'Should Have' requirements can be as important as the 'Must Have', but do not need to be finished as promptly in time. They are not as time-critical, and there might be other ways to add the requirements such that they can be added at a later time. 'Could Have' describes requirements that are desirable yet not necessary. The last of the requirements is 'Won't Have' and these are requirements that stakeholders agreed on to be the least-critical items. Therefore they are not planned into the schedule of the project. Within the project, no 'Won't Have' requirements were identified.

## 4.3. Concept generation

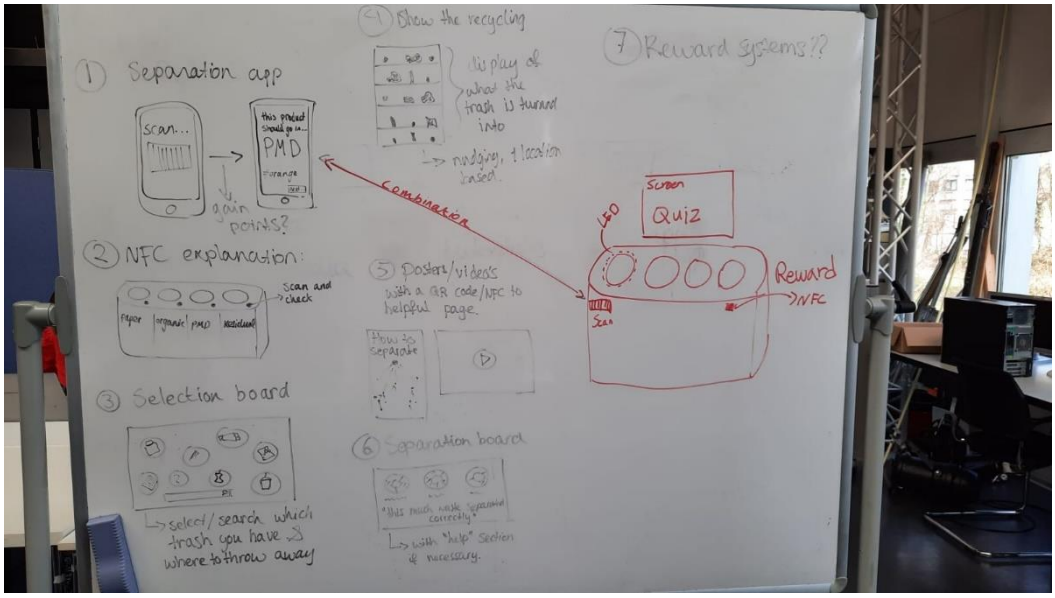
The stakeholder analysis conducted in the previous parts shows a clear overview of the people that are involved in this project, and the needs and requirements that need to be considered. Within this phase it is important that all ideas should be considered as concepts only to give the most space to creative additions that might come up. The preliminary requirements showed that there are eight critical characteristics that the possible solutions must have. This means that concepts that incorporate these critical aspects could show a range of options for the final concept design.

Concept generation was split into two parts: brainstorming and concept selection. The brainstorming was split into two parts as well: individual and mutual, were for the mutual brainstorming there was worked loosely together with co-researcher Younghun Rhee. The brainstorming mostly consisted out of concept/idea generation, of which the results were later discussed with the supervisors and clients.

### 4.3.1. Brainstorming

First, an individual brainstorming session was conducted during which possible concepts that are mostly focused on interactivity were thought of. The State of the Art, as presented in chapter 2, was taken into consideration during this process as existing solutions are used as inspiration for the possible concepts. This brainstorm was conducted with the use of a mind-map that discusses several possible solutions, as can be seen in Appendix V. The generated concepts were then discussed with co-researcher Rhee in a mutual brainstorm session during which the final concept(s) were generated. This mutual brainstorm session was conducted using a whiteboard to induce creativity by giving the option of flexibility in erasure and placement, see figure 17.

**Figure 17**
*Whiteboard concept generation collaboration*




From this moment on, the project was split into two parts over Younghun Rhee and myself. Where co-researcher Rhee focused on the smart-tech aspects of the concepts, I focused on the interactive media applications of them.

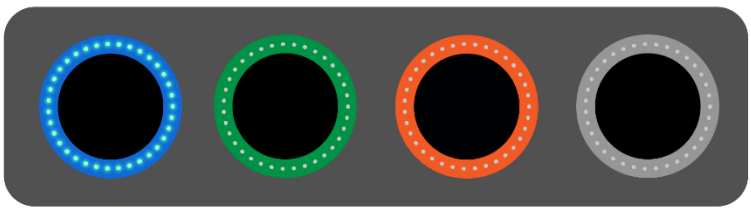
## 4.3.2. Element concepts

Within the concept generation, several elements of the final concept were thought of and then glued together. With these elements it was mostly important that the focus lies on the interactive media aspect, since that is what this project is focusing on.

### *4.3.2.1. LED indicators*

The first element idea is a string of LED lights around the waste stream holes (see figure 18). When a UT community member approaches the waste island, and then selects/scans their product, the waste stream that the product is supposed to be disposed in lights up due to the LEDs being activated. It is interactive such that the user interacts with the system by selecting/scanning their product, and it makes use of the simplification nudge since the LEDs make the 'choice' of waste stream very easy.

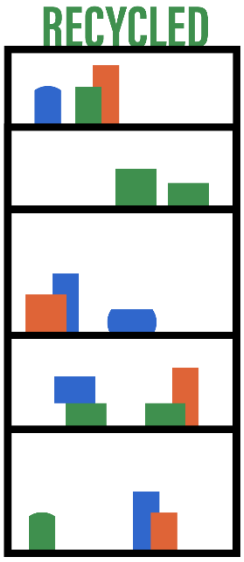
**Figure 18**
*LED indicators present on the waste island.*



### *4.3.2.2. Showcasing*

A showcasing element (see figure 19) in an intervention might make people more aware about how their waste behavior could have an impact, therefore a big cupboard with products made from recycled waste (specifically waste from the UT campus buildings) could be a potential element for a final solution. Giving the UT community members the knowledge that what they do with regards of waste separation will have an impact, might give them the little push to separate correctly. The main limit with this element is the lack of interactivity. The UT community members will see the showcasing, but are not able to interact with it any more than look at the products displayed.

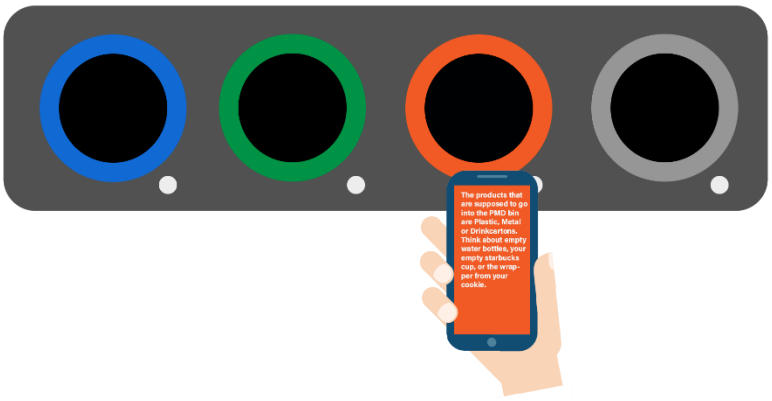
**Figure 19**
*A Showcasing cupboard showing products made of recycled materials.*




### *4.3.2.3. NFT scanner*

By adding an NFT scanner to the waste island streams (see figure 20) that links to an app that shows where the waste has to be disposed, the UT community members can check where to dispose their waste easily and quickly. The NFT badge links to a website or app (which does need to be downloaded on their phone) that then gives an informative screen. The UT community member making use of the NFT product interacts with the waste island streams and gains knowledge by reading the information provided. In addition, the possible website/app would fit perfectly within the interactive media aspect of this project.

**Figure 20**
*NFT badges placed on the waste island.*




### *4.3.2.4. Informative poster*

Informative posters (see figure 21) distributed around the UT campus buildings, specifically placed near/above the waste islands, can show the UT community members where to dispose their waste and give them information about general waste disposal/separation statistics. There is no distinct interaction procedure with this element, except that the UT community members can look at the

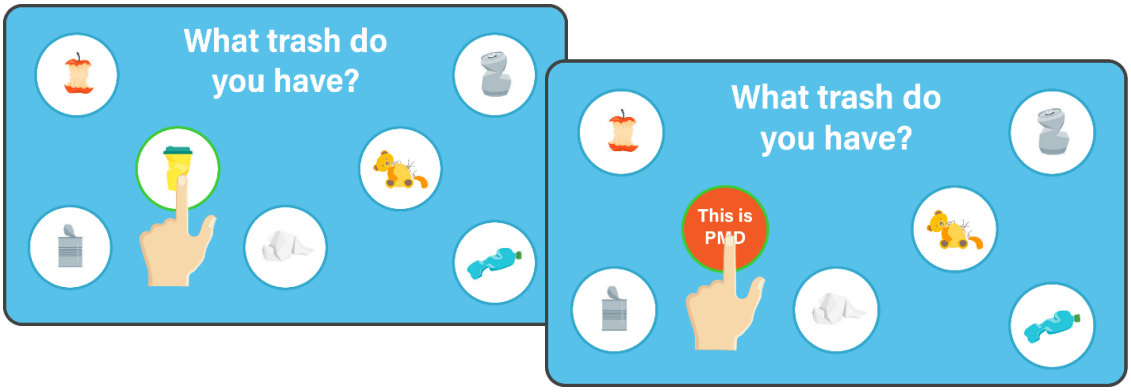
information presented and read the text visible on the poster. The poster is, however, able to give a broader view with regards to which waste should be disposed of in which stream, since there is more room on the poster for information than on the waste islands themselves.

**Figure 21**
*Waste separation informative poster example*


### *4.3.2.5. Selection board*

An interactive selection board, as presented in figure 22, shows the UT community members a selection screen that presents different types of waste like cups, food packets, drink cartons etc.; mainly the waste that is often disposed of wrongly. Once the UT community members get near the screen, they can select the type of waste that they would like to dispose of on the screen via touchscreen. This action results in a change on the screen; the circle in which the waste is shown changes to the color fitting to the waste type. This way the UT community member can easily see where their waste should be disposed. Next to the informative and interactive characteristics of this element, it also has a hint of education in there. The UT member that used the screen might remember the results, and does not need to use the screen the following time they would like to dispose of the same product.

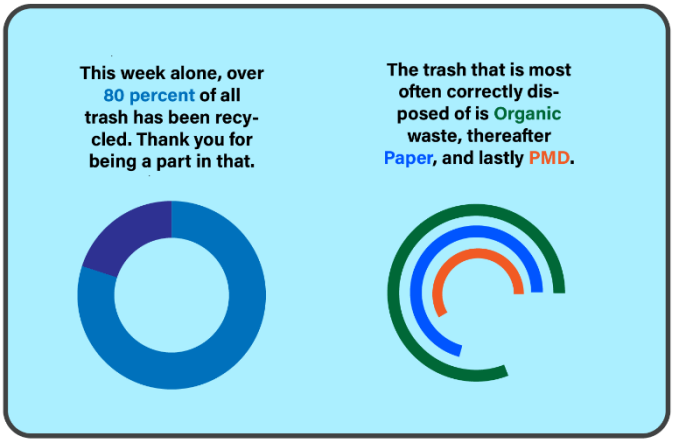
**Figure 22**
*Waste selection board, where a waste type is selected and thereafter the waste stream is shown.*



### *4.3.2.6. Waste information board*

The waste information board (figure 23) is presented on the same size board as the waste selection board, however, instead of a selection screen it shows information with regards to the waste disposed in the connected waste island. It is a dynamic and interactive information board. The graphs that show 'correctly separated waste' change as the UT community members throw away their waste properly. This way the user has influence over the information depicted, and it will make them feel responsible about keeping the amount of correctly separated waste high.

**Figure 23**
*Information board with potential pie chart ideas*




### *4.3.2.7. Requirements results*

When thinking about how all the previously discussed elements that could be part of the final concept and therefore solution, it is important to check if they conform to the preliminary requirements set by the stakeholders and the background research. This will be done by filling in the requirements table developed in the beginning of this chapter. From this table we can then conclude which of the elements conform to the most important requirements.

From filling in the table, it can be concluded that most of the 'Must' requirements are complied to by most of the conceptual elements that have been thought of during the brainstorming sessions. Concept 1, 3, and 5 do not conform to all of them, yet they could be great additions to the final concept as an partaking element if the others do comply with the requirements these do not meet. This is necessary, since the 'Must' requirements are of highest importance and without them the solution would not be seen as complete.

**Table 2**
*Concepts placed in the requirements table*

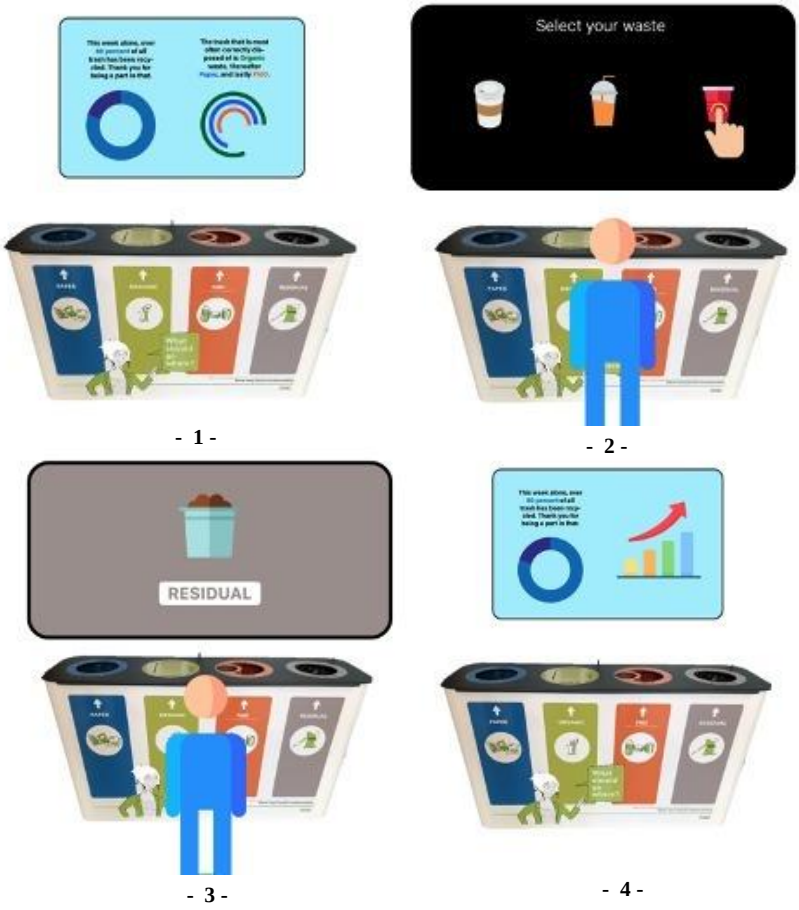
| Number | Requirement | Concept |
|---|---|---|
| 1. | MUST not change the waste island in any way: no adapting the stickers, size, nor waste dispensing holes in any way. | 2, 4, 5, 6 |
| 2. | MUST not move the waste islands in any way, they have to stay at the location they are now. | 1, 2, 3, 4, 5, 6 |
| 3. | MUST be easy to interact with. | 1, 2, 3, 4, 5, 6 |
| 4. | MUST give awareness about waste separation in a limited timeframe. | 2, 4, 6 |
| 5. | MUST provide an educational aspect such that the next time people know where to put the waste. | 1, 3, 4, 5 |
| 6. | MUST take a limited amount of actions. | 1, 2, 4, 5, 6 |
| 7. | MUST be installed close to the trash bin. | 1, 2, 3, 4, 5, 6 |
| 8. | SHOULD show the benefits of recycling. | 2, 4, 6 |
| 9. | SHOULD check if waste is disposed of in the right waste stream. | 1, 3, 5, 6 |
| 10. | SHOULD prevent the waste from being disposed of in the wrong | 1, 3, 4, 5, 6 |

| | | |
|---|---|---|
| | waste stream. | |
| 11. | COULD prevent technological discrimination. | 1, 2, 3, 4, 5, 6 |
| 12. | COULD work with positive reinforcement instead of negative. | 1, 2, 3, 4, 5, 6 |

## 4.4. Final concept

By combining several of the conceptual elements the final concept (see figure 24) is created. It was decided to combine concept 4, 5 and 6 to create the ultimate interactive and educational solution to the problem of incorrectly separated trash. With this concept all requirements necessary to create a proper final concept are checked off.

**Figure 24**
*The final concept*




The final concept works via four steps of human-technology interaction. The first step is the ‘standard’ screen display of the information screen which shows how much waste has been correctly/incorrectly disposed that day. The UT community member can see this information from a large distance. It educates the UT community member about the habits of other community members.

The second step happens when a UT community member comes close to the waste island. A sensor picks up on their movement, and when they get within a certain distance of the waste island, the information screen changes to the selection screen. This screen shows several waste type categories that contain all different types of waste types present at the University of Twente. The screen works via touchscreen, and the UT community member can touch the screen to select their waste type. The selection of waste type works hierarchically, e.g. they have a specific cup in their hand so they select the ‘cup’ imagery, after which the screen changes to a new page depicting all different types of cups present at the UT (e.g. paper coffee cup, Starbucks cup, plastic water cup).

The third step is that the UT community member selects their specific waste type in the hierarchy screen, and the icon of the waste type they selected changes to the colour and name of the waste bin they should dispose it into. LEDs light up around the correct waste bin. The system then checks via an internal sensor in the waste bins if they have executed the action correctly. A feedback screen is shown, notifying the user if they have executed their action correctly.

After this, the fourth step is executed. When they walk away, out of the distance sensor area, the screen changes back to the 'standard' information screen. However, the action the UT community member has taken influences the information board positively or negatively, depending if their waste disposal happened correctly. Thereby increasing the amount of waste correctly/incorrectly disposed which is displayed on the information screen.

### 4.4.1. Requirements

It is important that the final concept conforms to the requirements that originated from the background research and the stakeholders. For this reason, the final concept was discussed with the client and the supervisors of this project. From these discussions the results were placed in the requirements table, as can be seen in table 3. The final concept that was thought of conformed to all requirements, and therefore is a fitting and proper solution to the projects problem of incorrect waste separation at the UT campus.

**Table 3**

*Final concept and the requirements it fulfills, if it conforms to the requirement an 'X' is present in the 'Final concept' column.*

| Number | Requirement | Final concept |
|---|---|---|
| 1. | MUST not change the waste island in any way: no adapting the stickers, size, nor waste dispensing holes in any way. | X |
| 2. | MUST not move the waste islands in any way, they have to stay at the location they are now. | X |
| 3. | MUST be easy to interact with. | X |
| 4. | MUST give awareness about waste separation in a limited timeframe. | X |
| 5. | MUST provide an educational aspect such that the next time people know where to put the waste. | X |
| 6. | MUST take a limited amount of actions. | X |
| 7. | MUST be installed close to the trash bin. | X |
| 8. | SHOULD show the benefits of recycling. | X |
| 9. | SHOULD check if waste is disposed of in the right waste stream. | X |
| 10. | SHOULD prevent the waste from being disposed of in the wrong waste stream. | X |
| 11. | COULD prevent technological discrimination. | X |
| 12. | COULD work with positive reinforcement instead of negative. | X |

# 5. Specification

In the specification phase of this research, the final concept is specified by elaborating the final concept into a more detailed and complete concept. By taking all stakeholder requirements and turning them into functional and non-functional requirements. The identification of these requirements makes sure that the final product is most attractive and useful for the end user. In addition, a persona will be identified, which can be seen as a general user of the end product. After the persona identification, a concept storyline is written out defining all functions of the final concept. Finally a storyboard is created, showing the interaction with the concept visually.

