Creative Technology Bachelor Thesis

Faculty of Electrical Engineering, Mathematics, and Computer Science (EEMCS)

Improving Waste Separation Motivation at the UT Campus

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Abstract

The University of Twente (UT) is actively striving to enhance its sustainability efforts and reduce waste generation and disposal on campus. In order to achieve these objectives, the university recognizes the need to promote waste separation among its community. However, the motivation of the UT community to engage in waste separation practices is not currently at an optimal level. Consequently, the client of this project, Campus & Facility Management (CFM-UT), expressed interest in finding a creative and innovative solution. Thus, the primary goal of this research was to discover a method to improve the motivation of the UT community towards effective waste separation.

To understand why the motivation of the UT community is currently low and determine how to positively influence their behavior, a comprehensive research was conducted. Subsequently, a potential solution was developed. This solution takes the form of the BinBuddies Interactive Waste Island, designed to positively impact the motivation of the UT community and enhance their knowledge regarding the proper separation of commonly unknown waste items.

An evaluation was carried out through user testing involving members of the UT community. It was revealed that the BinBuddies interactive waste island holds great promise as a solution to improving individuals' motivation for waste separation. The concept proved moderately successful in influencing participants' motivation and was effective in improving their understanding of commonly unknown waste items. However, for long-term implementation, further development is required.

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1 Introduction

1.1 Context

Daily, people generate waste that must be disposed of efficiently, conveniently, and correctly. Because of the overload of waste generated in the late 1980s in the Netherlands, the Dutch government urged a change in waste management and developed five elements to help achieve their goals [1]. Out of the five key elements, one stands out as particularly crucial: correct waste separation. The government introduced a system that helps separate waste into four types: Organic, Paper, Plastic and Drinking Packaging (PD), and Glass. These four waste categories aim to simplify waste separation for the general public and streamline the recycling and reusing process of the disposed waste. The University of Twente shares the same goals for better waste separation and has therefore introduced this system by implementing waste separation islands which consist of four constrainers for Organic, Paper, PD, and Residual waste around the campus buildings [2]. Unfortunately, not all the waste is properly separated. To help the University of Twente successfully improve the waste separation on campus, it is essential to help motivate university staff and students towards correct waste separation and to explore behavioral nudges to help them apply the communicated knowledge effectively.

1.2 Problem Statement

Designing for behavioral change can present several challenges, especially when targeting specific user groups. In this case, the target users are the University of Twente students and staff, referred to as the UT Community. It is important to note that students, in particular, may face several barriers to proper waste separation. They are inclined to prioritize convenience and speed over correctly disposing of waste, despite having knowledge of proper waste separation [3]. Therefore, when designing the final product, it is important to consider these existing behaviors and develop a solution that motivates proper waste separation among the target user group. The product should aim to address these barriers and provide a convenient, accurate, and motivational way for users to separate their trash correctly.

1.3 Research Questions

Various variables can influence waste separation actions. One of those variables is motivation. When it comes to waste separation, motivational challenges can significantly impact how people dispose of their waste. Throughout the university, the waste separation islands are located in strategic areas to ensure that people walk past a separation island frequently. Due to that, there are also no waste bins in classrooms to motivate students to use the separation islands. However, this can sometimes lead to a counterproductive outcome, as some students may prioritize personal convenience over proper waste disposal by combining all of their waste and throwing it out in the residual bin. Therefore, the goal of this project is to design an installation that will influence the UT community's motivation in a way that will be helpful to them and improve their motivation to separate their waste. The research question for this project is to understand: *"How can interactive media be employed to influence the motivation of the UT community toward proper waste separation at the UT campus?"*

To help answer this research questions, several sub-research questions were created:

- What are behavioral nudges that encourage motivation for proper waste separation?
- How should waste currently be separated at the UT Campus?
- What design strategies are used in promoting waste separation?

1.4 Structure of Thesis

The structure of this paper aims to explain the development process of the installation for improving motivation for waste separation. It is structured into several chapters, starting with Chapter 1:

Introduction followed by Chapter 2: Background Research which will go deeper into the topic of motivation and explore the factors that influence motivation and how that is related to the current waste separation islands at the University of Twente. Chapter 3: Methods and Techniques will elaborate on the methods used to conduct this research such as observations of the UT community and their motivations, followed by Chapter 4: Ideation which will explain the ideation process for the intervention. Following, Chapter 5: Specifications, and Chapter 6: Realizations will elaborate on how the intervention will work and be realized. Chapter 7: Evaluation will evaluate the project and Chapter 8: Conclusion, Chapter 9: Discussion, and Chapter 10: Future work will conclude and discuss possible future work regarding the topic as well as the limitations, constraints, and possible improvements that could be made to this project.

2 Background Research

2.1 Literature Review

The following chapter discusses the literature research done on the topic of motivation and waste separation. The challenges that prevent individuals from properly separating their waste will be discussed, as well as the factors that motivate them to separate their waste and how can those factors be used and enhanced through the use of behavioral change influencers.

2.1.1 Waste Separation Challenges

Various variables can influence waste separation actions and there are several plausible explanations for incorrect waste separation. For the context of this paper, the term 'challenges' within waste separation refers to the various factors that make it difficult for individuals to perform proper waste separation, and as a result, may lead to demotivation and reluctance to engage in these actions. One of the factors that influence waste separation is convenience. In the literature review of Knickmeyer [4] the author explains that the perception of convenience varies from person to person and depends on how easy it is to understand and use the waste separation system. Therefore, the easier it is to use the system the more likely it is to be used, and vice versa. Based on Timlett and Williams ISB model, Knickmeyer concludes that the availability and accessibility of waste separation facilities also significantly influence people's willingness to participate in waste separation practices [4]. At the University of Twente, the waste separation islands are located outside of lecture halls and there are no waste islands near desks or inside lecture halls, meaning that individuals need to walk a longer distance to throw away their waste [2]. This may result in students combining their waste and disposing of it altogether without separation. Knickmeyer [4] supports this by saying that if facilities are not easily accessible or available, individuals may not be motivated to go out of their way to properly separate their waste. Similarly in their research, Arnadottir et al. [3] discovered that time pressure and laziness can also hinder proper waste separation, particularly among students.

Another important factor is the level of knowledge of individuals. As Barr highlights, if individuals lack the necessary knowledge to take appropriate actions, it could pose a significant barrier to behavior change and hinder their ability to properly separate waste [4]. Frequent changes to waste separation guidelines can result in a lack of knowledge among individuals, which may in turn demotivate them from taking proper actions. An example of this can be the introduction of mixed media packaging, such as paper and plastic combinations. In the literature review of Knickmeyer, Schüßler explains that these material mixes and multi-component packages can create confusion among individuals and discourage them from investing the time required to properly separate the different components [4]. Arnadottir et al. support this with their findings that "students are not willing to tear apart packaging that consists of both paper and plastic parts" [3, p. 5].

A final factor that can affect individuals' motivation to separate their waste is feeling excluded from the waste management system. In their research, Haksevenler et al. found that people are more likely to take responsibility for waste separation in their homes than on campus [5]. This may be due to the fact that individuals feel a greater sense of personal responsibility for their homes, whereas responsibility for waste management on campus may be more diffuse [5]. Bahcelioglu et al [6] agree with these findings as they also obtained similar results at the METU campus in Turkey. Therefore, it can be concluded that feeling part of the management system is an important aspect of waste separation.

2.1.2 Motivation as a Driver for Proper Waste Separation

Apart from identifying the challenges and barriers to proper waste separation, it is equally important to recognize the factors that encourage and motivate individuals to participate in waste separation. As previously mentioned, a sense of inclusion in the waste management system is crucial in motivating individuals to properly separate their waste [5]. The feeling of responsibility and a commitment to the community are also key drivers of motivation toward waste separation, as studies have shown that people may be demotivated when they feel that others are not paying sufficient attention to these practices [6]. Kamoen and Karahanoglu [7] also support these as they discovered that the drive for individuals to feel a sense of connection to their community and receive social validation could indeed be a motivator for waste separation.

Research has shown that an individual's attitude toward recycling and their general environmental concern plays a significant role in their recycling behavior [4]. Tonglet et al. explain that the primary driver of individuals' motivation to recycle is their pro-recycling and pro-environmental attitudes [4]. These attitudes can be influenced by several factors, including the availability of resources such as waste separation islands at reasonable distances, knowledge regarding correct waste separation, as well as the absence of physical barriers that prevent individuals from separating their waste, such as lack of time or inconvenient access to recycling bins.