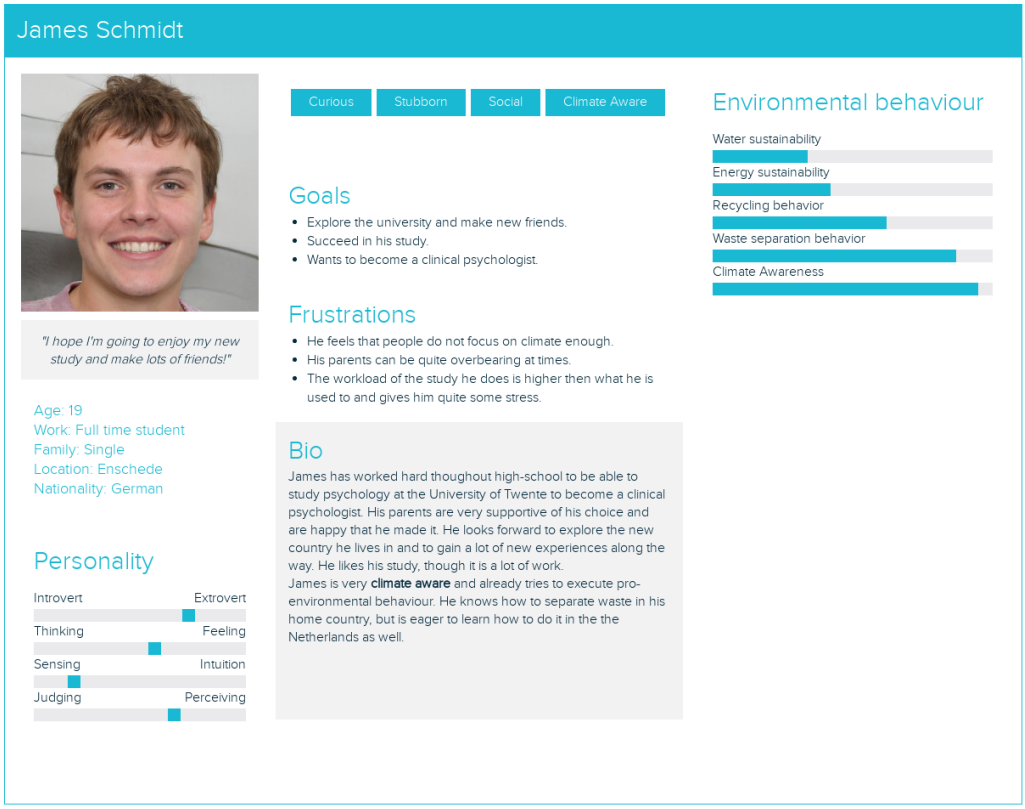
## 5.1. Persona

Using the in-browser program Xtensio (Xtensio, 2022), three different personas were created to better understand the needs and interactions of the users with regards to the final product designed during this research. When creating the personas it is important that they are relevant to the project and final product, and cover a broad scale of possible users. For the creation of personas with regards to this project, three user types were specified: climate aware, not climate aware, and indifferent.

### 5.1.1. Persona 1 – Climate aware

The first persona created, see figure 25, is a motivated international student who came to live in the Netherlands, is already climate aware and therefore knows about, and carries out, waste separation behavior. However, due to his nationality not being Dutch, he might not know the national waste separation guidelines that are known to the people living in the Netherlands. Therefore, this persona is more likely to already know how to separate waste properly according to the customs of his original country, and needs the product to learn how waste separation works in the Netherlands. This conforms to the information that resulted from the informal interviews conducted in the background research (chapter 2.3.2).

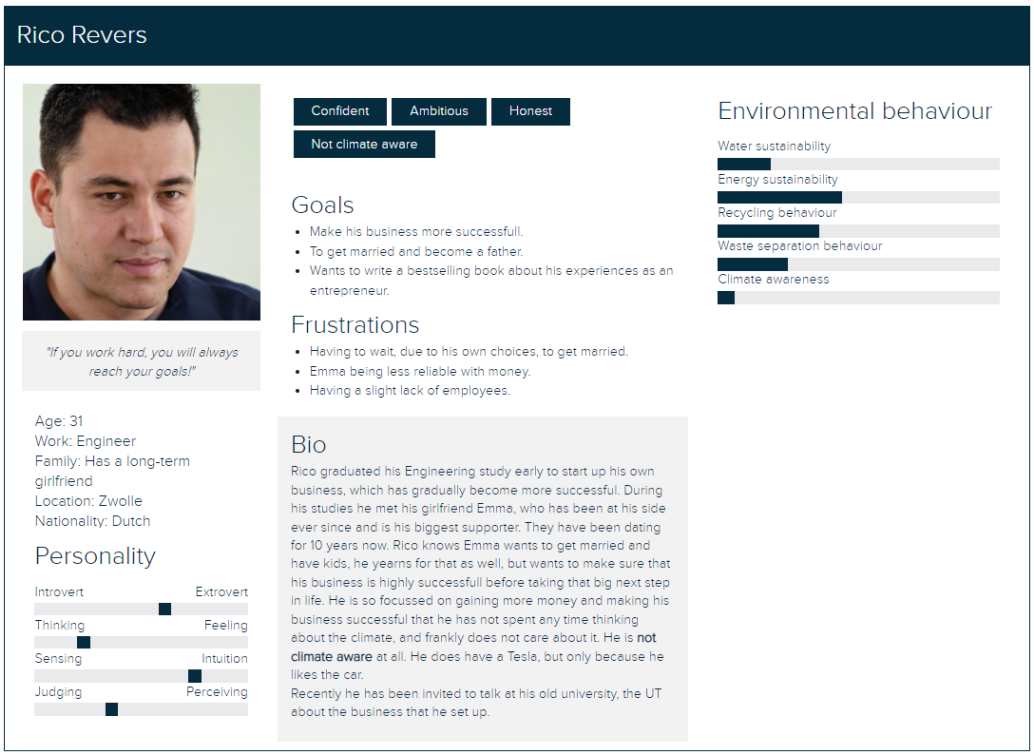
**Figure 25**
*Persona 1 – James Schmidt*



### 5.1.2. Persona 2 – Not climate aware

The second persona created for this project, see figure 26, is a Dutch entrepreneur who is visiting the University, and therefore has never seen the UT waste islands before. In addition, this person is not climate aware at all, and not even used to properly separating their waste. This poses as a valid character type for this project, as it is wished that even people who do not know the waste islands, and especially do not care much about waste separation, should interact with the product as well. Since the product should be non-discriminatory, a person with no knowledge with regards to the waste island and/or the screens should be able to use it. Therefore Rico is a fitting persona.

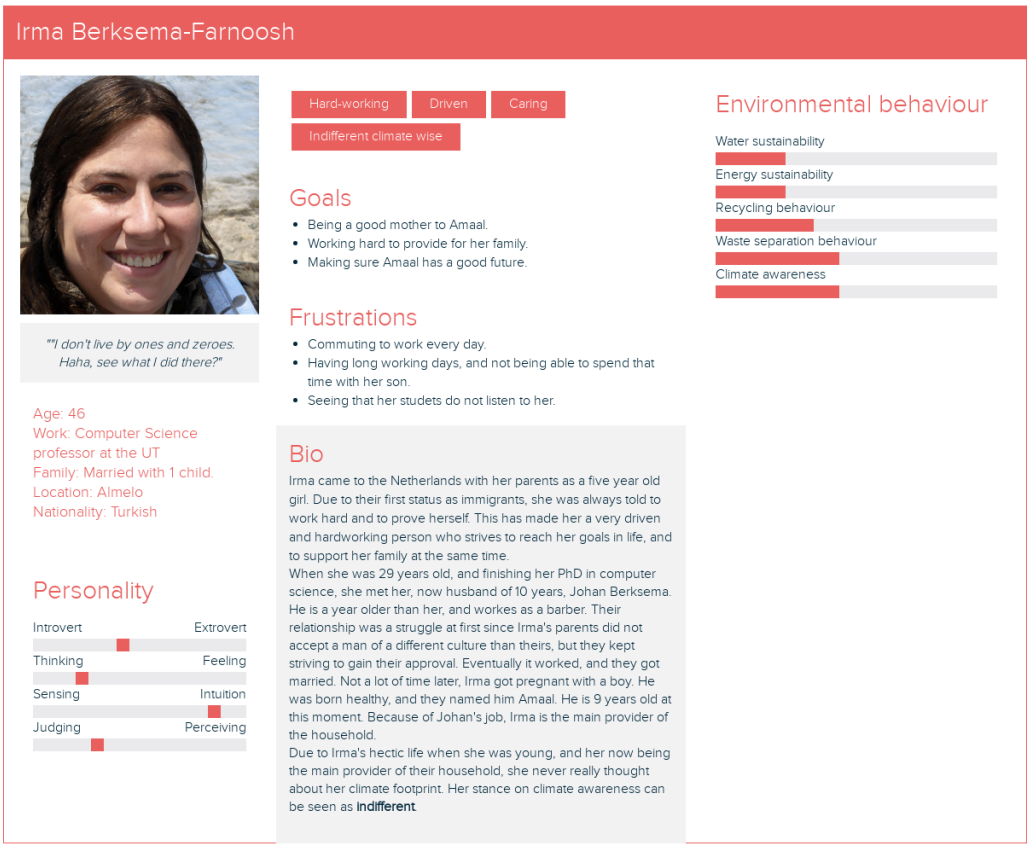
**Figure 26**
*Persona 2 – Rico Revers*




### 5.1.3. Persona 3 – Indifferent

The third persona (see figure 27) has the third character type: indifferent to climate awareness. This is a person who does not think about their impact on the climate due to personal reasons or just because they do not think in depth about their actions. During the background research (chapter 2) it was found that these types often do not know how to separate their waste, but also have not taken the actions to make sure that they learn. Irma is exactly this type of person. She is busy carrying the main financial load of their household, with busy working days, and in addition wanting to be there for their child as well. Their hectic lifestyle results in them not thinking about their climate footprint, and wanting to just handle all those aspects as quickly as possible.

**Figure 27**
*Persona 3 – Irma Berksema-Farnoosh*




## 5.2. Storylines

To give a better overview regarding all different interaction possibilities with the product, storylines are created. Each storyline covers a different interaction possibility. This way, it gives a better overview of what needs to be considered with regards to the interactive parts, and shows the feasibility of the product. Each storyline is divided into scenes to examine each part individually and properly work out all the steps necessary for the interactions. The storylines are based around the first persona, James, but the other personas are reflected in the storylines as well by means of a separate short part after each story.

### 5.2.1. Story 1: Uses product, nothing disposed

**Scene 1:** It is 10:30, and James is moving from his previous lecture to the next one, which starts at 10:45. He is in a calm mood, and only wearing his school backpack which is filled with the necessities he needs for university, his hands are free. He is excited to see his friends at the lecture. The hallway through which he walks is not busy. He can walk freely without getting in the way of other people.
**Scene 2:** While walking, he looks around the hallway. He spots a waste island with a big screen above. From a distance of 15 meters, it is hard to see for him what is presented on the screen, but as he gets closer he notices it represents information about waste disposal at this waste island.
**Scene 3:** He knows he has enough time to check the screen out to please his curiosity as he knows he has enough time to make it to his second lecture in time. He approaches the waste island to see it from closer by. As he moves closer, the information becomes more clear, and from a distance of about 5-10 meters the information is perfectly readable. He notices that it describes how waste is correctly disposed, and how much waste gets recycled.
**Scene 4:** He moves even closer, and when he is a 0.5 meter distance away from the waste island, the screen is suddenly changed, and LED lights around the waste bins are blinked. It surprises James, as he did not expect the changing of screens to happen. Instead of the information screen, a selection

screen is visible now. The selection screen shows him different types of waste, and the text “touch to select your waste type”.
**Scene 5:** James wonders how it works, so he thinks of random waste type, cup. He reaches for the screen, and touches the circle in which the cup is presented. After clicking the cup, the screen changes again, this time showing different types of cups. A paper cup is presented between several other cups on the screen.
**Scene 6:** James looks at the different cups presented on the screen, and decides to choose a paper cup randomly. He, again, reaches his hand to the screen, and touches the circle in which the paper cup is presented. After touching, the whole circle changes color. James notices that it turns gray. The paper cup in the circle has changed into text: “This is Residual”, it says. In addition, LED lights around the residual waste stream have turned on now, whereas the other waste streams are not lit up by LEDs.
**Scene 7:** However, James doesn’t have any waste to dispose of, he is just interested in how the system works, therefore he doesn’t throw anything away. After 10 seconds of no interaction, the screen goes back to the first step of selecting the waste type. Then he decides to leave the waste island. When he is further than 0.5 meters away from the screen, it changes to the information screen. As James is walking away from the waste island, he does not notice the change of screen.

**Persona 2 & 3:** In this story, the indifferent and climate unaware persona (Irma and Rico) would interact in a different way than James. Irma would be too busy to properly interact with the screen, but would read the information screen whilst walking past in a hurry. This means she would not see the screen change, as she does not get close by the screen. Rico however, would be curious about the new technology, though not fully interested in its purposes. This is why he would see the screen change, and interact, with nothing disposed.

### 5.2.2. Story 2: Walks up to the product, disposes waste without using

**Scene 1:** It is 10:40, and James is moving from his previous lecture to the next one, which starts at 10:45. He is in a slightly stressful mood, since he does not know if he will make it to his lecture on time. He is only wearing his school backpack which is filled with the necessities he needs for university, but he holds an empty paper coffee cup that he drank from in the previous lecture. He is excited to see his friends at the lecture. The hallway through which he walks is not busy. He can walk freely without getting in the way of other people.
**Scene 2:** While walking, he looks around the hallway to find a trash bin to throw away his empty paper coffee cup. He spots a waste island with a big screen above it. From a distance of 15 meters, it is hard to see for him what is presented on the screen, but as he gets closer he notices it represents information about waste disposal at this waste island. As he moves closer, the information becomes more clear, and from a distance of about 5-10 meters the information is perfectly readable.
**Scene 3:** He does not read the information presented, as he is stressed for being late for his lecture. James just wants to throw away his empty paper coffee cup and continue his route to his second lecture. He moves closer to the waste island to throw away his waste, and when he is a 0.5 meter distance away from the waste island, the screen is suddenly changed. LED lights around the waste island stream openings blink. It surprises James, as he did not expect the changing of screens to happen. Instead of the information screen, a selection screen is visible now. The selection screen shows him different types of waste, and the text “touch to select your waste type”.

***A. Disposes waste correctly***

**Scene 4A:** Since James is stressed, and knows his time limit to get to the lecture, he does not interact with the screen. He does not know how long interacting with the screen will take, and does not want to take the risk of ultimately being late for his second lecture. Therefore he takes his empty paper coffee cup, knows that it should be disposed of in Residual, and throws it in the residual waste bin.
**Scene 5A:** After his waste was disposed of in the residual waste stream, James notices that the screen changed again. Now it shows the text “Your waste was disposed in the residual waste stream,” with different images depicting types of residual waste, “are you sure you disposed of it correctly?” with three options for selection presented on the screen: ‘Yes’, ‘No’, and ‘I don’t know’.

**Scene 6A:** James is confident in his waste disposal decision, and presses the 'Yes' button. The screen The screen then changes again saying "Thank you! Please use the screen next time to be extra sure!" He reads it, considers the information, and quickly walks away to his lecture.
**Scene 7A:** When he is further than 0.5 meters away from the screen, it changes to the information screen. As James is quickly walking away from the waste island, he does not notice the change of screen. He makes it to his lecture on time.

***B. Disposes waste incorrectly***
**Scene 4B:** Since James is stressed, and knows his time limit to get to the lecture, he does not interact with the screen. He does not know how long interacting with the screen will take, and does not want to take the risk of ultimately being late for his second lecture. Therefore he takes his empty paper coffee cup, notices that it is made from paper, and therefore throws it away in the paper waste stream.
**Scene 5B:** After his waste was disposed of in the paper waste stream, James notices that the screen changed again. Now it shows the text "Your waste was disposed in the paper waste stream," with different images depicting types of paper waste, "are you sure you disposed of it correctly?" with three options for selection presented on the screen: 'Yes', 'No', and 'I don't know'.
**Scene 6B:** James turns doubtful about his waste disposal choice, as he just wanted to throw away his waste quickly and be done with it. He presses 'I don't know'. The screen then changes again saying "Thank you! Please use the screen next time, it might help you." He reads it, considers the information, and quickly walks away to his lecture.
**Scene 7B:** When he is further than 0.5 meters away from the screen, it changes to the information screen. As James is quickly walking away from the waste island, he does not notice the change of screen. He makes it to his lecture on time.

**Persona 2 & 3:** In this case, Rico would walk up to the screen, and dispose his waste without thinking. He would see the feedback screen saying "your waste was disposed in [waste stream] did you dispose correctly?' and click 'yes' to be done with the interaction. He does not really care about it, and is pretty sure he did it correctly anyway. However, after clicking yes, he cannot see the waste he disposed in the stream on the image depicting the waste types that are supposed to be disposed into it. This makes him think about his choice of disposal whilst walking away.

Irma would be very busy, and would walk up to the waste island in a hurry. She would want to dispose her waste somewhat correctly, so she would think about it for a second before disposing. She hopes she did it correctly. When the feedback screen is visible, she is already turned away and walks to the place she has to be soon.

### 5.2.3. Story 3: Uses product
**Scene 1:** It is 12:45, and James is finished with his second lecture. His break is starting, which means he can finally relax with his friends for a bit. They decided to meet up at their standard lunch spot in the cafeteria, and James is excited to meet them. He is only wearing his school backpack which is filled with the necessities he needs for university, but he holds an empty paper coffee cup that he drank from in the previous lecture, which he would like to dispose of. The hallway through which he walks is not busy. He can walk freely without getting in the way of other people.
**Scene 2:** While walking, he looks around the hallway to find a trash bin to throw away his empty paper coffee cup. He spots a waste island with a big screen above it. From a distance of 15 meters, it is hard to see for him what is presented on the screen, but as he gets closer he notices it represents information about waste disposal at this waste island.
**Scene 3:** As he moves closer, the information becomes more clear, and from a distance of about 5-10 meters the information is perfectly readable. He notices that it describes how waste is correctly disposed, and how much waste gets recycled.
**Scene 4:** He moves even closer, and when he is a 0.5 meter distance away from the waste island, the screen is suddenly changed, and LED lights around the waste bins are blinked. It surprises James, as he did not expect the changing of screens to happen. Instead of the information screen, a selection screen is visible now. The selection screen shows him different types of waste, and the text "touch to select your waste type".

**Scene 5:** One of the different types of waste presented on the screen is a cup. James connects the cup in his hand to the cup on the screen, as they look most similar, and decides to select the cup image. He reaches for the screen, and touches the circle in which the cup is presented. After clicking the cup, the screen changes again, this time showing different types of cups. A paper cup is presented between the several cups on the screen. James looks at the different cups presented on the screen, and can easily find the paper cup he holds in his hands at this moment.
**Scene 6:** He, again, reaches his hand to the screen, and touches the circle in which the paper cup is presented. After touching, the whole circle changes color. James notices that it turns gray. The paper cup in the circle has changed into text: "This is Residual" it says. In addition, the LED lights around the residual waste stream have turned on now, whereas the other waste streams are not lit up by LEDs. James now knows he has to dispose of the empty paper coffee cup into the residual waste stream, which surprises him. He thought paper cups needed to be disposed of in the paper waste stream.

***A.. Disposes waste correctly***
**Scene 7A:** He takes his cup and throws it into the residual waste stream. The screen changes again, showing a checkmark with the text "Thank you for disposing of your waste correctly!".
**Scene 8A:** He feels proud of himself due to the feedback. As he walks more than 0.5 meters away from the waste island, he turns to look back at the screen and notices that the information screen changed. The percentage of correctly separated waste presented on the screen has increased. He realizes that he has influence over the information presented on the screen.
**Scene 9A:** He is glad he did not dispose of his waste incorrectly, he did not want to ruin the score on the screen. James continues to walk towards the cafeteria to meet his friends, he is excited to tell them about his experience with the waste island.

***B. Disposes waste incorrectly***
**Scene 7B:** Therefore, the screen must be wrong, he thinks. He takes his cup and throws it into the paper waste stream. The screen changes again, showing a cross with the text "The waste should have been disposed of in Residual, try better next time!".
**Scene 8B:** He is disappointed. He really thought he had to dispose of his empty paper coffee cup in the paper waste stream, but now he doubts his knowledge. As he walks more than 0.5 meters away from the waste island, he turns to look back at the screen and notices that the information screen changed. The percentage of correctly separated waste presented on the screen has decreased. He realizes that he has influence over the information presented on the screen.
**Scene 9B:** He is disappointed in himself that he did not adhere to the information from the screen, as he now ruined the score on the screen. James continues to walk towards the cafeteria to meet his friends, he really wants to tell them about his experience with the waste island.