2.1.3 Influencing Motivation for Behavioural Change

Having explored the factors that discourage and encourage individuals to participate in waste separation, the next step is to consider how their motivation can be positively influenced to facilitate the waste separation process. A change in the environment can positively influence individuals' motivation. In the literature review of Knickmeyer [4] she identifies that placing waste separation islands strategically can serve as a constant reminder for individuals to separate their waste properly as they pass by. Bernstad and Rousta et al., support this as they say that decreasing the distance between waste separation islands can affect perceived convenience and hence improve waste separation practices [7]. Additionally, O'Connor et al. suggests that new waste bins designs can result in demotivation [8]. Hence, it is essential to ensure that the designs are easily recognizable and familiar.

Factors such as social pressure and social modelling can influence the motivation of individuals. The influence of others such as family members, friends, and colleagues can provide guidance and encourage positive intention and motivation for waste separation [4]. According to Osbaldiston and Schott, this can be a highly effective intervention strategy, since showing individuals that others comply with the separation rules can influence their compliance [7].

In addition, as stated by Klöckner and Oppedal individuals may feel a sense of moral obligation to recycle if they understand the detrimental effects of not doing so and are encouraged by the expectations of other people who participate in waste separation, ultimately leading to recognizing their ability to separate their waste and making them feel as part of the waste separation

system [4]. Understanding the detrimental effects of not separating waste is an important factor and can be communicated using smart visuals such as colors, shapes and graphics [4].

According to Huber and Hilty, a gamification approach was found to be a method that allows individuals to choose their own goals and connect their actions to social interaction [9]. Aurora and Itu explain that games that incorporate educational elements can have an indirect impact on players' behavior by motivating individuals to become personally involved and take action toward the issue [9]. When applying gamification this can refer to a reward or penalty system. In the research of Pivec and Hsu participants mentioned that having a penalty system or a reward system would be the best motivation for them to start separating their waste [9]. This contradicts the research done by Gursoy, Kavak, and Akpinar, where a participant explained that the best motivation for them would be giving incentives and more education and that on the opposite a penalty system was the least preferred option [5]. This was supported by Varotto and Spagnolli, who explain that any kind of benefit like a reward system can lead to an increase in motivation [4]. In Kamoen and Karahanoglu's [7] research, Geller also found incentives to lead to an increase in motivation, however Harder and Woodard found potential disadvantages of using incentives. According to Harder and Woodard, incentives are quite costly and require continuous monitoring of the behavior of individuals, and a possible consequence of the termination of the use of incentives can cause individuals to revert to their previous behavior [7].

2.1.4 CFM – UT background

CFM – UT is the Campus and Facility Management at the University of Twente [10]. After introducing a new waste collector in late 2017, new waste bins aimed to collect waste separately were introduced in central locations at the University of Twente educational buildings [2].

2.1.4.1 The Waste Islands

At the University of Twente, the waste separation bins are referred to as "Waste Separation Islands". These islands conspire of four distinct waste separation streams for Paper, Organic, PD, and Residual waste. The four bins are color-coded according to the color scheme employed by the Dutch government, with blue for paper, green for organic, orange for PD, and gray for residual waste. The color code is intended to encourage proper waste segregation among various locations.

To ensure that the colors are easily visible and recognizable, the UT waste separation islands are designed with prominently displayed color-coded bins. The colors and the names of each waste bin are represented at the front of the waste islands, as well as each bin hole is colored with the corresponding color as can be seen in Figure 1. Additionally, a description of the types of waste that go in each waste bin is also shown at the front of the waste islands. The PD bin has a specific hole designated for coffee cups and at the same time saves space in the bin itself. The Organic bin has a lid to ensure that the smell of food scraps does not contaminate the area surrounding the waste islands and is therefore kept clean.

Figure 1: UT Waste Island

2.1.4.2 Analysis of the Waste

In January 2020, waste from four different locations on campus was collected by CFM-UT [2]. The waste from the specific bins was categorized into four waste streams: Residual, Plastic Metals and Drinking Packaging (PMD), Paper, and Organic waste. From the collected waste the PMD and Residual waste were analyzed. The results of the analysis can be seen in Figure 2.

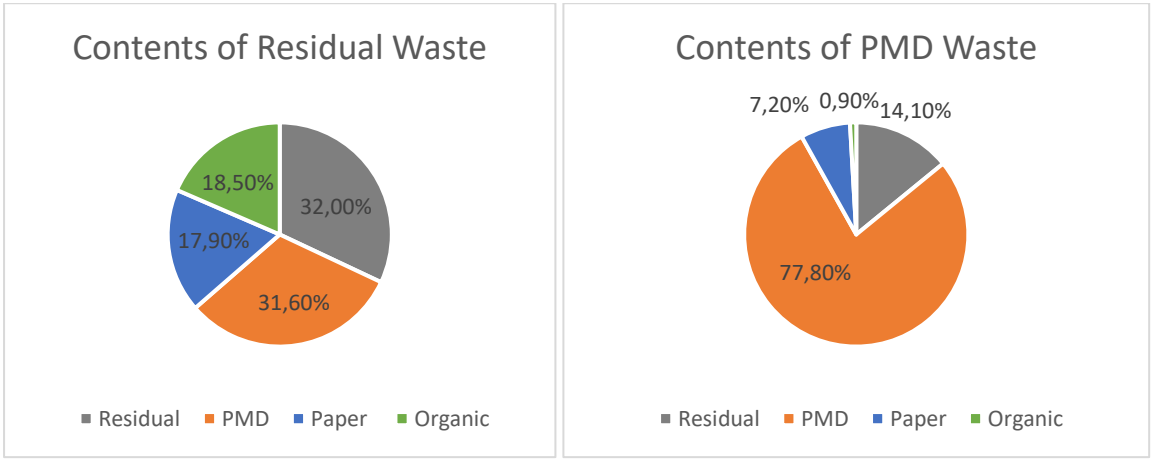


Figure 2: Pie chart results Residual and PMD Waste Contents

From the analysis, it was concluded that the UT Community considers the residual bin to be for mixed waste and is therefore being used for all waste streams [2]. This can be seen since only 32% of the waste in the residual bin is actually of the residual waste type, the rest 68% belongs to the three other waste streams. For the PMD waste bin, the majority is correctly disposed of as almost 78% is PMD. However, it is important to note that for PMD to be properly recycled, the amounts of other waste should be quite low, otherwise, the whole bin will be considered contaminated and will not be recycled.

2.2 State of the Art

To be able to properly design a solution to improve the motivation to separate waste at the UT it is important to conduct thorough state-of-the-art research. The following chapter includes the state of the art found from research as well as the actions taken by CFM-UT.

2.2.1 CFM – UT Activities

From an interview featuring B.Dragtstra, it was found that CFM-UT has executed several actions to promote proper waste separation on campus. One of the more recent ones is the creation of an animated video in collaboration with GreenHub Twente. The storyboards for the video can be found in Appendix I, Figure 42. The goal of the video is to communicate to the viewers what happens to their waste once it is collected, since, as stated in the interview, a lot of students tend to believe that their waste is combined and is not actually properly disposed of.

Another collaboration with GreenHub resolves around information posters which can be seen in Appendix II in Figure 43 and Figure 44. In this collaboration, the usual posters which are displayed around the waste islands which are constructed of words and explain which items go where, are displayed with pictures instead. This aims to aid the process of recognizing what items go where quicker and ease the waste separation process for the users.

2.2.2 Existing Technologies

Next to the actions taken by CFM-UT, there are many existing technologies and campaigns which encourage better waste separation. The following chapter explains the technologies that were found and their relevance.

2.2.2.1 SEGD Smart Bins

The SEGD Smart Bins is an interactive bin located at the University of Washington and was created by a group of Masters of Human-Computer Interaction and Design graduate students. The bins are constructed of three categories: compost, recycle, and landfill. The waste bins are equipped with a scale, microcomputer, and digital screen. In its idle state, the screen displays waste items that are to be separated into the corresponding waste bins. When the user throws away an item into one of the bins, the screen shows how much money the user just saved by properly separating their waste, as well as hypothetical savings for the campus if everyone did the same thing. From observing interactions with the bin, the creators found out that users felt engaged by the educational video loop that played in the idle state, and would even stop to watch the video for several minutes without having any waste to dispose of. The installation increased correct composting by 20% and decreased incorrect recycling by 15% [11]. Figure 3 displays the idle state (left) and the interaction state (right).