**Persona 2 & 3:** Irma would use the screen, and tries to learn from her interactions. When she selects her waste type she would do this carefully and considerately. The LEDs would surprise them, but she would think them to be helpful with selecting the correct waste bin. After she disposed correctly, the "Thank you for disposing of your waste correctly!" would surprise her pleasantly.

Rico would first find the screen an interesting new technology, but would be skeptical about it. He would ask himself why the screen knows this all so correctly, and why his disposal would in some cases be wrong. When using, he would like the touchscreen and new technology, the LEDs would be an eyecatcher for him. After his disposal he would not like the feedback screens as much, but he does like the product in general.

## 5.3. Time sequence diagram

A Time Sequence Diagram (TSD) can be a great help in directly visualizing each action that the user takes, and the interaction between them and the different aspects of the product, via one diagram. The TSD created during this project was made via Lucid Chart (Lucid Chart, 2022). The diagram consists out of three parts that interact with each other: The user, the screen, and the waste island.

**Figure 28**
*Time Sequence Diagram depicting – uses product, disposes using the product*

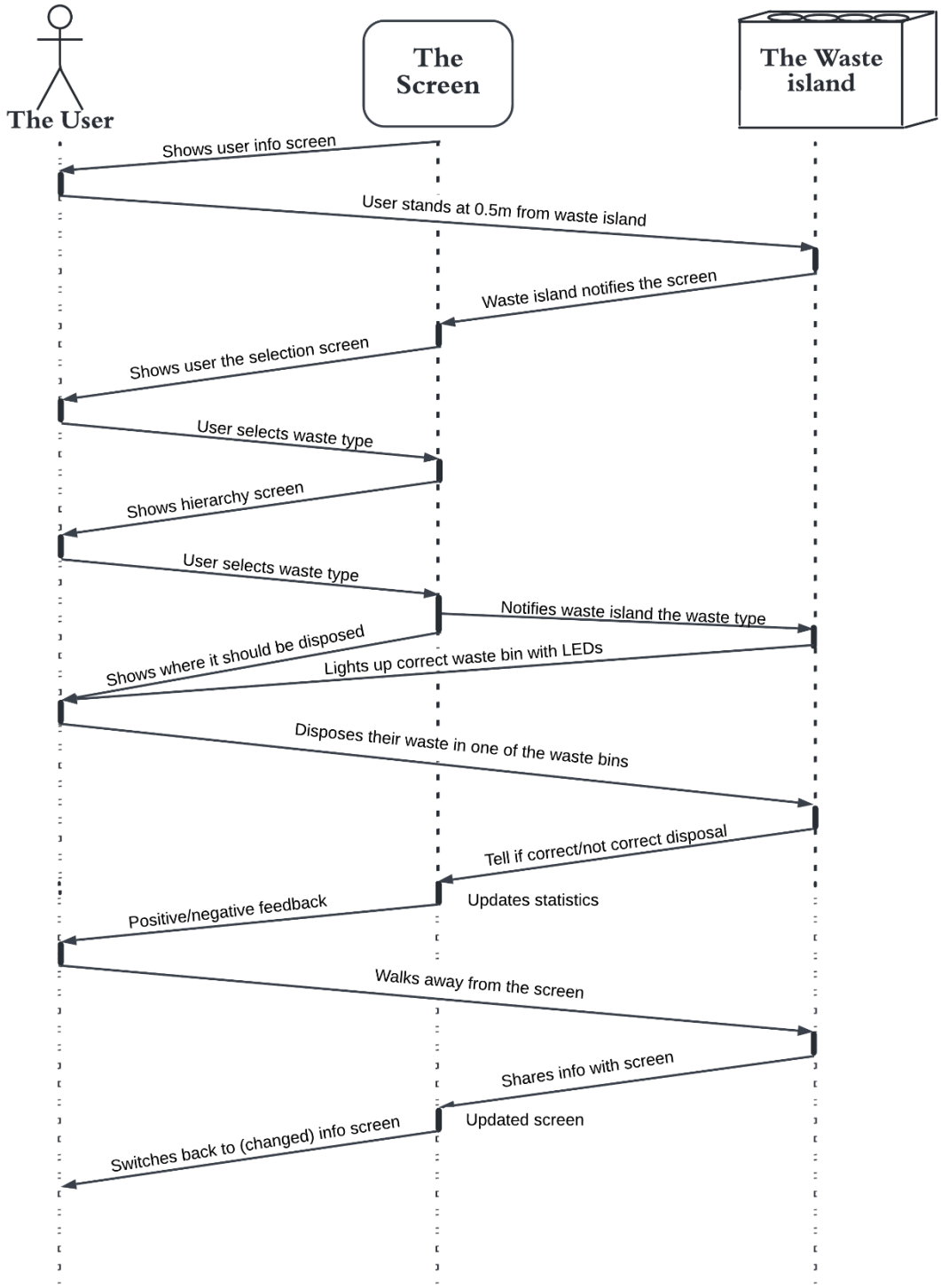


**Figure 29**
*Time Sequence Diagram – using product, disposes nothing*

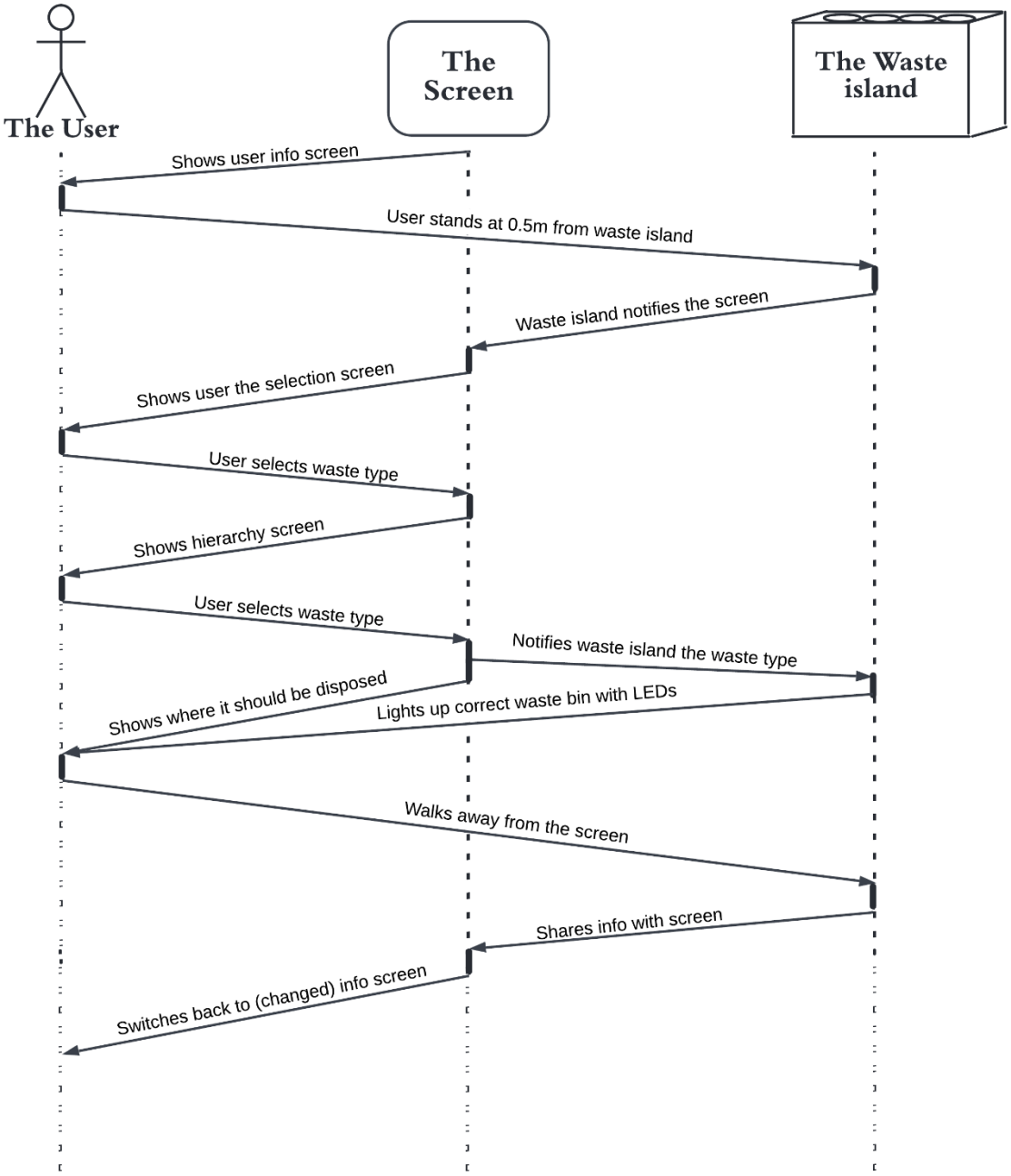
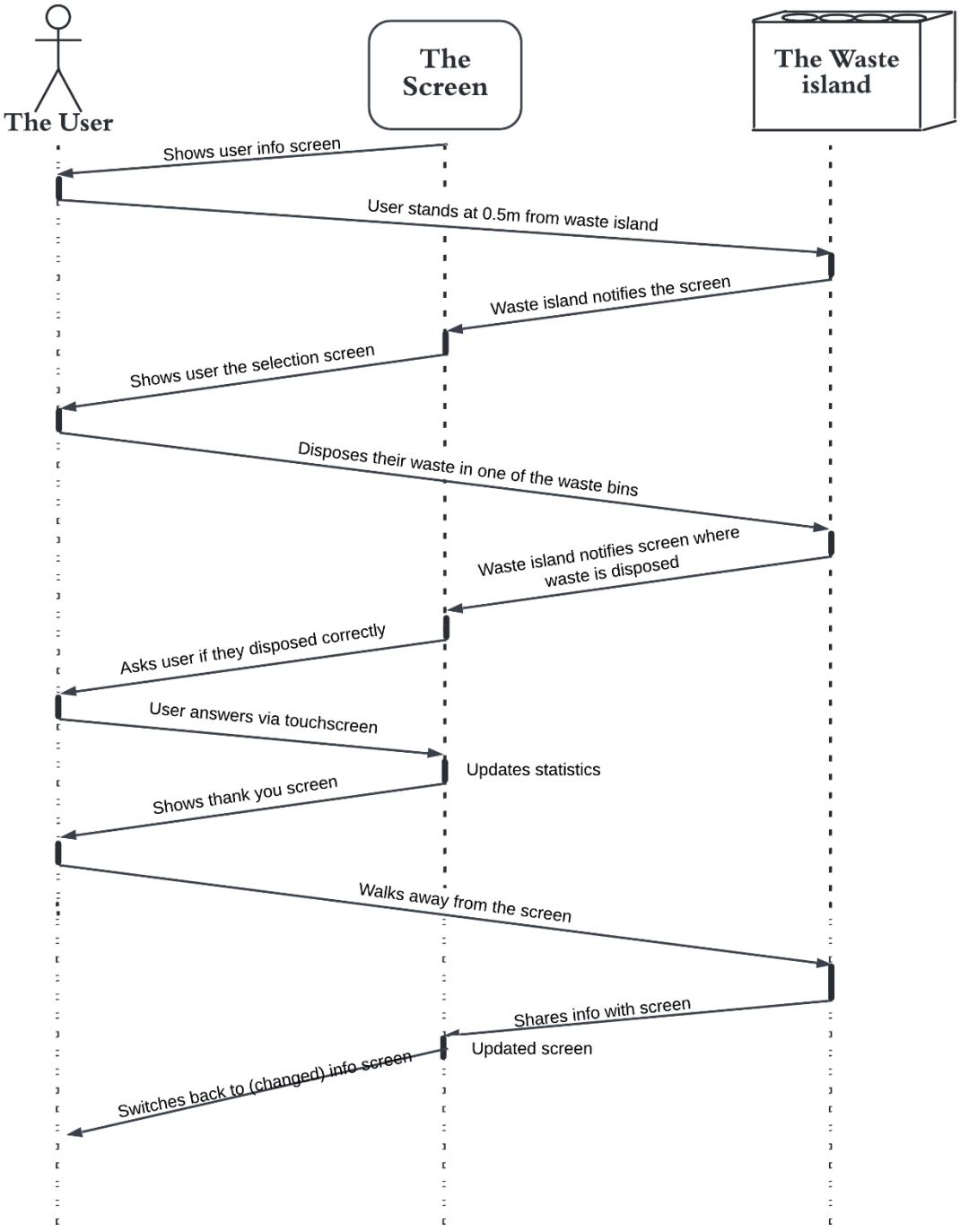


**Figure 30**
*Time Sequence Diagram – does not use the product, disposes waste*




Something distinctly noticeable in the different TSDs, as seen in figure 28 – 30, is the interaction between the screen and the waste island. Whereas the user mainly interacts with the screen, and only uses the waste island for disposal, the screen is prominently used during all of the interactions. In addition, the waste island shows visual cues (the LEDs) based on the user's interaction with the screen.

## 5.4. Visualization requirements

The persona creation, interaction storyline and the time sequence diagram created show critical insights about what the final product should include in terms of features and visuals. These insights can be translated into functional and non-functional requirements. To create a proper overview of these requirements, they are divided in two different tables and prioritized using the MoSCoW method (Haughey, 2011), as was also used during the stakeholder preliminary requirements listing in chapter 4. Not only the aspects discussed in this chapter are used for these requirements, but also the background research and stakeholder research is used for additional information with regards to finding the proper requirements. Due to the interactive media nature of this project, the requirements that will be focused on are mostly targeted to the visual and interactive aspects of screen that is part of the final product.

### 5.4.1. Functional requirements

Functional requirements describe what the product should *do*. These are presented in table 4.

**Table 4**
*Functional requirements*

| Number | Requirement | MoSCoW priority |
|---|---|---|
| 1. | Changes the information screen based on the waste selection of the users. | Must |
| 2. | Give feedback about waste disposal even if the screen has not been used. | Must |
| 3. | Has a selection hierarchy to make picking the waste types easier. | Must |

### 5.4.2. Non-functional requirements

Non-functional requirements describe *how* the product should achieve its functions. These are presented in table 5.

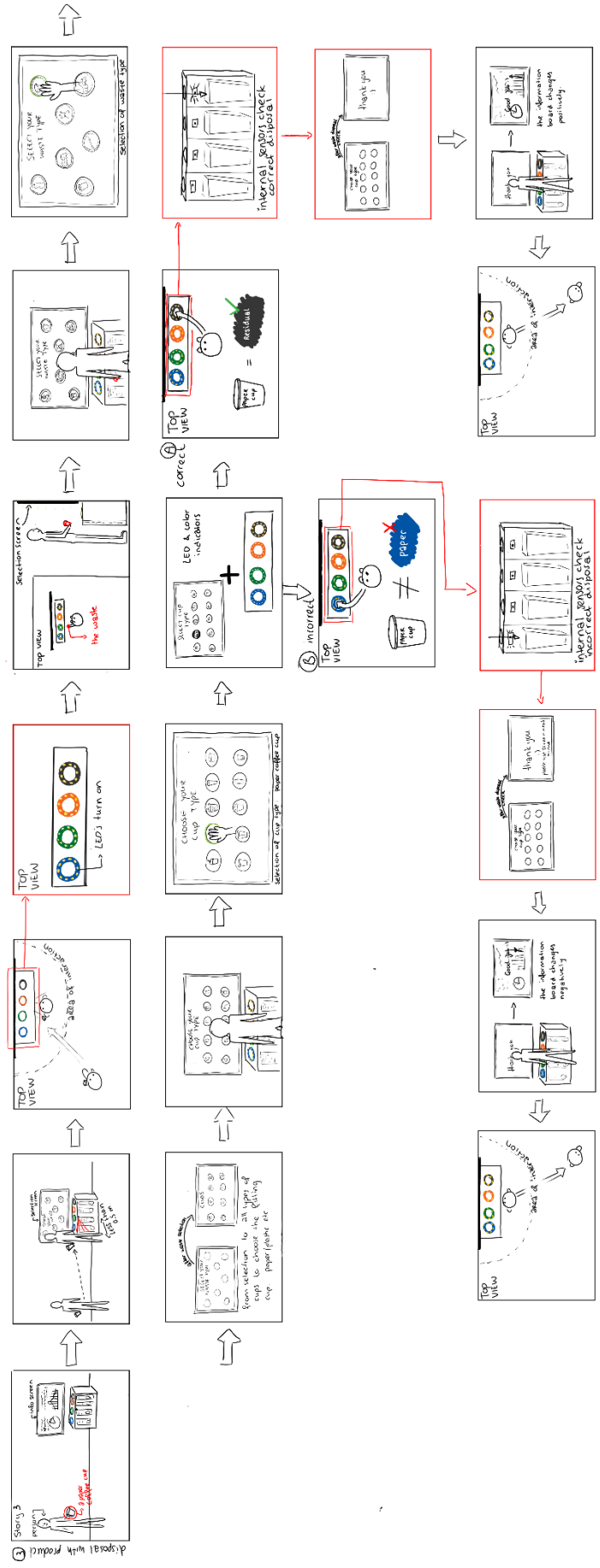
**Table 5**
*Non-functional requirements*

| Number | Requirement | MoSCoW priority |
|---|---|---|
| 1. | Be visually attractive such that it attracts users. | Should |
| 2. | Imagery used is understandable for all users. | Must |
| 3. | The text is readable in terms of size and font. | Must |
| 4. | Be inviting, such that people will use the screen. | Should |
| 5. | Use realistic visuals. | Could |
| 6. | Use touchscreen | Should |
| 7. | Clearly readable and understandable for every user. | Must |
| 8. | Use the UT house-style colors. | Could |
| 9. | Not have a brightness that is too high. | Could |
| 10. | Make use of engaging texts. | Should |
| 11. | Easy in use, without the need of explanation. | Should |
| 12. | Educate the users about waste separation. | Must |
| 13. | The images used are coherent and similar in style | Should |

## 5.5 Storyboard

To get a better view of the full storyline and interactions, a storyboard is created to visually show how the interactions work. The storyboard depicting interaction three can be seen in figure 31, the others are in appendix VI.

**Figure 31**
*Storyboard: "How improve waste separation at the University of Twente?" the third interaction possibility*



## 5.6 Visualisation components

An intervention only truly comes to its right when it is properly understood by the users. In order to reach this goal, there are several visualization components of the product that are key: colour, font style, and the icon style/sizing.

### 5.6.1 Colours

The first choice that has to be made is the main colour that will be used throughout the intervention. This colour will determine the background and overall style. Since the intervention is created for the University of Twente, by University of Twente students, it felt fitting to use a UT specific colour for this. Therefore, the UT house style colours (which can be seen in figure 32) were carefully considered.

**Figure 32**
*The UT house style colours*
(Visual Identity / House Style UT (Huisstijl UT) | Service Portal | University of Twente, 2022)


When only selecting colours to fit the UT house style, all of the above colour options could be a fitting one for this project. However, it must be considered that colours often have underlying meanings and could therefore unintentionally influence the user of the final intervention. Looking at this colour theory, a few colours could already be determined to be not useful for this project:

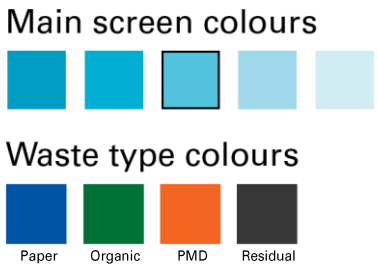
- The black and white colours are too intense for this project: black insinuates negative emotions, and could make people think of death, mourning, and emptiness. The white in contrast is too bright, especially to use on a screen, since the contrast will be very high.
- The red and green hues have too big of a ‘correct/incorrect’ annotation, though green often stand for nature and environment.
- Yellow has the associated meaning of happiness, being cheerful, joy, and is often a colour targeted at kids. In addition, yellow is a colour that is not often seen within the UT style, except for highlights.
- Purple is often associated with mourning, easter, but also luxury and ambition. It is often used in feminine design or also when promoting children’s products.
- Pink also gives the feel of childishness and hyper femininity (Rodin, 2018).

The main colour that was chosen for the project was the UT house style colour “05_UT_Blauw”, as can be seen in figure 31. Blue signifies wisdom, truth, understanding and patience but is also widely used in the promotion of products that are related to cleanliness, consciousness and intellect. In addition, it is often used to suggest precision in high-tech product promotion (Rodin, 2018). Since our intervention is targeted at correctly separating waste, and being precise with that, in addition to gaining more knowledge with regards to waste separation, the blue colour seemed the perfect fit. Next to having a correct colour association, blue is also a colour that matches with a lot of different colours

without it being ugly. It provides a neutral background colour that does not take the attention away of the information being presented on the screen.

The blue colour selected has different types of opacity. You have the original blue which is darkest, and four other options that are less saturated. For this project, the middle colour was selected (see figure 32). This means that the lighter and darker colours can be used as accent colours. In addition to the background colour, the waste type colours also have to be chosen. For this, the colours that seemed closest to the original waste type were selected using Adobe Illustrator (2019). These colours can also be seen in figure 33.

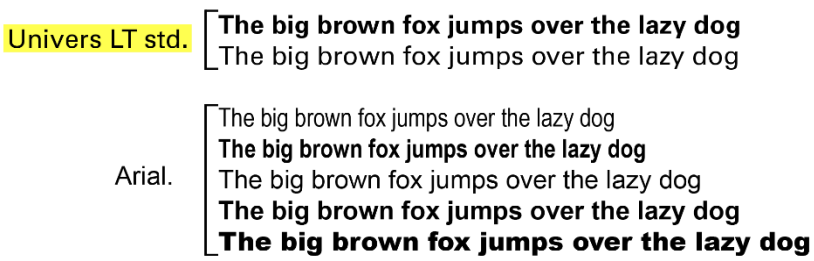
**Figure 33**
*The colours selected*




### 5.6.2 Fonts

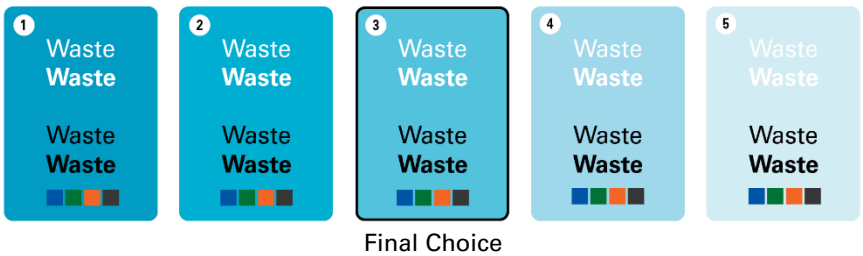
Next to the UT having house-style colours, the UT also has a house-style font. Officially this is the Univers LT std. font, but on the website they mention that Arial can also be used (*Visual Identity / House Style UT (Huisstijl UT)* | Service Portal | University of Twente, 2022). For this project, all types of the fonts (bold, italic, narrow, normal) were typed out and compared (as can be seen in figure 34). Ultimately, the Univers LT std. font was picked over the Arial font, as the Univers LT std. better captures the UT identity as its official font.

**Figure 34**
*The UT fonts*




After the font was selected, the two different styles (natural and bold) were placed on the chosen colour choices (as determined in 5.6.1) in the colours white and black to find the best contrast options. This also added to the final colour choice (option 3, as visible in figure 35). The waste colours were also placed on the small coloured shapes to identify the contrast and to see how they fit with the text colour. In the end, option 3 was chosen with the bold white text. Black seemed too dark of a contrast, and made the waste colours seem less vibrant, whereas the white gave a lighter feel and made the waste colours jump out more.

**Figre 35**
*Colour and font combination options*

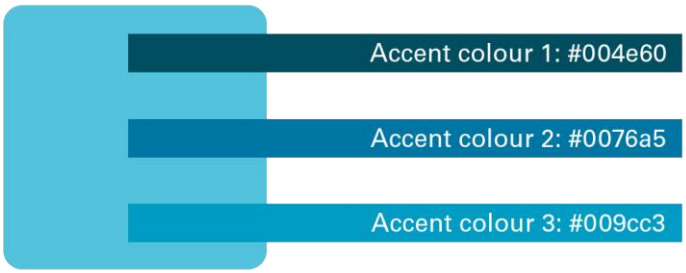


### 5.6.3 Icon style/size

As presented in the first sketches of the intervention (see figure 18 & 23), the screen will have circles with different types of waste presented in them. However, the style of the circles must be determined, especially the border colour and border thickness.

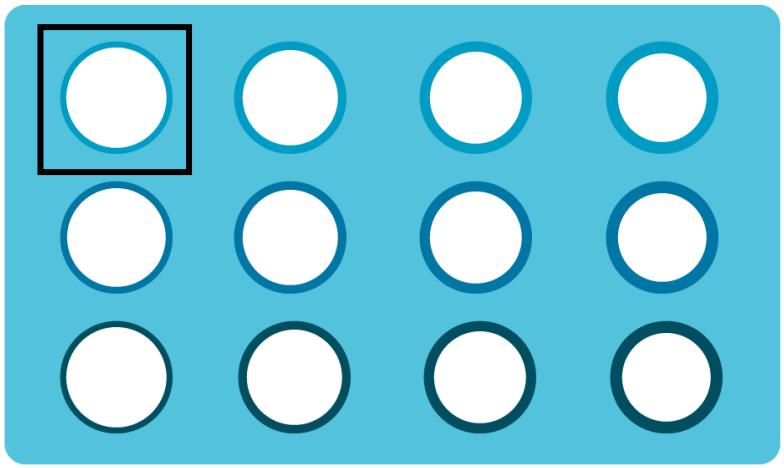
Three accent colours, which are darker versions of the main screen background colour (as chosen in 5.6.1), have been selected as potential border colours, see figure 36. The goal is to separate the whiteness of the circles from the background colour while still providing an in-between colour to make the difference less harsh and create a sense of coherence between the different images.

**Figure 36**
*Accent colours*




The choice of accent colour was not only determined by comparing the potential accent colours to the main screen background colour, but also seeing how they compared to the background colour when used as the border of the circle. This test (see figure 37) was executed by putting four different border thicknesses in each colour on the background colour, and comparing them to each other to see which one fits best.

**Figure 37**
*Border colour comparison*



After carefully considering each option it was decided that the upper left border type fitted best, therefore naming accent colour 3 the best fit (see figure 37). This colour nicely blends the circle and the background screen together, and gives a subtle highlight to the circle that makes sure that the user's eyes get pulled to the object presented inside of the circle. Especially since the touchscreen will be quite big, as its touchscreen, the border line should not be too big.

The icon style has been decided (see figure 37), but the looks of the icon inside is also an important aspect to consider. In the functional requirements it was said that the waste images should be as realistic as possible. However, when making pictures of the waste they cannot be presented perfectly and the super-realistic style does not fit with the rest of the screen aesthetic. There are several levels of realism that can be complied to; ranging from uber-realistic to sketchy. These levels are visualized in figure 38 with the use of a water bottle image.

**Figure 38**
*Different realism types*


The right-most image is the most sketchy visualization of the bottle, whereas the left-most image is the realistic one; this one has not been recreated using Adobe Illustrator 2019 and is just a regular water bottle image. It is noticeable that the least realistic one has very few colours and mainly rough shapes. This did not fit the non-functional requirement defined in part 5.4.2 of 'realistic visuals'. In addition, the water bottle might still be recognizable without much additional detail, but this might be different for other types of packaging (like highly detailed snack boxes, or chips packaging).

The middle images are eerily similar, however the left of the two has a little more detail in its shapes, and a bit more depth in terms of colour. It looks highly similar to the realistic image on the far left. However, when zooming in, the differences can be discovered. In figure 39 it can be seen that the right image (the more sketchy one) has more shape-like features than the left one (realistic image). From a distance this is hardly visible, but when presented on a big touchscreen the sketchier one fits better with the background and further styling of the screen.

**Figure 39**
*Realistic (left) vs. Sketch-like (right) details*


Another reason for choosing a more sketchy art-type approach is that all images used on the screen will have a sense of coherence. There are a lot of different types of waste that might not fit together very well. Especially since most pictures will be self-made, the quality of all of them will differ and they might not fit together quite nicely. To combat this, presenting them in the same artistic style elicits a sense of togetherness which makes the screen prettier to view and gives a professional view.

# 6. Realization

The realization phase focusses itself on creating the product that was imagined during the ideation phase and specified during the specification phase. First, all the separate parts that need to be designed and realized have to be identified. What follows is an explanation of *how* these parts have been realized, which are afterwards reflected on using the functional and non-functional requirements identified in chapter 5.

## 6.1. Identification of sub-parts

To create and assess the final prototype, it needs to be separated into the different parts that make up the full design. By doing this, a better overview is created, using which the designer can focus not only on the bigger picture, but also work out the smaller details that each sub-part should have to make the whole product better. For this design and product, there is a clear distinction between three parts: Visual, Nudging and Coding.

1. *Visual part:* the visual part focuses itself on showing the different waste types to the users, and makes sure that the screen is attractive to potential users. In addition, the nudging techniques should be applied here. Its most crucial function is informing the users of the screen about correct waste disposal.
2. *Nudging part:* the nudging part are the aspects that focus on the behavior influencing without the user necessarily noticing that their behavior is influenced.
3. *Coding part:* the coding part makes sure that the users can click the screen, thereby selecting a waste type, and that the screens switch. In addition, it makes sure that when a waste type is selected, the circle changes into the color of the waste stream where that specific waste type should be disposed.

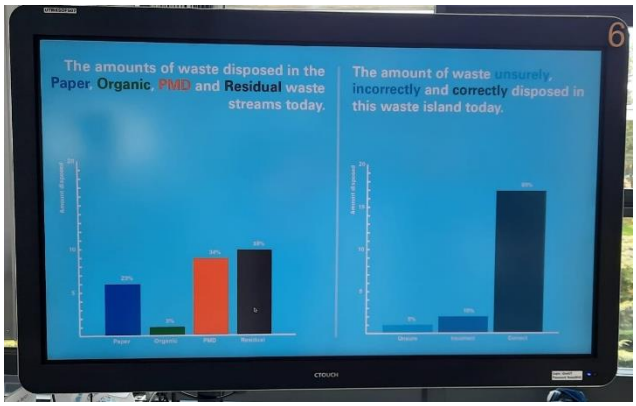
## 6.2. Realization of sub-parts

After the 3 sub-parts where identified, the realization was started. They were broken down in the separate components necessary to make sure that it worked. Per sub-part, the way of realizing the part will be discussed, but also the tools and systems used and the research that was executed.

### 6.2.1. Visual

For the visualization part of the product, different design aspects are necessary. Firstly, the main screens (information & selection) have to be designed. On the selection screens, the waste types will be shown. Therefore the second part is the design of the waste types. In addition, the feedback screens have to be designed and created as well; this is the third design aspect. Each of these design aspects were created using Adobe Illustrator 2019 and Adobe Photoshop (2019), graphic driven softwares that have all the proper tools to design and create images. Careful attention was paid to making sure all images are coherent with each other. A design tool used to create the images is the Huion Kamvas 13 drawing tablet (Huion NL, 2022) which uses a pressure driven pen to make movements and selections. Using this tablet, very small details can be added to the images which helps them become more coherent and professional-looking.

**Figure 40**
*The information screen*



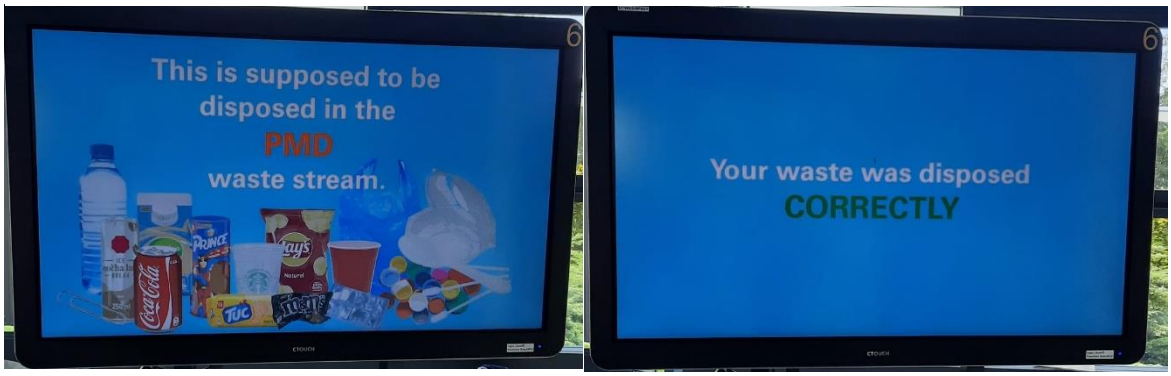
The information screen (figure 40) was made with grabbing the attention of potential users in mind. Bar charts were used so that people walking past can understand it in one go. This way each individual bar can be compared to another in a single go. Since people read from left-to-right, the most important information is presented on the left side, this being the types of waste disposed. On the right side the correctness level is displayed. The bar charts were made using the coding language Python in the software program PyCharm (Pycharm, 2021). The background of the information screen, including the text, was created in Adobe Illustrator 2019.

**Figure 41**
*The waste type selection screen (left) and the main selection screen (right)*


The main selection screens (see figure 41) were realized based on the colour and style choices made in the previous chapter (5.6). The final storyboard and sketches are used as a basis for the screens, as the placement of images has not changed since the beginning (see figure 22). The chosen style is simple, yet professional, but not in such a way that it makes people nervous to make mistakes. It was distinctly chosen that the screens should come over as non-offensive and non-discriminatory. That is why clear, big, imagery is used and the addition of a textual explanation underneath the picture for if people might not understand the imagery. High-contrast images are used to make sure that colour-blind people can also properly identify the waste types shown. The circles on each selection are positioned with enough space from each other such that it is hard to mis-click.

The waste types are created with the use of the ‘image trace’ function in Adobe Illustrator 2019. Via this function, images are traced and turned into shapes which can range from realistic until very animated and sketch-like. To create the images, pictures were taken from products sold around the campus. This makes sure that the waste presented is UT specific, and therefore easy to recognize by the users of the product. For the products that could not be found around the UT, Google Images (2001) was consulted. The pictures taken were first edited and cut-out in Adobe Photoshop 2019 after which they were transformed into shapes in Adobe Illustrator with the ‘image trace’ function. After this, the transformed images were individually placed in a circle with text underneath that described the waste type. For the selection buttons that show each waste category, the most seen waste types of that category were put together in one image to create a proper overview of what that waste category entails. This way, the user can connect their waste to the waste presented in that waste category without doubting about if their waste fits the name of the category. They can just connect the waste to the most similar images.

**Figure 42**
*Feedback screens used in the prototype*




The feedback screens (2 examples seen in figure 42) were designed with the goal to be as non-aggressive yet informative as possible. People must not get the feeling that they are being attacked for making a bad choice of disposal, instead they should feel informed and like they have learned something from the feedback. For this reason, non-attacking language is used. For the feedback after disposal *with* use of the selection screen, only a "You disposed correctly/incorrectly" text is used on the screen. If the user did not use the selection screen, a question is posted "This is supposed to be disposed in [waste stream]. Did you dispose correctly?". This question is meant to make the user think about their choices.

### 6.2.2. Nudging

Nudging was a big aspect of the existing solutions and technologies presented in the background research, and is therefore also implemented in this project's intervention. Within the screens, nudging techniques are used to motivate users to use the screen and separate their waste correctly. Each of the applied nudging techniques will be described here.

1. *Simplification*

   The simplification technique is realized by making the waste type images as recognizable as possible. This way the user only has to recognize the waste they hold in their hand, and connect it to the image. In addition, the waste categories consisting out of the main images of waste type *from* that category is also a form of simplification. The hierarchy makes it easier since users do not have to filter through all waste types each time, but can select the category and find their waste there. Using a touchscreen instead of something with a mouse also makes the interaction easier, and since the selection screen automatically appears when a potential user comes too close to the waste island it motivates the user to use the selection screen as well since 'its there now anyway'.

2. *Default rules*

   The preferred action of using the screen has been set as a default, since the information automatically into the selection screen instead of the potential user having to select the selection screen to be able to use it. This is motivating for the potential user since the action does not cause them to have any more work.

3. *Informing of choices*

   By showing the choices that people made previously on the information screen, the nudge of 'informing of choices' is realized. This way, people can see the behavior of previous users of the system, and might adapt their behavior to it.

4. *Precommitment strategies*

   People most likely continue with desired behavior when they have already committed to it. Therefore, changing the information screen to the selection screen automatically sets the first step for a potential user of the system. Then, when used once, the potential user could be motivated more to user the system more often, as the first time is the biggest step.

5. *Increase in ease and convenience*

   The simplifications of the actions the potential users have to undertake with disposing their waste using the screens, eases the action and makes waste disposal more convenient. Because the feedback screens appear with or without the screen, the user is taught something about waste separation without having to act out any more additional behaviors. This helps realizing the nudge of convenience. In addition, placing the text and icons prominently on the screen helps catching the potential users eyes, making them curious and thereby using the screen.

6. *Use of social norms*

   By showing how many people have separated their waste, and have done it correctly on the information screen, the use of social norms is realized. Informing people that others have already engaged in the behavior can motivate them to execute the behavior as well. Additionally, presenting the feedback screens after disposal shows the next potential user the result of the person before them. This puts slight pressure on the first person to do it correctly, and motivates the next user to use the screen as well.

### 6.2.3. Coding

The images cannot be used on the screen if they are not put inside the python code that runs the screen and its interactions. Therefore, each image created, first had to be converted from a .png to a .bmp file. This was done via the online converter called Online Converter (2015). This was the only online converter that did not require a paid subscription, however it meant that each image had to be put into the converter, changed to a .bmp, and downloaded individually. After each of the images was converted they could be loaded into the python file.

As for the coding in general, it was done using PyCharm (2021). This is a system in which python can be easily used and added to by being able to download several imports using pip files. For the addition of bar chart graphs on the information screen, the imports ‘pygame’ and ‘math’ were necessary. For the inclusion of the graphs on the screens, the extension ‘math’ had to be downloaded.

The images were added by use of a dictionary that ruffles through the several maps that contain the images. Because each image is put into a specific waste category, each map is named after one of the specific categories. This gives a better overview, and helps with making the coding aspect easier. Within the dictionary, each image was individually placed at the set location, and linked to the page that the screen should change into after the image gets clicked by the user. All code can be found in appendix VII.

## 6.3. Functional requirements review

After all parts were integrated in the design, the system was evaluated according to the functional requirements set up in the previous chapter (see chapter 5.4.1). It is especially important that all the ‘must’ requirements are complied. Table 6 shows that all requirements are met.

**Table 6**
*Functional requirements review*

| Number | Requirement | MoSCoW priority | Implemented? |
|---|---|---|---|
| 1. | Changes the information screen based on the waste selection of the users. | Must | Yes |
| 2. | Give feedback about waste disposal even if the screen has not been used. | Must | Yes |
| 3. | Has a selection hierarchy to make picking the waste types easier. | Must | Yes |

# 7. Evaluation

The last part of the Creative Technology design process is the Evaluation phase, this is where the product that was created during the realization is tested and where the non-functional requirements are assessed. All the aspects were evaluated with the use of user-testing.

The user testing was done physically in DesignLab in June 2022, and executed with 22 participants in total. The participants were divided into two groups of eleven participants. One control group to test how they separate waste without the intervention, and one with which the influence of the prototype was tested. By having two different groups they participants could not learn from their previous waste disposal. This made sure that each response was perfectly authentical and original.