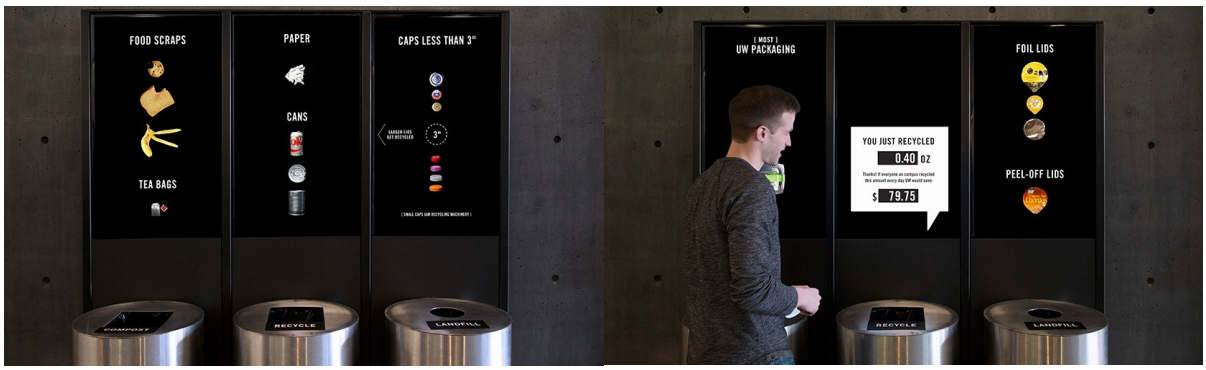


Figure 3: SEGD Smart Bins [11]

2.2.2.2 Bin-E

Bin-e is a smart waste bin that uses AI technology and is intended for public use, intending to simplify the recycling process. It can automatically sort and compress waste, monitor its fill level, and collect data to facilitate convenient waste management. In addition, it offers an app that provides information about the fill level of the Bin-e devices and notifies the owner when it is full. It also gives insights and detailed statistics about waste production. Bin-E has the option to be accompanied by a 50" screen which allows the owners to display marketing content and sustainability initiatives which can all be controlled from the app [12]. Figure 4 displays this set up.

Figure 4: Bin-E [12]

2.2.2.3 TrashbotZero

"TrashBot is a smart recycling bin that sorts out waste at the point of disposal"[13]. TrashBot is another example of an AI-using bin that sorts out waste for the user. It sorts out waste at an accuracy level of 95%. In addition, it provides high-quality data on waste disposal, has a trier for when the bin is full, and a display for video content. It is designed for high-traffic public areas where users do not have the time to pay attention to how to separate their waste, such as airports, hospitals, and stadiums. Since the waste bin uses AI and machine learning to recognize and separate the waste, it is also connected to the cloud where the waste data is collected. This helps the bin become more intelligent over time, therefore increasing its separation capabilities [13]. Figure 5 displays TrashBotZero on the outside (left) and the system on the inside (right).

Figure 5: TrashBotZero [13]

2.2.2.4 Throwise

Throwise is a waste disposal system designed for elementary schools which alters the interaction between students and waste bins by implementing a gamification aspect to the process. The idea is that students must pay for their waste by using a "Ren", a payment system invented for this campaign. The lesser waste students produce, the more Rens they will save up, which increases their chance to be the winning class and receive an award. The goal is to reduce the waste thrown into the residual bin and to reduce the "throw-it-for-granted" attitude [14]. Figure 6 demonstrates Throwise.

Figure 6: Throwise [14]

2.2.2.5 Improving Accuracy of waste sorting through behavioral nudges

The following installation was designed by Harvard University students to improve waste separation practices at their campus. To improve the situation they design a nudging-based solution which can be seen in Figure 7. The installation was placed in what was decided to be a high-traffic area for the designing team to have easy access to it and to reach more users. The design utilized 3 nudging concepts: 1) Loss aversion: which highlights the downsides of not sorting waste, 2) social norms: which were based on the location of the bins, since it was in a high-traffic area and therefore students can see each other disposal behavior, and 3) simplification: which simplified the presentation of which waste items should go in which bin by displaying physical items and adding simple tag lines. Using these three nudge concepts, the installation resulted in an increase in correctly disposed of waste [15].