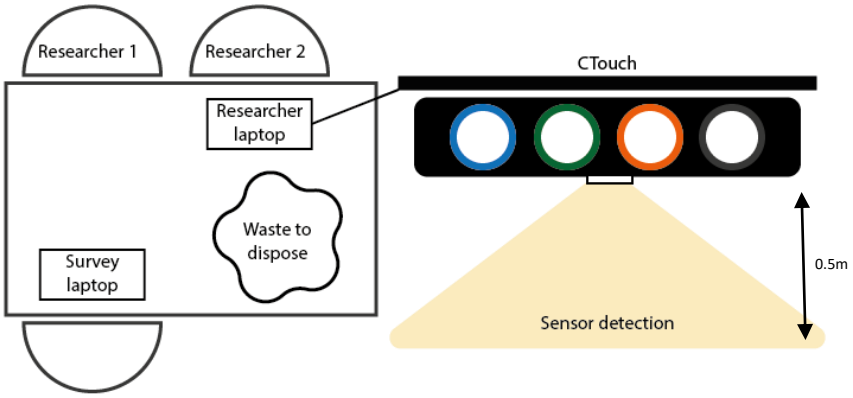
Both groups got the task to dispose of various (clean) wastes. Both groups had to dispose the same 15 waste product types that were carefully selected for the user evaluation. Some waste types were recognizable on the screen, and some waste types can only be disposed by linking the waste to another waste type presented on the screen.

Within the user testing, the topics of general waste disposal confidence and experience, the experience with the screen, and the participants experience with the waste island were tested. For this project however, only the first two topics play a big role. The waste disposal correctness rate, easiness level, and the correctness level in the participants' own opinion were reflected against each other using a small sample two individual samples T-Test via the software program SPSS (SPSS Statistics - Overview, 2021).

## 7.1. Set-up

Since the touchscreen is a critical aspect of the prototype, the evaluation procedure had to be conducted in DesignLab as the CTouch (CTOUCH Europe BV, 2022) screens are not allowed to leave that area. For both user evaluations (with and without the screen) the same place in the room was used. This for the reason that the location would not impact the results.

**Figure 43**
*Depiction of the evaluation set-up*




For the user evaluations the researchers would sit at a table next to the waste island set-up and overlook the waste island from the side to observe the waste disposal behavior form the participants. The CTouch screen is placed close to the waste island, such that the screen is positioned right above the waste island. For the test without the prototype, the CTouch would be turned off. For the test with the prototype the CTouch would be turned on.it was important that there is enough walking space for the participant, such that they can take some distance from the screen if they would like to. The detailed set up can be seen in figure 43.

## 7.2. Procedure

The user testing procedure was the following:

1. The participant is invited up to the table, and is presented the ethical consent forms and the information brochure (you can find these in Appendix VIII. The participant is asked to read the information brochure, and to ask any questions if they would like to. The participant then fills in and signs the consent form. Directly afterwards their task is explained: disposing the waste in the waste island, and afterwards filling in a short survey.
2. The participant takes the waste and disposes it in the waste island, depending on which test they partake in they are allowed to use the prototype or not.
3. While disposing the waste, the researchers note down in which waste bin the participant disposes their waste.
4. When the participant is finished, they are given a survey (or they can choose for an interview if they prefer that method) and fill in each question honestly. In the meantime, the researchers check how much waste was disposed correctly, and how much was disposed incorrectly.
5. After filling in the survey, the participant can give any remark about the prototype/experience they would like.
6. The participant is thanked for their help and contribution to the research. The researchers make the set-up ready again for the next participant.

## 7.3. Results

The user testing for this research focused on evaluating two main topics. In addition, general observations and comments from the participants were taken into consideration while taking the results as well.

### 7.3.1. Waste disposal experience results

For the waste disposal experience evaluation, the user-test results from participants doing the test with and without the prototype were compared in SPSS (SPSS Statistics – Overview, 2021). The SPSS results can be found in Appendix IX.

From the results, the number of correctly disposed wastes between the groups with and without the prototype were significantly different, the correctness level of the participants without prototype being 68%, and the level from the participants using the prototype 81% (see figure 45). This means that the prototype had a positive impact on waste separation quality and therefore improved the waste separation of partaking participants.

For the easiness and confidence level no significant difference was found. This means that the prototype does not necessarily increase the ease of waste separation, nor does it give the user more confidence about their waste separation quality. On the other hand, this does show that the product has the same levels in these aspects as normal waste separation without the product, not adding any more difficulties or trouble.

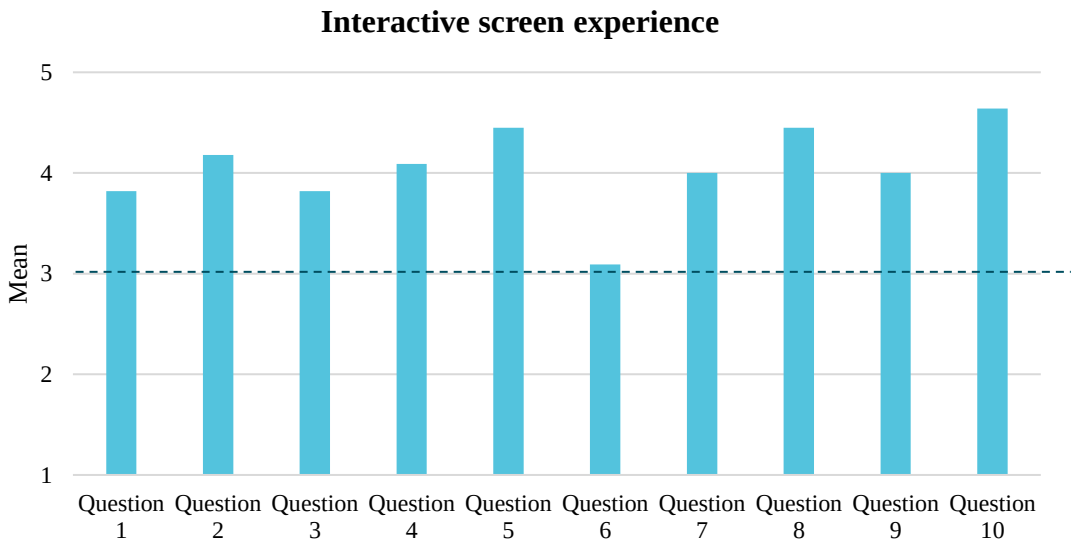
### 7.3.2. Interactive screen experience results

For the interactive screen experience, several aspects were evaluated. These being the screens attractiveness in general, how understandable and informative the screens were, and if the screens were educating to the users. These three aspects were evaluated using a survey created in Qualtrics (Qualtrics XM // The Leading Experience Management Software, 2022). In total, 10 questions were asked in the form of a statement which the participant should answer on a 5 part scale from ‘strongly disagree’ to ‘strongly agree’, with in the middle ‘neither agree nor disagree’. Each scale is given a correlating number from 1 to 5, with 1 being ‘strongly disagree’ and 5 being ‘strongly agree’. Each answers then gets the correlating number value and this way the mean is calculated. All question results are visible in Appendix X.

In figure 44 the mean results per question are visible. When the mean amount is higher than 3, it can be concluded that the answer was overall positive. The ten statement questions were the following:

1. The screen was inviting to use;
2. The screen was appealing to me;
3. The screen was easy to understand;
4. The screen gave me informative feedback;
5. The imagery used was realistic;
6. The screen was easy to navigate;
7. The screen has educated me about waste separation;
8. The imagery used was recognizable;
9. The waste type categories were clearly understandable;
10. The text was clearly readable.

**Figure 44**
*Bar chart depicting each mean per question asked in the survey.*




From the results presented in the bar chart, it can be concluded that most of the statement questions have been answered positively, all means ending up around the value of 4 and above the dotted line representing the value 'neutral'. Only question 6, "the screen was easy to navigate", ended up lowest around the 3-value. Possible reasons for this lower score are that the screen bugged a few times during user testing, and the residual waste sensor acted up which switched the screens quite quickly. In addition, some participants had trouble finding certain waste types on the screen because they did not notice the 'previous' and 'next' buttons present on the screen.

### 7.3.3. General comments & observations

During the user testing, specifically in the survey, the participants could give comments about the prototype. Additionally, the researchers observed their behavior. The comments and observations made during the user testing *with* the prototype were the following;

*Observations:*

- Participants had a hard time finding the waste type 'brochure' (classified under the type 'flyers'). It is placed in 'Others' but people tried to find it in the 'Paper' categories.
- Participants had a hard time finding the carton drink packaging. It is placed in the waste type category 'Carton & Paper packaging' but people tried to find it in the categories 'Cups' and 'Plastics'.
- Most participants did not use the 'Did you dispose correctly?' screen, and seemed like they did not understand what to do with it.
- A few participants did not see the 'Previous' and 'Next' buttons. They did not see them on the screen.

- The ‘Salad box’ waste type was misunderstood. Participants did not see it as a plastic packaging that could also be seen as packaging for e.g. cookies.
- Some participants did not use the prototype until they were at least halfway through the 15 waste types they were asked to dispose. They did not notice the screen, only the LEDs.

*Comments:*

- Participant 1: “I think the bin bugged a few times, which is why it I got unsure.”
- Participant 2: “It was easier to find where I had to dispose certain types of waste, however it was sometimes a bit confusing category should be chosen on the prototype.”
- Participant 3: “Difference between when to put it definitely in residual.”
- Participant 4: “Some waste is unclear where it’s supposed to go.”
- Participant 5: “The pictures made it very easy.”
- Participant 6: “For many products I am not sure if there is plastic in it.”
- Participant 7: “Especially printed paper I wasn’t sure to put in paper or residual.”
- Participant 8: “At first I did not get the screen would tell me what to do.”
- Participant 9: “Some items I was not sure of.”
- Participant 10: “Most of them made sense.”
- Participant 11: “Pressure to do it correctly.”

These observations and comments can be ordered in two categories: personal opinion, and options for change. Personal opinions are remarks and observations that are specific to one or two participants only and are based on opinion, and cannot really be accommodated for by making changed in the system. The options for change are comments and observations that could be added/changed in future adaptions of the intervention. In table 7 each observation and comment is separated into these two categories.

**Table 7**
*Options for change and opinions*

| **Options for change** | **Opinions** |
|---|---|
| Participants had a hard time finding the waste type ‘brochure’ (classified under the type ‘flyers’). It is placed in ‘Others’ but people tried to find it in the ‘Paper’ categories. | “At first I did not get the screen would tell me what to do.” |
| Participants had a hard time finding the carton drink packaging. It is placed in the waste type category ‘Carton & Paper packaging’ but people tried to find it in the categories ‘Cups’ and ‘Plastics’. | “Some items I was not sure of.” |
| Most participants did not use the ‘Did you dispose correctly?’ screen, and seemed like they did not understand what to do with it. | “Pressure to do it correctly.” |
| The ‘Salad box’ waste type was misunderstood. Participants did not see it as a plastic packaging that could also be seen as packaging for e.g. cookies. | “Difference between when to put it definitely in residual.” |
| Participants had a hard time finding the waste type ‘brochure’ (classified under the type ‘flyers’). It is placed in ‘Others’ but people tried to find it in the ‘Paper’ categories. | “Most of them made sense.” |
| Some participants did not use the prototype until they were at least halfway through the 15 waste types they were asked to dispose. They did not notice the screen, only the LEDs. | “The pictures made it very easy.” |
| “I think the bin bugged a few times, which is why it I got unsure.” | “For many products I am not sure if there is plastic in it.” |
| “It was easier to find where I had to dispose certain types of waste, however it was sometimes a bit confusing category should be chosen on the prototype.” | “Especially printed paper I wasn’t sure to put in paper or residual.” |

| | |
|---|---|
| “Some waste is unclear where it’s supposed to go.” | A few participants did not see the ‘Previous’ and ‘Next’ buttons. |

## 7.4. Non-functional requirements evaluation

With the results from the evaluation, the non-functional requirements can be checked for their implementation. As can be seen in table 8, almost all requirements were properly implemented following the user evaluation. Only requirement 11 is a little doubtful. Since the navigation is not as positive as wished for, with a mean value of 3.09, it does need some work. In addition, the participant comments and observations also showed that using the screen was sometimes difficult. Therefore, careful attention should be paid in improving that requirement.

**Table 8**
*Non-functional requirements implementation*

| Number | Requirement | MoSCoW priority | Implemented? |
|---|---|---|---|
| 1. | Be visually attractive such that it attracts users. | Should | Yes |
| 2. | Imagery used is understandable for all users. | Must | Yes |
| 3. | The text is readable in terms of size and font. | Must | Yes |
| 4. | Be inviting, such that people will use the screen. | Should | Yes |
| 5. | Use realistic visuals. | Could | Yes |
| 6. | Use touchscreen | Should | Yes |
| 7. | Clearly readable and understandable for every user. | Must | Yes |
| 8. | Use the UT house-style colors. | Could | Yes |
| 9. | Not have a brightness that is too high. | Could | Yes |
| 10. | Make use of engaging texts. | Should | Yes |
| 11. | Easy in use, without the need of explanation. | Should | Partially |
| 12. | Educate the users about waste separation. | Must | Yes |
| 13. | The images used are coherent and similar in style | Should | Yes |

## 7.5. Conclusion

Overall it can be concluded that the participants found the product to be useful and could understand it properly. In addition, the prototype helped improve waste separation, as the amount of correctly separated waste while using the prototype increased significantly compared to the participants not using the prototype, as seen in part 7.3.1. Some changes need to be made with regards to the navigation aspects found in part 7.3.2, and therefore some aspects need to be changed in the prototype to make it a fully functional product.

# 8. Conclusion & Discussion

With as a client a member of CFM-UT, it was found that the UT community does not dispose their waste correctly. The content of the residual waste bin consist out of 32% PMD, 18% organic, and 18% paper waste, next to a mere 32% of residual waste. This does not conform to the sustainability and recycling goals that the UT has set for the upcoming years. This research project was aimed at finding a proper solution for this problem, and to design an intervention that increases waste separation behavior and quality.

To do this properly, a research question was set up, aiming at finding a solution through interactive media. In the background research different behavioral theories were examined, of which 'nudging' was the best fit for this project. In addition, three reasons for not separating waste properly were found: laziness, a lack of accessibility, and a lack of knowledge and education. Through interviews with the client and with student peers the latter reason for incorrect waste separation was proven to be true. Though the CFM-UT had already come up with several solutions, none of them seemed to work as well as they should have, and so other existing technologies were examined during the state-of-the-art of the background research as well. These technologies showed different ways of improving waste separation behavior which in turn were used as an inspiration for the ideation phase of the project.

During the ideation, the stakeholders were identified and requirements were set-up accordingly. A brainstorm was conducted based on the information gathered from the background research and the stakeholder requirements, which was later worked out in concept ideas after which some of these ideas were combined into the final concept. This concept consists out of an interactive touchscreen and an adapted waste island with distance sensors and LEDs which should educate and motivate the UT community members about correct waste separation.

Following the ideation, the specification phase specified the product. Personas were created to assess the behavior of different types of users: from climate aware to climate unaware. Storylines were created based on the expected behavior of the persona's showing each interaction with the product possible. Based on the storylines, a storyboard was created to visually depict these interactions, and Time Sequence Diagrams were made to show the order of interactions between the user, waste island and interactive screen. Based on these, the functional and non-functional requirements were identified, after which the visual aspects of the product were explained.

In the realization phase, the three sub-parts of the product were identified: the visual aspect, the nudging aspect, and the coding aspect. Per each of these parts the steps taken to create them were explained in detail, making sure that the product can be recreated on basis of reading this thesis. In addition, a fully functioning prototype was created and tested for bugs. The prototype was also checked for fulfilling the functional requirements.

After this, the prototype was evaluated by doing user testing. 22 participants were asked to participate, and were split into two groups: 11 did the test without the prototype, and the other 11 did the testing *with* the prototype. These evaluations were conducted in the last week of June 2022 with random participants. The evaluation showed that the product was a success: the amount of correctly separated waste increased with an amount of 13% (went up from a 68% to a 81% correctness rate) after using the prototype. In addition, the interactive screen was positively received, with only the 'navigation' ending up with a lower rating.

Finally, the CFM-UT showed a real interest in the product and would like to use it during their sustainable product testing. They would like to see how it works when applied in real life after some more development, and hopefully the product will be useable at the University in the near future.

Therefore, the research question *"How can interactive media be used to influence the UT community members' behavior of waste separation at the UT campus?"* can be answered as follows: with the use of an interactive waste island, the UT community members can be sufficiently motivated and educated about correct waste disposal behavior. Even when not using the intervention, they can still be educated about correct separation.

## 8.1 Discussion

After all steps of the research and design process, it can be concluded and understood that a solution for incorrect waste separation must contain an educational aspect in addition to accurate waste type

separation information. For these two aspects, the interactive screen waste island seems to be successful in providing them. The screen is informative, and gives its users proper feedback about their waste disposal behavior.

Following the evaluation, it can be said that the interactive screen is a successful product. The waste separation quality increased, and the product was mainly received positively. The imagery was recognizable, and the screen was deemed attractive by the participants of the evaluation session. The nudging aspects identified in the background research were properly included in the product, as most participants mentioned they would use the screen again. The screen was easy in use, and the imagery and text was understandable. However, the navigation needs some improvement. This is critical, as the screen navigation impacts the time it takes to select the waste type on the screen, and therefore might increase the total disposal time.

In addition, though the evaluation results prove that the product was successful in improving waste separation behavior, it must be considered that the ease in use and confidence of the evaluation participants had not a significant increase. Another aspect that should be taken into consideration is that the evaluation was only conducted with a smaller group of people, that cannot be taken as a full reflection of all UT community members. Therefore, a bigger amount than 22 testing participants is needed to give a better reflection of the UT community.

# 9. Future work

Though the interactive waste island is a successful product according to this research, there is still room for some improvement. Following the prototype evaluation phase, there are some recommendations for future research, if it may be continued.

First, it must be taken into consideration that more waste types should be added. Now, there is a selection of approximately 125 waste types presented on the screen. However, there is more waste, and waste can change over time. As the University becomes more sustainable, its packaging will change together with this mentality. For this reason, the waste types presented on the screen should be changed accordingly. The product also uses a lot of UT-specific waste types and style. Therefore it is hard to place the interactive waste island at another location outside of the University of Twente. If so, the waste types need to be changed to those location-specific waste types, and the style should also be changed accordingly.

Furthermore, the information screen only allows for up to 25 responses before the bar charts are completely filled up. This was enough for the user testing, as 22 participants were invited for it, but it is too little for real-life use. Since the waste island will be placed in locations were a lot of waste is going to be disposed, the bar charts should be cleansed of data every few hours, or the amount of possible responses should be increased to at least over a hundred.

In addition, the prototype only worked with a laptop as a processor. First the idea was to have the data stored on a Raspberry Pi (Raspberry Pi Foundation, 2022), but the images took up too much storage and the Raspberry Pi's capacity was too low for that. This made the interactions very slow, so therefore the laptop had to be used instead. For a future revisitation of this project, it is advised to find a Raspberry Pi (or any other product) with a higher storage capacity such that the screen can work on its own without the use of a laptop.

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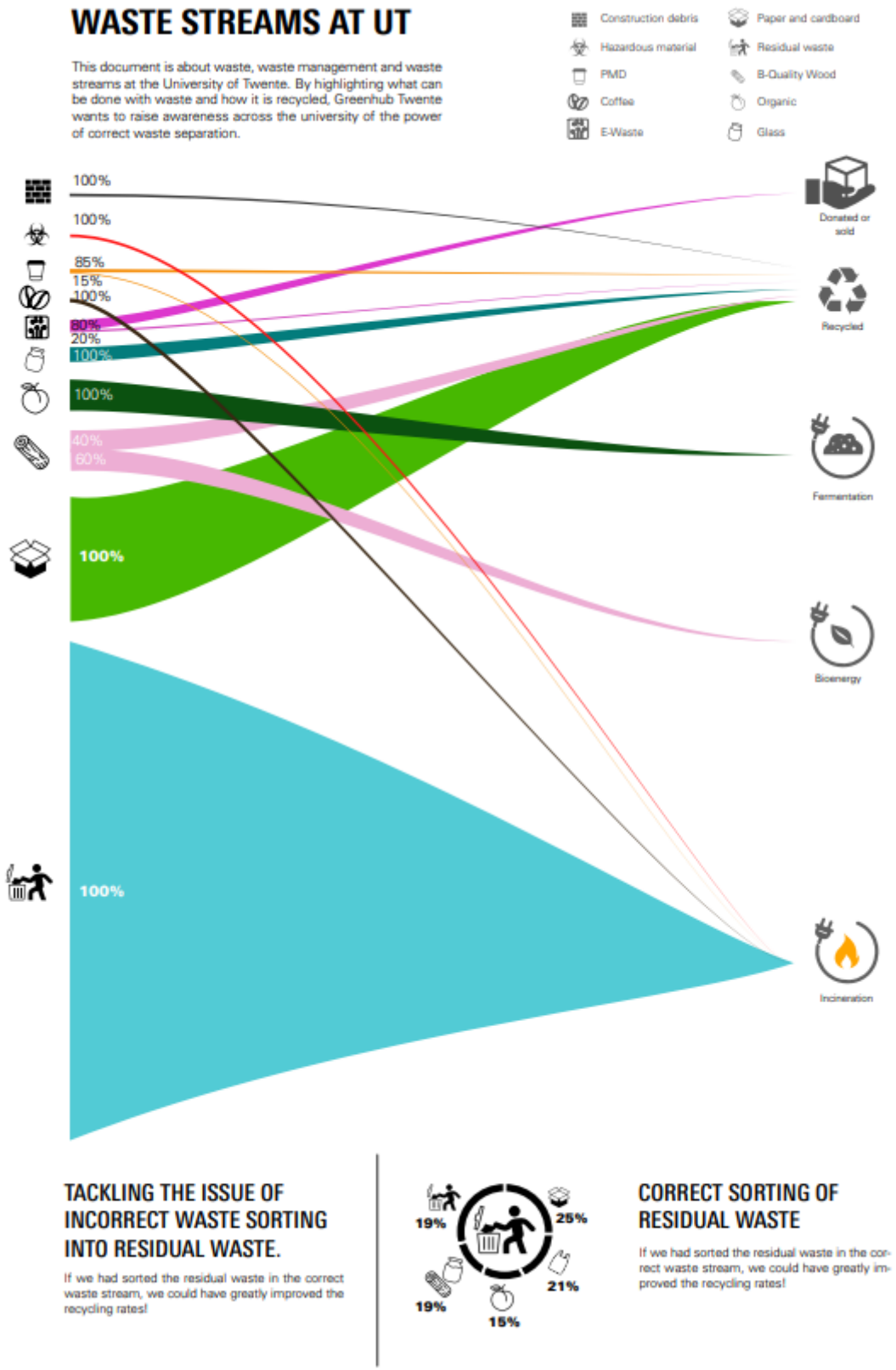
# Appendix I

The 10 different types of nudges by Sunstein, 2014.

1. *Default rules:* The preferred action has been set as a default, such that people need to actively change the default if they do not want to act out the preferred action, e.g. automatic enrolment in programmes, savings, organ donation. Due to the fact that people will most often not actively change the default setting out of e.g. laziness the preferred action will be successful.
2. *Simplification:* By simplifying the preferred action, each person can understand how to act out the action without confusion. If the complexity is too high, people might avoid the action out of fear for failure and humiliation. Thus, simplification increases participation.
3. *Uses of social norms:* Informing people that most of the others are engaged in a certain behaviour can motivate them to execute the action as well. Promoting the preferred activity by emphasizing that it is something that 'most people' do, will make the ones who do not do it feel left out. Since people are social animals, they will most likely try it out as well.
4. *Increases in ease and convenience:* People are known for making the easy choice without all too much hassle. Reducing various barriers in encouraging a specific type of behaviour can be helpful. Resistance to the preferred option is often out of perceived difficulty or ambiguity, e.g. placing healthy foods or more ecological products in a more visible spot.
5. *Disclosure:* These are nudges which highlight possible risks of privacy infringement in order to raise awareness to the person in order to prevent them from compromising their private information. However, disclosure nudges can also be applied by presenting decision-relevant information in a clear and concise way – ensuring that an individual knows the important details prior to making a choice. E.g. environmental costs associated with energy use, large amounts of data (data.gov), or the full cost of certain credit cards.
6. *Warnings:* By warning people of certain negative effects of making the 'bad' choice, e.g. buying cigarettes, they can be reminded of the long-term results of their choices which counteracts the tendency towards optimism that people have. This can be executed in a graphic way, but also by using large fonts with bold letters and bright colours.
7. *Precommitment strategies:* People most likely continue with desired behaviour when they have committed to it, e.g. enrolling in a programme. Committing to an action at an exact pinpointed future moment better motivates action and reduces procrastinating the action.
8. *Reminders:* These can have a significant impact, because people usually have a lot on their mind during a day. A reminder can thus be a great call to action. Timing in this instance really matters, people have to be able to act immediately.
9. *Eliciting implementation intentions:* People are more likely to participate in an activity when someone knows their intent to do the activity. When it comes to wished-for behaviours, a simple question about future behaviour can have a big impact. Emphasizing people's identities also works, since this makes them feel compelled to act out past behaviour (e.g. "you voted last year, will you do it again?")
10. *Informing people of the nature and consequences of their own past choices:* Institutions often have a lot of information about people's past choices, and can use this to their advantage. However, people often lack that information. If they would obtain their personal information, their behaviour could change which could make markets work better (Sunstein, 2014).

# Appendix II

CFM-UT poster about the different waste streams in collaboration with Greenhub**.**



# Appendix III

First intake Interview with the research client B. Dragtstra about the current situation and the actions by CFM-UT that are already taken, and will be taken in the future. The text is transcribed from Dutch to English.

*Q1. The UT wants to achieve their waste plan by applying the 7R's. Which of these R's would you say are of highest importance with complying to the waste plan?*
Answer: In the document they are presented in order of importance. So the first R, Rethink, which stands for preventing waste from happening, is the most important.

*Q2. What, would you say, is the greatest issue regarding waste separation at the UT?*
Answer: International students have a lot of trouble with separating waste. Especially the PMD stream seems to be difficult. Thus throwing it away in the Residual stream is thus easiest. Another issue is that there are no waste bins all around the UT anymore. They are placed in more specific spots, which makes it harder to separate. A cup with a lot of waste pushed in is just thrown into residual instead of separated.

*Q3. In the document it is mentioned that the UT wants to stimulate correct waste separation to facilitate the proper recycling of resources. This stimulation is mainly done via the waste islands mentioned later in the document I presume. How were the locations determined?*
Answer: Yes. The location of the waste islands was looked at closely. There were 4 team leaders, who would change the location if the location of the waste island is a cause of problems. This was decided during the new contract. They would look at where most trash would be produced, and implement the rule of 'every few meters a trash can' and then place them accordingly.

*Q4. How do you think the design of the waste islands influences people's (hopefully correct) distribution of waste?*
Answer: The design was thought bout. Residual is placed right because people read from left to right. The paper stream has a slot which is reminiscent of a piece of office paper. We placed stickers on the bins showing the waste to let the users know what should be disposed of where. The colors are the national Dutch waste colors but sadly the internationals don't know this. Too much other waste in especially the PMD waste stream gets rejected. PMD 'groenbeheer' checks each bag, and throws the individual bags away if they contain too much other waste. People think the entire container will then be incinerated, but this is not the case. At the UT only bags get rejected, not containers.

> *Q4.1 How does the separate coffee cup part help in your opinion?*
> Answer: It's to motivate people to throw away their coffee cups in there. Because it is a single spot they fall into each other and take up less space in the waste bin.

*Q5. Are there any other ways in which the UT plans to stimulate correct waste separation?*
Answer: Greenhub created a poster with each waste stream that explains what happens to the waste after disposal for awareness, but it's hard to reach a big target group. Nudging is something that we would like to try. Everyone is completely free to think of ideas: e.g. show which products are made from recycled trash. This could be made into a showcasing with an awareness campaign around it. You could also apply nudging by adding small steps on the floor, or have an AI trash bin which separates it for you. Greenhub works with people who have such a trash bin. You can put posters or screens above the waste islands with information or example products. Minimalize extra steps though! And text works less well than pictures.

*Q6. In the document it is said that students & employees are stakeholders of the waste. What would you say is the best way to inform and stimulate the students and employees to minimize the waste they create and to correctly separate it?*
Answer: e.g. games, interactive ideas, QR codes linking to information pages.

*Q7. In the chapter 'Desired Future Situation' you talk about the desired situations regarding all waste types. Which of those is of greatest importance to you/the UT?*
Answer: Reduce the amount of PMD and residual waste. Improve the separation of waste. Reduce the amount of waste from the other streams as well.

*Q8. In chapter 4, 'Planning', there is a mention of a Serious Gaming app. What exactly does this app entail, and how are you planning on using it?*
Answer: They are pretty far with testing. At the kick-in they want to teach the new students in a fun way how to separate waste. It should be some sort of scavenger hunt where you can scan waste islands.

# Appendix IV

Textual description of the informal interviews conducted with peers about their trash habits and waste separation knowledge.

***IV.a. Peer 1***

1. *Would you say that you always properly separate your waste? Why yes/no?*
   I do not. I'm too lazy to always separate it properly.

2. *Do the UT waste islands help with waste separation in your opinion? Why yes/no?*
   I did not understand them at first. Especially the PMD, what is that? But now I've lived here for about 2 to 3 years and I kind of understand how they work though I'm still confused about some products.

3. *How would you rate your waste separation knowledge on a scale from 0 to 10? Why?*
   A solid 7. Because I thought that if I have a paper cup and I had tea, I could just throw it in the paper bin. But it turns out you have to put it in residual because there was tea in the cup. Then I ask myself, why not only use residual since we apparently have to throw in most of our trash in there anyway.

***IV.b. Peer 2***

1. *Would you say that you always properly separate your waste? Why yes/no?*
   Most of the time but not always, because every place that I live at does it and I can't be bothered to put it all in one place since I've been separating for a while now.

2. *Do the UT waste islands help with waste separation in your opinion? Why yes/no?*
   The waste islands were a bit confusing but I only use plastic so I just put that in the assigned spot. They were confusing because there were pretty big lists of what could go in each bin.

3. *How would you rate your waste separation knowledge on a scale from 0 to 10? Why?*
   About a 5, I know the basics and some tricks but I could probably not answer complicated questions about waste separation.

***IV.c. Peer 3***

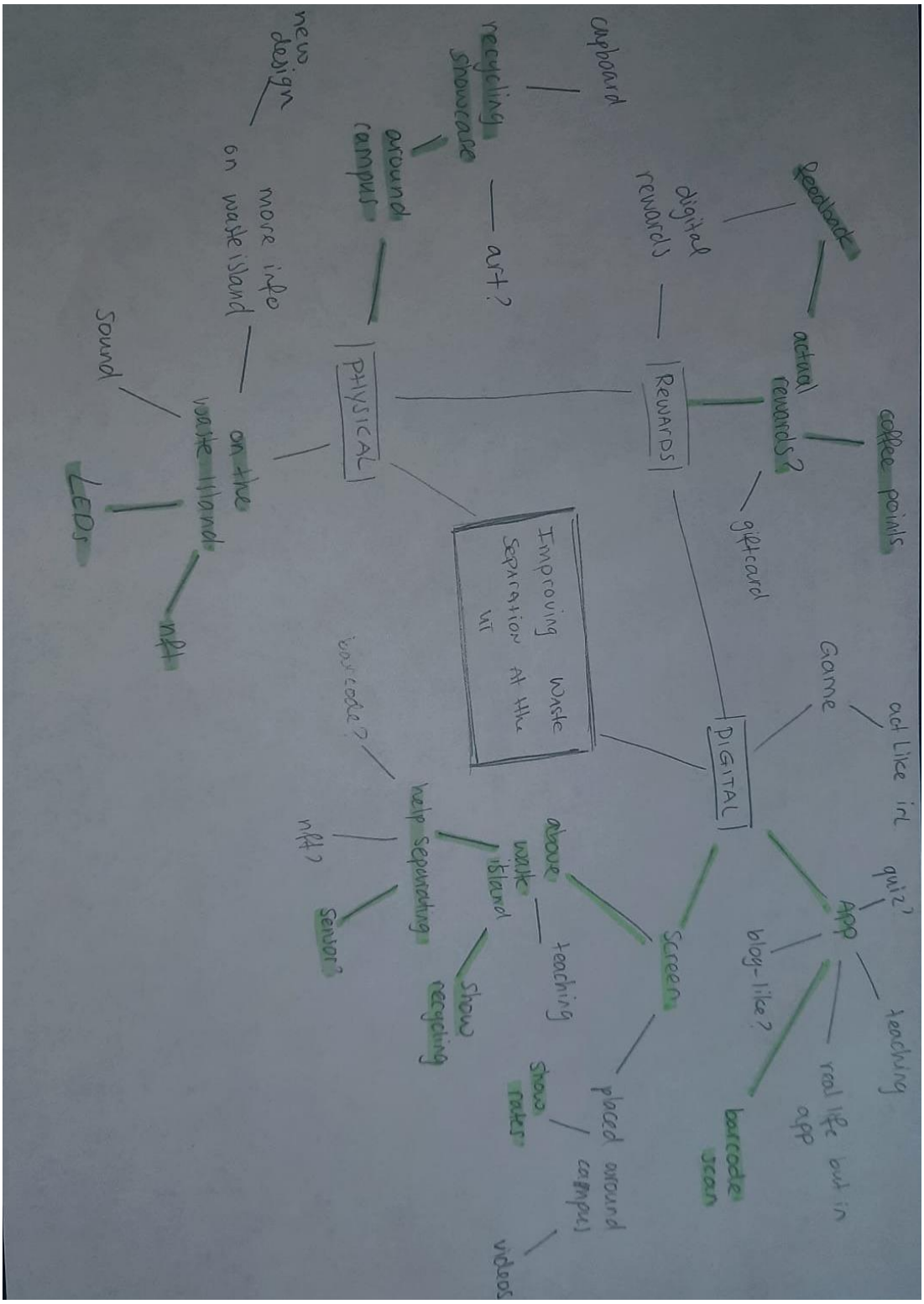
1. *Would you say that you always properly separate your waste? Why yes/no?*
   No. Even though I'd like to, I'm not always aware of which waste should go where.

2. *Do the UT waste islands help with waste separation in your opinion? Why yes/no?*
   They do help a little, but they are kind of unclear. Especially the imagery present on the bins is put too low for me, I can't see them properly so that makes it hard for me to see if I separate my waste correctly or not.

3. *How would you rate your waste separation knowledge on a scale from 0 to 10? Why?*
   7-8. I feel like I'm alright at separating waste, but with some items I still have trouble to decide which bins they should go in. Additionally, I'm not sure how they are recycled either, so if they're anything I can do to better my separation.

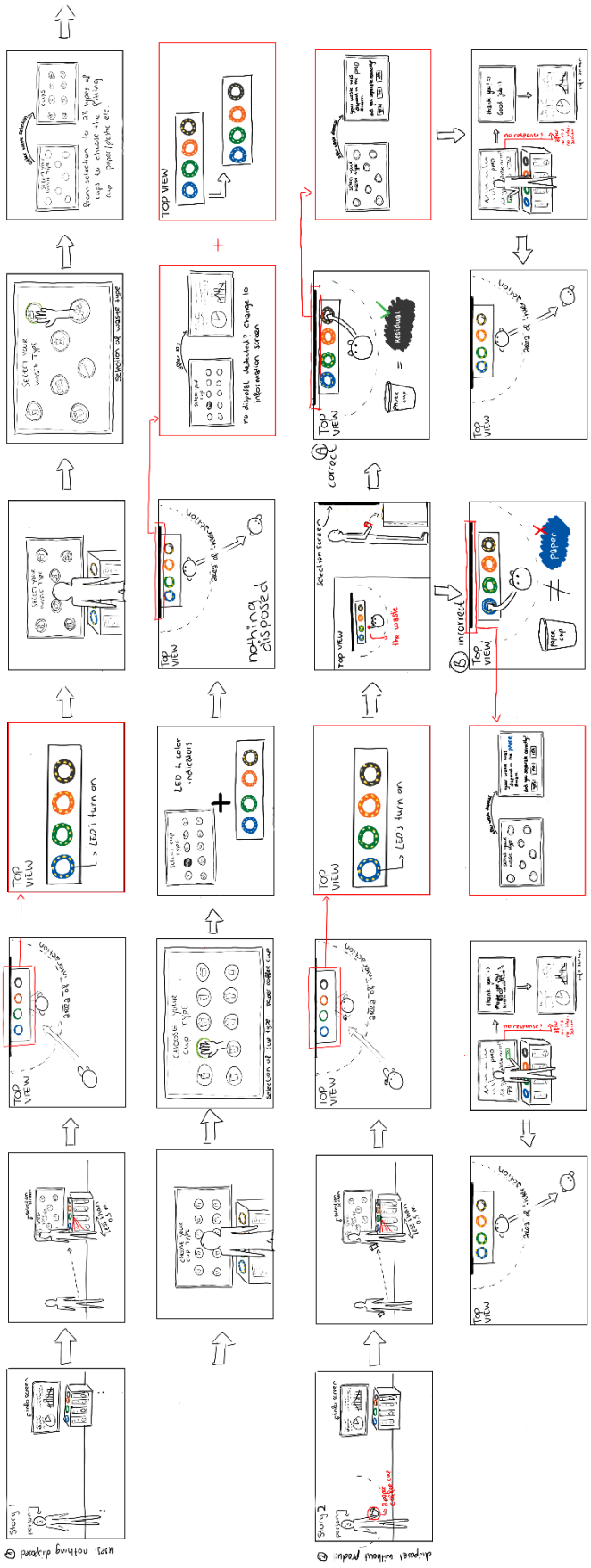
# Appendix V

The brainstorm mind-map showing possible technologies that can be used for the future intervention.



# Appendix VI

Storyboards for interaction types 1 and 2.