Figure 7: Signs above the trash bins at Harvard University [15]

2.2.2.6 Trash Behavior Nudge

The installation, created as part of the "Design Research" class at Cornell Tech, aims to enhance recycling engagement and awareness through nudging techniques. It combines various components, including LEDs, a timer, a trash platform, and audio, and can be seen in Figure 8. The setup consists of two bins: a Trash Bin and a Plastic Bin, with the goal of encouraging users to recycle their plastic by disposing of it in the designated bin. Several nudges are employed to promote this behavior.

LEDs are strategically placed around the Trash Bin and connected to a sensor that detects user proximity, activating the screen display. When users approach the bin holding plastic waste, the screen instructs them to deposit it in the Plastic Bin. A 10-second timer is provided for the user to either correct their action by placing the plastic in the correct bin or neglect the timer and leave it in the Trash Bin. Once the timer runs out, the trash platform drops the waste into the trash bin.

If the user corrects their action, the screen displays a message acknowledging the positive impact of recycling plastic, accompanied by green LED lights. Conversely, if the plastic waste ends up in the trash bin, indicating a failure to correct the action, the LEDs turn red, and an audio message explains the non-corrective nature of the action.

By employing these nudging elements, the installation aims to engage users, provide informative feedback, and encourage proper recycling practices [16].

Figure 8: Two-bin Nudging Installation [16]

2.2.2.7 Waste Sorting Game

The Waste Sorting Game is an engaging and interactive solution designed to assess and improve people's recycling knowledge in an enjoyable way. By utilizing this digital product, users can remotely learn proper recycling techniques, saving valuable time and resources. The game offers multiple levels of challenges, and upon completing each level, users are rewarded with various items to decorate their park, adding a fun and rewarding element to the experience. The game covers a range of waste types, including general recycling, organic waste, bulk items, and hazardous waste, providing comprehensive knowledge on proper waste sorting. At the end of the game, users have the option to share their results with others and even receive a personalized certificate as recognition for their achievements. [17]. Screenshots of the various game screens can be seen in Figure 9.

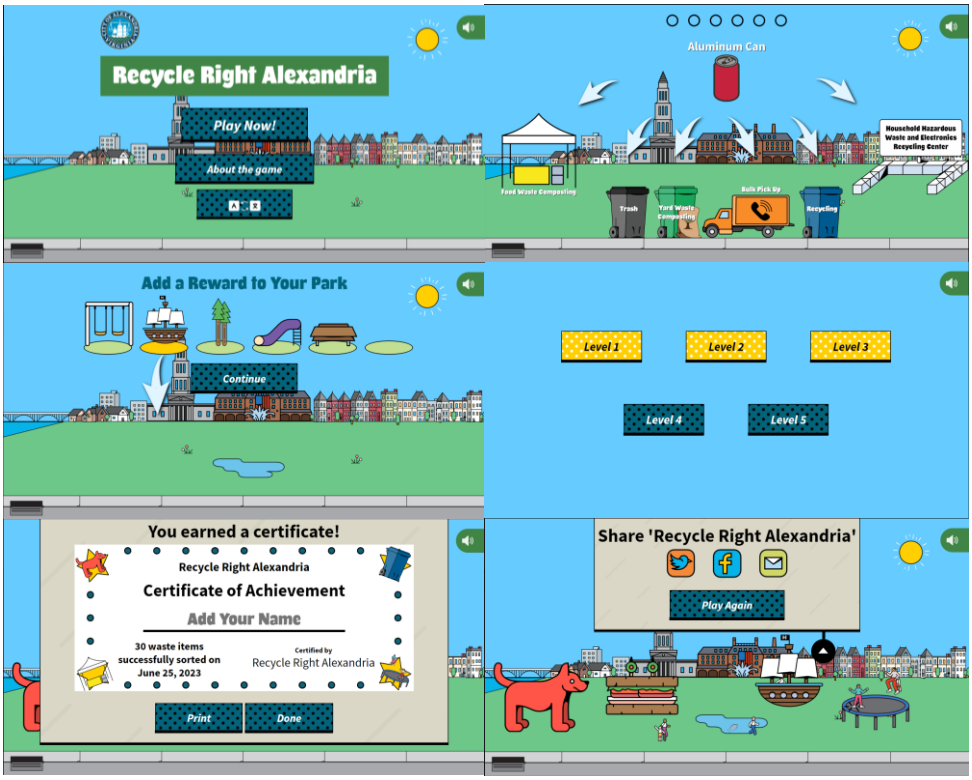


Figure 9: Waste Sorting Game [17]