# Appendix VII

The python code written in PyCharm for the inclusion of the images.

```
import pygame
import math


class Screen:

    def __init__(self):
        self.running = True

        self.width = 1920
        self.height = 1080
        self.screen = pygame.display.set_mode((self.width, self.height))
        self.background =
pygame.image.load("images/selection/mainselection.bmp")
        self.subBackground =
pygame.image.load("images/selection/wastetype.bmp")
        pygame.display.set_caption("TEST")

        self.isSelected = False
        self.isSubSelected = False

        self.run_once = True
        self.posControl = True
        self.last_pos = ()

        self.selectedCategory = None

        self.counter = 0
        self.last_time = pygame.time.get_ticks()

        self.font = pygame.font.Font(None, 20)
        self.selectedIcon = ""
        self.menu = "main"

        # dictionary variable that contains all the information about all
the icons
        self.iconControl: dict = {
            # The main selection screen: all the icons include what sub-
selection screen they link to
            "main": {
                "Cups": {
                    "imgXPos": 150,
                    "imgYPos": 200,
                    "imageID": "images/Maingroups/cups.bmp",
                    "linksTo": "CUPS"
                },
                "CartonPaper": {
                    "imgXPos": 450,
                    "imgYPos": 450,
                    "imageID": "images/Maingroups/cartonpaper.bmp",
                    "linksTo": "CARTONPAPER"
                },
                "Metals": {
                    "imgXPos": 800,
                    "imgYPos": 700,
                    "imageID": "images/Maingroups/metals.bmp",
                    "linksTo": "METALS"
```

```
                },
                "Organic": {
                    "imgXPos": 150,
                    "imgYPos": 700,
                    "imageID": "images/Maingroups/organic.bmp",
                    "linksTo": "ORGANIC"
                },
                "Others": {
                    "imgXPos": 1150,
                    "imgYPos": 450,
                    "imageID": "images/Maingroups/others.bmp",
                    "linksTo": "OTHERS"
                },
                "paperNapkin": {
                    "imgXPos": 1450,
                    "imgYPos": 200,
                    "imageID": "images/Maingroups/papernapkin.bmp",
                    "linksTo": "PAPERNAPKIN"
                },
                "Plastic": {
                    "imgXPos": 1450,
                    "imgYPos": 700,
                    "imageID": "images/Maingroups/plastic.bmp",
                    "linksTo": "PLASTIC"
                }
            },

            # The sub-selection screens: all the icons include the sort
waste they are
            # cups
            "CUPS": {
                "foodCup": {
                    "imgXPos": 75,
                    "imgYPos": 200,
                    "imageID": "images/cups/foodcup.bmp",
                    "sortWaste": "residual"
                },
                "noodlesCups": {
                    "imgXPos": 425,
                    "imgYPos": 200,
                    "imageID": "images/cups/noodlescup.bmp",
                    "sortWaste": "residual"
                },
                "paperCup1": {
                    "imgXPos": 775,
                    "imgYPos": 200,
                    "imageID": "images/cups/papercup1.bmp",
                    "sortWaste": "residual"
                },
                "paperCup2": {
                    "imgXPos": 1125,
                    "imgYPos": 200,
                    "imageID": "images/cups/papercup2.bmp",
                    "sortWaste": "residual"
                },
                "paperCup3": {
                    "imgXPos": 1475,
                    "imgYPos": 200,
                    "imageID": "images/cups/papercup3.bmp",
                    "sortWaste": "residual"
                },
```

```
            "pastaCup": {
                "imgXPos": 75,
                "imgYPos": 600,
                "imageID": "images/cups/pastacup.bmp",
                "sortWaste": "residual"
            },
            "plasticCup": {
                "imgXPos": 425,
                "imgYPos": 600,
                "imageID": "images/cups/plasticcup.bmp",
                "sortWaste": "pmd"
            },
            "starbuckPaperCup": {
                "imgXPos": 775,
                "imgYPos": 600,
                "imageID": "images/cups/starbuckspaper.bmp",
                "sortWaste": "residual"
            },
            "coffeecups": {
                "imgXPos": 1125,
                "imgYPos": 600,
                "imageID": "images/cups/coffeecups.bmp",
                "sortWaste": "residual"
            },
            "starbucksPlasticCup": {
                "imgXPos": 1475,
                "imgYPos": 600,
                "imageID": "images/cups/starbucksplastic.bmp",
                "sortWaste": "pmd"
            },
            "PreviousButton": {
                "imgXPos": 775,
                "imgYPos": 830,
                "imageID": "images/selection/previousbutton.bmp",
                "linksTo": "main"
            }
        },

        # carton and paper
        "CARTONPAPER": {
            "cartonBasket": {
                "imgXPos": 75,
                "imgYPos": 200,
                "imageID": "images/cartonpaper/cartonbasket.bmp",
                "sortWaste": "residual"
            },
            "cartonBox": {
                "imgXPos": 425,
                "imgYPos": 200,
                "imageID": "images/cartonpaper/cartonbox.bmp",
                "sortWaste": "paper"
            },
            "cartonHolder": {
                "imgXPos": 775,
                "imgYPos": 200,
                "imageID": "images/cartonpaper/cartonholder.bmp",
                "sortWaste": "paper"
            },
            "coasters": {
                "imgXPos": 1125,
                "imgYPos": 200,
```

```
                "imageID": "images/cartonpaper/coasters.bmp",
                "sortWaste": "residual"
            },
            "drinkCarton": {
                "imgXPos": 1475,
                "imgYPos": 200,
                "imageID": "images/cartonpaper/drinkcarton.bmp",
                "sortWaste": "pmd"
            },
            "eggCarton": {
                "imgXPos": 75,
                "imgYPos": 600,
                "imageID": "images/cartonpaper/eggcarton.bmp",
                "sortWaste": "paper"
            },
            "paperBags": {
                "imgXPos": 425,
                "imgYPos": 600,
                "imageID": "images/cartonpaper/paperbags.bmp",
                "sortWaste": "residual"
            },
            "paperBreadBags": {
                "imgXPos": 775,
                "imgYPos": 600,
                "imageID": "images/cartonpaper/paperbreadbag.bmp",
                "sortWaste": "residual"
            },
            "pizzaBox": {
                "imgXPos": 1125,
                "imgYPos": 600,
                "imageID": "images/cartonpaper/pizzabox.bmp",
                "sortWaste": "residual"
            },
            "teaBagPaper": {
                "imgXPos": 1475,
                "imgYPos": 600,
                "imageID": "images/cartonpaper/teabagpaper.bmp",
                "sortWaste": "residual"
            },
            "PreviousButton": {
                "imgXPos": 775,
                "imgYPos": 830,
                "imageID": "images/selection/previousbutton.bmp",
                "linksTo": "main"
            }
        },

        # metals
        "METALS": {
            "bottleCaps": {
                "imgXPos": 250,
                "imgYPos": 200,
                "imageID": "images/metals/bottlecaps.bmp",
                "sortWaste": "pmd"
            },
            "energyDrink": {
                "imgXPos": 600,
                "imgYPos": 200,
                "imageID": "images/metals/energydrink.bmp",
                "sortWaste": "pmd"
            },
```

```
            "icedCoffeeCan": {
                "imgXPos": 950,
                "imgYPos": 200,
                "imageID": "images/metals/icedcoffeecan.bmp",
                "sortWaste": "pmd"
            },
            "metalBox": {
                "imgXPos": 1300,
                "imgYPos": 200,
                "imageID": "images/metals/metalbox.bmp",
                "sortWaste": "pmd"
            },
            "paperclip": {
                "imgXPos": 250,
                "imgYPos": 600,
                "imageID": "images/metals/paperclip.bmp",
                "sortWaste": "residual"
            },
            "sodaCan": {
                "imgXPos": 600,
                "imgYPos": 600,
                "imageID": "images/metals/sodacan.bmp",
                "sortWaste": "pmd"
            },
            "tunaCan": {
                "imgXPos": 950,
                "imgYPos": 600,
                "imageID": "images/metals/tunacan.bmp",
                "sortWaste": "pmd"
            },
            "PreviousButton": {
                "imgXPos": 775,
                "imgYPos": 830,
                "imageID": "images/selection/previousbutton.bmp",
                "linksTo": "main"
            }
        },

        # organics
        "ORGANIC": {
            "appleCore": {
                "imgXPos": 425,
                "imgYPos": 200,
                "imageID": "images/organic/applecore.bmp",
                "sortWaste": "organic"
            },
            "bananaPeel": {
                "imgXPos": 775,
                "imgYPos": 200,
                "imageID": "images/organic/bananapeel.bmp",
                "sortWaste": "organic"
            },
            "pizza": {
                "imgXPos": 1125,
                "imgYPos": 200,
                "imageID": "images/organic/pizza.bmp",
                "sortWaste": "organic"
            },
            "teaBag": {
                "imgXPos": 425,
                "imgYPos": 600,
```

```
                "imageID": "images/organic/teabag.bmp",
                "sortWaste": "organic"
            },
            "tosti": {
                "imgXPos": 775,
                "imgYPos": 600,
                "imageID": "images/organic/tosti.bmp",
                "sortWaste": "organic"
            },
            "PreviousButton": {
                "imgXPos": 275,
                "imgYPos": 830,
                "imageID": "images/selection/previousbutton.bmp",
                "linksTo": "main"
            }
        },

        # others
        "OTHERS": {
            "bandAids": {
                "imgXPos": 75,
                "imgYPos": 200,
                "imageID": "images/others/bandaids.bmp",
                "sortWaste": "residual"
            },
            "barrierTape": {
                "imgXPos": 425,
                "imgYPos": 200,
                "imageID": "images/others/barriertape.bmp",
                "sortWaste": "residual"
            },
            "bikeLights": {
                "imgXPos": 775,
                "imgYPos": 200,
                "imageID": "images/others/bikelights.bmp",
                "sortWaste": "residual"
            },
            "chewingGum": {
                "imgXPos": 1125,
                "imgYPos": 200,
                "imageID": "images/others/chewinggum.bmp",
                "sortWaste": "residual"
            },
            "ductTape": {
                "imgXPos": 1475,
                "imgYPos": 200,
                "imageID": "images/others/ducttape.bmp",
                "sortWaste": "residual"
            },
            "earPlugs": {
                "imgXPos": 75,
                "imgYPos": 600,
                "imageID": "images/others/earplugs.bmp",
                "sortWaste": "residual"
            },
            "flyers": {
                "imgXPos": 425,
                "imgYPos": 600,
                "imageID": "images/others/flyers.bmp",
                "sortWaste": "residual"
            },
```

```
            "lighter": {
                "imgXPos": 775,
                "imgYPos": 600,
                "imageID": "images/others/ligher.bmp",
                "sortWaste": "residual"
            },
            "metalPacket": {
                "imgXPos": 1125,
                "imgYPos": 600,
                "imageID": "images/others/metalpacket.bmp",
                "sortWaste": "pmd"
            },
            "mouthMasks": {
                "imgXPos": 1475,
                "imgYPos": 600,
                "imageID": "images/others/mouthmasks.bmp",
                "sortWaste": "residual"
            },
            "NextButton": {
                "imgXPos": 1275,
                "imgYPos": 830,
                "imageID": "images/selection/nextbutton.bmp",
                "linksTo": "NextOthers"
            },
            "PreviousButton": {
                "imgXPos": 275,
                "imgYPos": 830,
                "imageID": "images/selection/previousbutton.bmp",
                "linksTo": "main"
            }
        },

        # next others
        "NextOthers": {
            "mustardPacket": {
                "imgXPos": 75,
                "imgYPos": 200,
                "imageID": "images/others/mustardpacket.bmp",
                "sortWaste": "residual"
            },
            "pens": {
                "imgXPos": 425,
                "imgYPos": 200,
                "imageID": "images/others/pens.bmp",
                "sortWaste": "residual"
            },
            "plasticCaps": {
                "imgXPos": 775,
                "imgYPos": 200,
                "imageID": "images/others/plasticcaps.bmp",
                "sortWaste": "pmd"
            },
            "strawpackaging": {
                "imgXPos": 1125,
                "imgYPos": 200,
                "imageID": "images/others/strawpackaging.bmp",
                "sortWaste": "residual"
            },
            "sunglasses": {
                "imgXPos": 1475,
                "imgYPos": 200,
```

```
                "imageID": "images/others/sunglasses.bmp",
                "sortWaste": "residual"
            },
            "tape": {
                "imgXPos": 250,
                "imgYPos": 600,
                "imageID": "images/others/tape.bmp",
                "sortWaste": "residual"
            },
            "woodenCutlery": {
                "imgXPos": 600,
                "imgYPos": 600,
                "imageID": "images/others/woodencutlery.bmp",
                "sortWaste": "residual"
            },
            "woodenMixers": {
                "imgXPos": 950,
                "imgYPos": 600,
                "imageID": "images/others/woodenmixsticks.bmp",
                "sortWaste": "residual"
            },
            "PreviousButton": {
                "imgXPos": 775,
                "imgYPos": 830,
                "imageID": "images/selection/previousbutton.bmp",
                "linksTo": "OTHERS"
            }
        },

        # paper and napkins
        "PAPERNAPKIN": {
            "cleanPaper": {
                "imgXPos": 250,
                "imgYPos": 200,
                "imageID": "images/papernapkin/cleanpaper.bmp",
                "sortWaste": "paper"
            },
            "coffeeFilter": {
                "imgXPos": 600,
                "imgYPos": 200,
                "imageID": "images/papernapkin/coffeefilter.bmp",
                "sortWaste": "residual"
            },
            "dirtyNapkin": {
                "imgXPos": 950,
                "imgYPos": 200,
                "imageID": "images/papernapkin/dirtynapkin.bmp",
                "sortWaste": "residual"
            },
            "handkerchiefs": {
                "imgXPos": 1300,
                "imgYPos": 200,
                "imageID": "images/papernapkin/handkerchiefs.bmp",
                "sortWaste": "residual"
            },
            "napkins": {
                "imgXPos": 250,
                "imgYPos": 600,
                "imageID": "images/papernapkin/napkins.bmp",
                "sortWaste": "residual"
            },
```

```
            "newsPaper": {
                "imgXPos": 600,
                "imgYPos": 600,
                "imageID": "images/papernapkin/newspaper.bmp",
                "sortWaste": "paper"
            },
            "noteBooks": {
                "imgXPos": 950,
                "imgYPos": 600,
                "imageID": "images/papernapkin/notebooks.bmp",
                "sortWaste": "residual"
            },
            "paperStraws": {
                "imgXPos": 1300,
                "imgYPos": 200,
                "imageID": "images/papernapkin/paperstraws.bmp",
                "sortWaste": "residual"
            },
            "PreviousButton": {
                "imgXPos": 775,
                "imgYPos": 830,
                "imageID": "images/selection/previousbutton.bmp",
                "linksTo": "main"
            }
        },

        # plastics
        "PLASTIC": {
            "candyWrappers": {
                "imgXPos": 75,
                "imgYPos": 200,
                "imageID": "images/plastic/candywrappers.bmp",
                "sortWaste": "residual"
            },
            "chipsPackaging": {
                "imgXPos": 425,
                "imgYPos": 200,
                "imageID": "images/plastic/chipspackaging.bmp",
                "sortWaste": "residual"
            },
            "cookieWrapper": {
                "imgXPos": 775,
                "imgYPos": 200,
                "imageID": "images/plastic/cookiewrapper.bmp",
                "sortWaste": "residual"
            },
            "crackerPacket": {
                "imgXPos": 1125,
                "imgYPos": 200,
                "imageID": "images/plastic/crackerpackaging.bmp",
                "sortWaste": "residual"
            },
            "milkCarton": {
                "imgXPos": 1475,
                "imgYPos": 200,
                "imageID": "images/plastic/milkCarton.bmp",
                "sortWaste": "pmd"
            },
            "plasticBags": {
                "imgXPos": 75,
                "imgYPos": 600,
```

```
                "imageID": "images/plastic/plasticbags.bmp",
                "sortWaste": "pmd"
            },
            "plasticBottle1": {
                "imgXPos": 425,
                "imgYPos": 600,
                "imageID": "images/plastic/plasticbottle1.bmp",
                "sortWaste": "pmd"
            },
            "plasticBottles": {
                "imgXPos": 775,
                "imgYPos": 600,
                "imageID": "images/plastic/plasticbottles.bmp",
                "sortWaste": "pmd"
            },
            "snacks": {
                "imgXPos": 1125,
                "imgYPos": 600,
                "imageID": "images/plastic/snacks.bmp",
                "sortWaste": "pmd"
            },
            "plasticGloves": {
                "imgXPos": 1475,
                "imgYPos": 600,
                "imageID": "images/plastic/plasticgloves.bmp",
                "sortWaste": "residual"
            },
            "NextButton": {
                "imgXPos": 1275,
                "imgYPos": 830,
                "imageID": "images/selection/nextbutton.bmp",
                "linksTo": "NextPlastic"
            },
            "PreviousButton": {
                "imgXPos": 275,
                "imgYPos": 830,
                "imageID": "images/selection/previousbutton.bmp",
                "linksTo": "main"
            }
        },

        "NextPlastic": {
            "plasticSpoons": {
                "imgXPos": 75,
                "imgYPos": 200,
                "imageID": "images/plastic/plasticspoons.bmp",
                "sortWaste": "residual"
            },
            "plasticSticks": {
                "imgXPos": 425,
                "imgYPos": 200,
                "imageID": "images/plastic/plasticsticks.bmp",
                "sortWaste": "residual"
            },
            "saladBox": {
                "imgXPos": 775,
                "imgYPos": 200,
                "imageID": "images/plastic/saladbox.bmp",
                "sortWaste": "pmd"
            },
            "saucePackets": {
```

```
                    "imgXPos": 1125,
                    "imgYPos": 200,
                    "imageID": "images/plastic/sauchepackets.bmp",
                    "sortWaste": "residual"
                },
                "PreviousButton": {
                    "imgXPos": 775,
                    "imgYPos": 830,
                    "imageID": "images/selection/previousbutton.bmp",
                    "linksTo": "PLASTIC"
                }
            }
        }

        # The size of all the icons
        self.sz = 350;
        self.iconSize = (self.sz, self.sz)

    def calculateDistance(self, x1, y1, x2, y2):
        dist = math.sqrt((x2 - x1) ** 2 + (y2 - y1) ** 2)
        return dist

    def drawNormalMode(self):
        pygame.draw.rect(self.screen, (255, 255, 255), pygame.Rect(0, 0,
self.width, self.height))

    def drawCorrect(self):
        pygame.draw.rect(self.screen, (0, 255, 0), pygame.Rect(0, 0,
self.width, self.height))
        text = self.font.render("Thank you for correct separation!", True,
(0, 0, 0))
        img = pygame.image.load("images/selection/disposedCorrect.bmp")
        self.screen.blit(img, (25, 0))

    def drawWrong(self):
        pygame.draw.rect(self.screen, (255, 0, 0), pygame.Rect(0, 0,
self.width, self.height))
        text = self.font.render("It's WRONG!", True, (0, 0, 0))
        img = pygame.image.load("images/selection/disposedIncorrect.bmp")
        self.screen.blit(img, (25,0))

    def drawNotSelected(self, cat):
        pygame.draw.rect(self.screen, (0, 0, 0), pygame.Rect(0, 0,
self.width, self.height))
        text = self.font.render("Your waste is " + str(cat), True, (255,
255, 255))
        # text2 = self.font.render(cat, True, (255, 255, 255))
        if cat == "paper":
            img = pygame.image.load("images/selection/disposedPaper.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "organic":
            img = pygame.image.load("images/selection/disposedOrganic.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "pmd":
            img = pygame.image.load("images/selection/disposedPMD.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "residual":
            img =
pygame.image.load("images/selection/disposedResidual.bmp")
            self.screen.blit(img, (25, 0))
```

```
    def drawNotSelectedSecondScreenNOandIDK (self, cat):
        pygame.draw.rect(self.screen, (0, 0, 0), pygame.Rect(0, 0,
self.width, self.height))
        text = self.font.render("Your waste is " + str(cat), True, (255,
255, 255))
        # text2 = self.font.render(cat, True, (255, 255, 255))
        if cat == "paper":
            img = pygame.image.load("images/selection/papertypes.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "organic":
            img = pygame.image.load("images/selection/organictypes.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "pmd":
            img = pygame.image.load("images/selection/pmdtypes.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "residual":
            img = pygame.image.load("images/selection/residualtypes.bmp")
            self.screen.blit(img, (25, 0))

    def drawNotSelectedSecondScreenYES (self, cat):
        pygame.draw.rect(self.screen, (0, 0, 0), pygame.Rect(0, 0,
self.width, self.height))
        text = self.font.render("Your waste is " + str(cat), True, (255,
255, 255))
        # text2 = self.font.render(cat, True, (255, 255, 255))
        if cat == "paper":
            img = pygame.image.load("images/selection/ThankYouPaper.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "organic":
            img = pygame.image.load("images/selection/ThankYouOrganic.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "pmd":
            img = pygame.image.load("images/selection/ThankYouPlastic.bmp")
            self.screen.blit(img, (25, 0))
        if cat == "residual":
            img =
pygame.image.load("images/selection/ThankYouResidual.bmp")
            self.screen.blit(img, (25, 0))

    # The method that draws all the selection screens
    def draw(self):
        # Draw a background
        if self.menu == "main":
            background = pygame.transform.scale(self.background,
(self.width, self.height))
        else:
            background = pygame.transform.scale(self.subBackground,
(self.width, self.height))

        self.screen.blit(background, (0, 0))

        # Loop through all the icons in the current menu (self.menu)
        for currentIcon in self.iconControl.get(self.menu):
            # Load the image of the current icon
            img =
pygame.image.load(self.iconControl.get(self.menu).get(currentIcon).get("ima
geID"))
            # Scale the current icon
            img = pygame.transform.scale(img, self.iconSize)
            # Display the current icon in the position specified in the
iconControl
```

```
            self.screen.blit(img,
(self.iconControl.get(self.menu).get(currentIcon).get("imgXPos"),

self.iconControl.get(self.menu).get(currentIcon).get("imgYPos")))

            # If a (sub-selection screen) icon has been selected
            if self.selectedIcon != "":
                # Load the image of the icon of the sort waste selected
                img = pygame.image.load(
                    "images/selection/" +
self.iconControl.get(self.menu).get(self.selectedIcon).get(
                        "sortWaste") + ".bmp")
                # Scale the waste type icon
                img = pygame.transform.scale(img, self.iconSize)
                # Display the waste type icon on the position of the
selected icon
                self.screen.blit(img,
(self.iconControl.get(self.menu).get(self.selectedIcon).get("imgXPos"),

self.iconControl.get(self.menu).get(self.selectedIcon).get("imgYPos")))

self.categoryCheck(self.iconControl.get(self.menu).get(self.selectedIcon).g
et(
                        "sortWaste"))

    def drawEnd(self):
        pygame.draw.rect(self.screen, (255, 255, 255), pygame.Rect(0, 0,
self.width, self.height))
        text = self.font.render("Thank you for correct separation!", True,
(0, 0, 0))
        self.screen.blit(text, (700, 404))

    def categoryCheck(self, type):
        # if type == "paper":
        #     self.selectedCategory = "paper"
        #     print("paper")
        # elif type == "organic":
        #     self.selectedCategory = "organic"
        #     print("organic")
        # elif type == "pmd":
        #     self.selectedCategory = "pmd"
        #     print("pmd")
        # elif type == "residual":
        #     self.selectedCategory = "residual"
        #     print("res")

        self.selectedCategory = type
        # print(type)

    def touch(self, x, y):
        # Loop through all the icons in the current menu (self.menu)
        if pygame.mouse.get_pressed()[0]:
            for currentIcon in self.iconControl.get(self.menu):
                # Check if the current icon has been clicked
                if self.calculateDistance(x, y,
self.iconControl[self.menu][currentIcon]["imgXPos"] + self.sz / 2,

self.iconControl[self.menu][currentIcon][
                                                "imgYPos"] + self.sz / 2) <
self.sz / 2:
```

```
                    # If the current menu is the main selection screen
                    if self.menu == "main" or currentIcon == "NextButton"
or currentIcon == "PreviousButton":
                        # Change the current menu to the menu the selected
icon links to
                        self.selectedIcon = ""
                        self.menu =
self.iconControl.get(self.menu).get(currentIcon).get("linksTo")

                    # If the current menu is a sub-selection screen
                    else:
                        # Set the selected icon to the current icon
                        self.selectedIcon = currentIcon

                    break

    def timer(self):
        time = pygame.time.get_ticks()
        # Every one second, counter -1
        if time - self.last_time > 1000:
            self.counter += 1
            self.last_time = time
            print(self.counter)

    def loop(self, active):
        self.drawNormalMode()
        if active:
            self.draw()
            mouseX = pygame.mouse.get_pos()[0]
            mouseY = pygame.mouse.get_pos()[1]
            self.touch(mouseX, mouseY)

    def touchControl(self, x, y):
        if self.isSelected and not self.isSubSelected:
            if self.run_once:
                self.lastPos = (x, y)
                self.run_once = False
                self.posControl = False

            if self.lastPos != (x, y):
                self.posControl = True

        if self.posControl:
            self.touch(x, y)

    def loop(self, active, category):
        self.drawNormalMode()
        if active:
            self.draw()
            # if self.isSubSelected:
            #     if self.selectedCategory == category:
            #         self.drawCorrect()
            #         self.timer()
            #     elif category is not None:
            #         self.drawWrong()
            #         self.timer()
            # elif category:
            #     self.drawNotSelected(category)
            #     self.timer()

            mouseX = pygame.mouse.get_pos()[0]
```

```
            mouseY = pygame.mouse.get_pos()[1]

            self.touchControl(mouseX, mouseY)

        pygame.display.flip()




import math
import pygame

pygame.init()

width = 1920
height = 1080

screen = pygame.display.set_mode((width, height))
background = pygame.image.load("images/selection/informationscreen.bmp")
text_rotate_degrees = 0

#Font text waste types LEFT
display_surface = pygame.display.set_mode()
pygame.display.set_caption('Show Text')
font = pygame.font.Font('freesansbold.ttf', 20)

textPaper = font.render('Paper', True, (255, 255, 255))
textRectPaper = textPaper.get_rect()
textRectPaper.center = (250, 1020)

textOrganic = font.render('Organic', True, (255, 255, 255))
textRectOrganic = textOrganic.get_rect()
textRectOrganic.center = (400, 1020)

textPMD = font.render('PMD', True, (255, 255, 255))
textRectPMD = textPMD.get_rect()
textRectPMD.center = (550, 1020)

textResidual = font.render('Residual', True, (255, 255, 255))
textRectResidual = textResidual.get_rect()
textRectResidual.center = (700, 1020)

text1 = font.render('Residual', True, (255, 255, 255))
textRect1 = text1.get_rect()
textRect1.center = (700, 1020)

textPercPaper = font.render('%%', True, (255, 255, 255))
textRectPercPaper = textPercPaper.get_rect()
textRectPercPaper.center = (250, 800)

textPercOrganic = font.render('%%', True, (255, 255, 255))
textRectPercOrganic = textPercOrganic.get_rect()
textRectPercOrganic.center = (400, 800)

textPercPMD = font.render('%%', True, (255, 255, 255))
textRectPercPMD = textPercPMD.get_rect()
textRectPercPMD.center = (550, 800)

textPercResidual = font.render('%%', True, (255, 255, 255))
textRectPercResidual = textPercResidual.get_rect()
textRectPercResidual.center = (700, 800)
```

```
#Font text waste types LEFT
textAmount = font.render('Amount disposed', True, (255, 255, 255))
textAmount = pygame.transform.rotate(textAmount, 90)
textRectAmount = textAmount.get_rect()
textRectAmount.center = (60, 490)

text5a = font.render('5', True, (255, 255, 255))
textRect5a = text5a.get_rect()
textRect5a.center = (1080, 850)

text10a = font.render('10', True, (255, 255, 255))
textRect10a = text10a.get_rect()
textRect10a.center = (1080, 700)

text15a = font.render('15', True, (255, 255, 255))
textRect15a = text15a.get_rect()
textRect15a.center = (1080, 550)

text20a = font.render('20', True, (255, 255, 255))
textRect20a = text20a.get_rect()
textRect20a.center = (1080, 400)



#Font text amount disposed RIGHT
textUnsure = font.render('Unsure', True, (255, 255, 255))
textRectUnsure = textUnsure.get_rect()
textRectUnsure.center = (1250, 1020)

textIncorrect = font.render('Incorrect', True, (255, 255, 255))
textRectIncorrect = textIncorrect.get_rect()
textRectIncorrect.center = (1450, 1020)

textCorrect = font.render('Correct', True, (255, 255, 255))
textRectCorrect = textCorrect.get_rect()
textRectCorrect.center = (1650, 1020)

textPercUnsure = font.render('%%', True, (255, 255, 255))
textRectPercUnsure = textPercUnsure.get_rect()
textRectPercUnsure.center = (1250, 800)

textPercIncorrect = font.render('%%', True, (255, 255, 255))
textRectPercIncorrect = textPercIncorrect.get_rect()
textRectPercIncorrect.center = (1450, 800)

textPercCorrect = font.render('%%', True, (255, 255, 255))
textRectPercCorrect = textPercCorrect.get_rect()
textRectPercCorrect.center = (1650, 800)

#Font text amount disposed RIGHT
textAmount2 = font.render('Amount disposed', True, (255, 255, 255))
textAmount2 = pygame.transform.rotate(textAmount2, 90)
textRectAmount2 = textAmount2.get_rect()
textRectAmount2.center = (1050, 490)

text5b = font.render('5', True, (255, 255, 255))
textRect5b = text5b.get_rect()
textRect5b.center = (90, 850)

text10b = font.render('10', True, (255, 255, 255))
```

```
textRect10b = text10b.get_rect()
textRect10b.center = (90, 700)

text15b = font.render('15', True, (255, 255, 255))
textRect15b = text15b.get_rect()
textRect15b.center = (90, 550)

text20b = font.render('20', True, (255, 255, 255))
textRect20b = text20b.get_rect()
textRect20b.center = (90, 400)


while True:
    screen.blit(background, (0, 0))

    # Draw the bar charts on the LEFT
    # Paper
    pygame.draw.rect(screen, (0, 84, 166), pygame.Rect(195, 700, 120, 300))
    # Organic
    pygame.draw.rect(screen, (0, 114, 54), pygame.Rect(345, 700, 120, 300))
    # PMD
    pygame.draw.rect(screen, (242, 101, 34), pygame.Rect(495, 700, 120,
300))
    # Residual
    pygame.draw.rect(screen, (54, 54, 54), pygame.Rect(645, 700, 120, 300))
    # Bar Chart lines
    pygame.draw.line(screen, (255, 255, 255), (110, 1000), (110, 400), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 1000), (850, 1000), 5)
    # number lines
    pygame.draw.line(screen, (255, 255, 255), (110, 970), (120, 970), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 940), (120, 940), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 910), (120, 910), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 880), (120, 880), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 850), (120, 850), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 820), (120, 820), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 790), (120, 790), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 760), (120, 760), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 730), (120, 730), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 700), (120, 700), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 670), (120, 670), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 640), (120, 640), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 610), (120, 610), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 580), (120, 580), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 550), (120, 550), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 520), (120, 520), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 490), (120, 490), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 460), (120, 460), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 430), (120, 430), 5)
    pygame.draw.line(screen, (255, 255, 255), (110, 400), (120, 400), 5)

    # Draw the bar charts on the RIGHT
    # unsure
    pygame.draw.rect(screen, (0, 156, 195), pygame.Rect(1160, 700, 180,
300))
    # incorrect
    pygame.draw.rect(screen, (0, 118, 165), pygame.Rect(1360, 700, 180,
300))
    # correct
    pygame.draw.rect(screen, (0, 78, 96), pygame.Rect(1560, 700, 180, 300))

    # Bar Chart lines
```

```
    pygame.draw.line(screen, (255, 255, 255), (1100, 1000), (1100, 400), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 1000), (1800, 1000),
5)
    #number lines
    pygame.draw.line(screen, (255, 255, 255), (1100, 970), (1110, 970), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 940), (1110, 940), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 910), (1110, 910), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 880), (1110, 880), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 850), (1110, 850), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 820), (1110, 820), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 790), (1110, 790), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 760), (1110, 760), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 730), (1110, 730), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 700), (1110, 700), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 670), (1110, 670), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 640), (1110, 640), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 610), (1110, 610), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 580), (1110, 580), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 550), (1110, 550), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 520), (1110, 520), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 490), (1110, 490), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 460), (1110, 460), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 430), (1110, 430), 5)
    pygame.draw.line(screen, (255, 255, 255), (1100, 400), (1110, 400), 5)

    # The text
    display_surface.blit(textPaper, textRectPaper)
    display_surface.blit(textOrganic, textRectOrganic)
    display_surface.blit(textPMD, textRectPMD)
    display_surface.blit(textResidual, textRectResidual)
    display_surface.blit(textAmount, textRectAmount)
    display_surface.blit(textAmount2, textRectAmount2)
    display_surface.blit(textUnsure, textRectUnsure)
    display_surface.blit(textIncorrect, textRectIncorrect)
    display_surface.blit(textCorrect, textRectCorrect)
    display_surface.blit(text5a, textRect5a)
    display_surface.blit(text10a, textRect10a)
    display_surface.blit(text15a, textRect15a)
    display_surface.blit(text20a, textRect20a)
    display_surface.blit(text5b, textRect5b)
    display_surface.blit(text10b, textRect10b)
    display_surface.blit(text15b, textRect15b)
    display_surface.blit(text20b, textRect20b)
    display_surface.blit(textPercPaper, textRectPercPaper)
    display_surface.blit(textPercOrganic, textRectPercOrganic)
    display_surface.blit(textPercPMD, textRectPercPMD)
    display_surface.blit(textPercResidual, textRectPercResidual)
    display_surface.blit(textPercUnsure, textRectPercUnsure)
    display_surface.blit(textPercIncorrect, textRectPercIncorrect)
    display_surface.blit(textPercCorrect, textRectPercCorrect)

    for event in pygame.event.get():
        if event.type == pygame.QUIT:
            pygame.quit()
            quit()

        pygame.display.update()

    pygame.display.flip()
```

# Appendix VIII

The ethical documents (information brochure and consent form) used during the evaluation of this research project.

## Information Brochure for Graduation Project on Waste Separation

*Institution*: University of Twente (053 489 9111)

*Researcher information*: Senna Claes, s.h.j.claes@student.utwente.nl (06403410790) & Younghun Rhee
y.rhee@student.utwente.nl (0619802745) supervisors: Kasia Zalewska: k.zalewska-kurek@utwente.nl & Richard Bults: r.g.a.bults@utwente.nl

This research has been approved by the EEMCS Ethics Committee ethicscommittee-cis@utwente.nl.

*Title*: Improving Waste Separation at the University of Twente

*Purpose*: The purpose of this research is to observe the waste separation behaviour of the UT community members.

*Procedures*: You will be asked to participate in a user test, where you test the prototype of our final product. You will be given a task to separate a bunch of different clean waste (such as plastic bottle, coffee cup, empty crisps bag, cookie wrapper, empty sandwich bag, fresh banana peel) provided by us and disposing of it in a UT waste island. Afterwards we will ask you several questions via an interview or survey. The choice of which one you would like to do is up to you. The interview will be AUDIO RECORDED and TRANSCRIBED into text afterwards. Then the audio file will be deleted. If you wish, you can tell one of the researchers after the session and say that you do not want your data to be used. The survey can be conducted online or on paper, depends on your preference. If you do not want your survey data to be used, tell one of the researchers that the data should be deleted. There will be NO PERSONAL DATA used in the research. During the user testing, the researchers may take notes of how the participant disposes of waste and perceived easiness or difficulties with separating provided trash.

You can withdraw from the research at any moment. If you wish to stop the session at any point, please let the moderator know. If you are uncomfortable for any reason, tell one of the researchers and the session will be stopped. IMPORTANT: the audio files will be deleted after the sessions have been transcribed anonymously.

*Duration*: Approximately 15-20 minutes.

*Risks*: The participants will be required to be present at university. Covid-19 regulations will be implemented, as well as additional precautions to ensure the health and safety of the participants.

*Benefits*: The participants will make an impact with regards to waste separation quality improvement.

*Alternatives to participation*: There are no alternatives to the user testing.

*Confidentiality*: The participants will not be required to disclose any personal information. The findings from the research will be reported in a thesis in an anonymized and aggregated way and the

study will not process any personal data. You can ask at any point in the research for your data to not be used. The contact information to do so has been given in this brochure as well as the consent form.

## Consent Form for CreaTe

**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 [18-06-2022], 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. | ○ | ○ |
| I consent voluntarily to be a participant in this study and understand that I can refuse to take part in the user testing, interview/survey, and I can withdraw from the study at any time, without having to give a reason. | ○ | ○ |
| I understand that taking part in the study involves working with a physical prototype and taking part in an interview/survey. I also understand that for the choice of the interview, it will be recorded and transcribed to text after which the recordings are destroyed, and that the data that will be collected is saved for research purposes. I understand that for the choice of survey, that the data will be saved and processed for research purposes. | ○ | ○ |
| **Use of the information in the study** | | |
| I understand that information I provide will be used for research into the waste habits of the community members of the UT, which will be translated into a report. This report will be published online, and might be used for further research. Furthermore, the research could be published on the website from CFM. | ○ | ○ |
| I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team. | ○ | ○ |
| I agree that my information can be quoted in research outputs | ○ | ○ |
| **Future use and reuse of the information by others** | | |
| I give permission that the data taken from the interview will be saved in the archive. The data will be saved in the form of a report. The deposited data will be anonymised. Participants will be referred to as 'participants' and no names, or any other personal identifiable information will be published. | ○ | ○ |

**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:**

**Senna Claes**

**s.h.j.claes@student.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

# Appendix IX

SPSS results of the two sample individual T-Test results from the user evaluation part about waste disposal experience.

```
 Your license will expire in  1 day.
GET
  FILE='/Users/young/GP SPSS.sav'.
DATASET NAME DataSet1 WINDOW=FRONT.
T-TEST GROUPS=SystemPresent(1 2)
  /MISSING=ANALYSIS
  /VARIABLES=Correct
  /CRITERIA=CI(.95).
```

## T-Test

```
[DataSet1] /Users/young/GP SPSS.sav
```

**Group Statistics**

| | SystemPresent | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Correct | No | 11 | 10.2727 | 1.42063 | .42834 |
| | Yes | 11 | 12.1818 | 2.27236 | .68514 |

**Independent Samples Test**

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | |
|---|---|---|---|---|---|
| | | F | Sig. | t | df |
| Correct | Equal variances assumed | 6.785 | .017 | -2.363 | 20 |
| | Equal variances not assumed | | | -2.363 | 16.781 |

**Independent Samples Test**

| | | t-test for Equality of Means | | |
|---|---|---|---|---|
| | | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Correct | Equal variances assumed | .028 | -1.90909 | .80802 |
| | Equal variances not assumed | .030 | -1.90909 | .80802 |

**Independent Samples Test**

| | | t-test for Equality of Means | |
|---|---|---|---|
| | | 95% Confidence Interval of the Difference | |
| | | Lower | Upper |
| Correct | Equal variances assumed | -3.59459 | -.22360 |
| | Equal variances not assumed | -3.61556 | -.20263 |

```
T-TEST GROUPS=SystemPresent(1 2)
 /MISSING=ANALYSIS
 /VARIABLES=Easy
 /CRITERIA=CI(.95).
```

# T-Test

**Group Statistics**

| | SystemPresent | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Easy | No | 11 | 3.2727 | .90453 | .27273 |
| | Yes | 11 | 3.1818 | 1.07872 | .32525 |

**Independent Samples Test**

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | |
|---|---|---|---|---|---|
| | | F | Sig. | t | df |
| Easy | Equal variances assumed | .554 | .465 | .214 | 20 |
| | Equal variances not assumed | | | .214 | 19.410 |

**Independent Samples Test**

| | | t-test for Equality of Means | | | |
|---|---|---|---|---|---|
| | | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence ... Lower |
| Easy | Equal variances assumed | .833 | .09091 | .42446 | -.79450 |
| | Equal variances not assumed | .833 | .09091 | .42446 | -.79622 |

**Independent Samples Test**

| | | t-test for Equality of... 95% Confidence Interval of the... Upper |
|---|---|---|
| Easy | Equal variances assumed | .97631 |
| | Equal variances not assumed | .97804 |

```
T-TEST GROUPS=SystemPresent(1 2)
 /MISSING=ANALYSIS
 /VARIABLES=Confident
 /CRITERIA=CI(.95).
```

# T-Test

**Group Statistics**

| | SystemPresent | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Confident | No | 11 | 3.4545 | .93420 | .28167 |
| | Yes | 11 | 3.7273 | 1.00905 | .30424 |

**Independent Samples Test**

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | |
|---|---|---|---|---|---|
| | | F | Sig. | t | df |
| Confident | Equal variances assumed | .021 | .885 | -.658 | 20 |
| | Equal variances not assumed | | | -.658 | 19.882 |

**Independent Samples Test**

| | | t-test for Equality of Means | | |
|---|---|---|---|---|
| | | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Confident | Equal variances assumed | .518 | -.27273 | .41461 |
| | Equal variances not assumed | .518 | -.27273 | .41461 |

**Independent Samples Test**

| | | t-test for Equality of Means | |
|---|---|---|---|
| | | 95% Confidence Interval of the Difference | |
| | | Lower | Upper |
| Confident | Equal variances assumed | -1.13759 | .59213 |
| | Equal variances not assumed | -1.13792 | .59246 |

# Appendix X

User evaluation results:  interactive screen.

| Statement | Strongly Disagree (1) | Somewhat Disagree (2) | Neither Agree nor Disagree (3) | Somewhat Agree (4) | Strongly Agree (5) | Mean |
|---|---|---|---|---|---|---|
| 1. The screen was inviting to use. | 0 | 2 | 2 | 3 | 4 | 3.82 |
| 2. The screen was appealing to me. | 0 | 0 | 0 | 9 | 2 | 4.18 |
| 3. The screen was easy to understand. | 0 | 1 | 2 | 6 | 2 | 3.82 |
| 4. The screen gave me informative feedback. | 0 | 0 | 2 | 6 | 3 | 4.09 |
| 5. The imagery used was realistic. | 0 | 0 | 1 | 4 | 6 | 4.45 |
| 6. The screen was easy to navigate. | 1 | 2 | 3 | 5 | 0 | 3.09 |
| 7. The screen has educated me about waste separation. | 0 | 1 | 2 | 4 | 4 | 4.00 |
| 8. The imagery used was recognizable. | 0 | 0 | 1 | 4 | 6 | 4.45 |
| 9. The waste type categories were clearly understandable. | 0 | 0 | 3 | 5 | 3 | 4.00 |
| 10. The text was clearly readable. | 0 | 0 | 1 | 2 | 8 | 4.64 |