2.2.2.8 Tetra Bin

TetraBIN explores how digital technologies can make a positive impact in urban areas. It uses gamified approaches to turn the simple task of throwing trash into a bin into an enjoyable experience. By incorporating game mechanics, it aims to make urban interactions more engaging and encourage active participation. The project addresses littering by associating rubbish disposal with a fun game, similar to the puzzle video game Tetris [18]. Participants interact with a computer-controlled screen surrounding the bin, where each piece of trash is linked to a virtual game action. This turns the act of throwing trash into the bin into a meaningful task, as participants need to time their actions correctly to progress in the game. This immersive experience encourages participants to think about environmental issues, particularly waste collection and management in the city [19]. The TetraBIN can be seen in Figure 10.

Figure 10: TetraBIN [19]

2.2.2.9 World's Deepest Trash Bin

The world's deepest trash bin, as can be seen in Figure 11, is an interactive installation designed to raise awareness about the importance of proper waste disposal by implementing the Fun theory. The Fun Theory suggests that making mundane tasks enjoyable and engaging can inspire behavioral change and encourage positive actions [20]. The World's deepest trash bin is set up in a public space and resembles a regular trash bin. However, when someone approaches and attempts to throw the trash into the bin, the bin plays a sound effect and gives the illusion that the trash is falling into a deep hole. This visual and auditory feedback aims to surprise and educate individuals about the significance of responsible waste management. The intention behind the installation is to encourage people to think twice before littering and to promote a cleaner environment [21].

Figure 11: World's Deepest Trash Bin [21]

2.3 Interviews and Observations

The following chapter focuses on the insights obtained from interviews conducted with the project's client, CFM-UT, as well as informal peer interviews, which provided valuable information and enhanced understanding of the problem at hand.

2.3.1 Interview with CFM-UT

Throughout the project's duration, several meetings were conducted with CFM-UT, the client. In these meetings, B. Dragtstra from CFM-UT discussed the essential aspects of waste separation and highlighted its major challenges. The client emphasized the importance of fostering a mindset shift, urging individuals to rethink their approach to waste and strive for waste reduction in their daily lives.

Regarding the waste islands implemented on the UT Campus, it was acknowledged that the system is relatively new, leading to some clarity issues regarding which items should be placed in specific bins. The PD waste stream posed significant management difficulties, with a considerable amount of PD waste mistakenly disposed of in the Residual stream. The waste islands were strategically designed and evenly distributed throughout the campus, with color-coded bins representing the national colors for easy waste separation and bin identification. The placement order of the different waste streams aimed to encourage people to consider the other streams before the Residual bin, as individuals tend to read from left to right. Each bin was labeled with stickers indicating the appropriate items to be placed inside. However, despite these efforts, the waste separation process did not reach the desired level of effectiveness.

The client also highlighted the strict controls implemented for the waste streams. At the end of each day, the waste collection company meticulously inspects the bags, and if the proportion of "other" waste exceeds a certain threshold, the entire bag is considered contaminated and rejected for further separation. To address the challenge of waste separation, GreenHub [22], a student environmental initiative, attempted to create visual displays showcasing proper waste disposal. However these displays did not align with the UT house style and were not effective in reaching a large audience. It was discussed with the client that using engaging visuals and nudging techniques, which rely on imagery rather than text, could be more successful in promoting proper waste separation practices.

2.3.2 Informal peer interviews

Three informal peer interviews were conducted to gain a better understanding of their waste separation habits, knowledge, and motivation. The interviews were semi-structured and had an easy flow such as a conversation. The interview had four main sections. The first was a personal section in which students were asked their opinions and practices of waste separation, followed by a section about self – efficacy which aimed to understand the level of confidence the students have with waste separation. The third section was regarding waste separation at the UT and the last section was regarding social norms which focused to understanding whether students felt social pressure from waste separation. In the personal section, the first participant explained that their motivation to separate their waste is quite low. This was because they felt that their efforts were going to waste since they believe the waste at the UT is being combined after separation instead of taken off properly. They also do not take the time to separate their waste because of this reason and therefore do not feel it is as important to separate their waste on campus. The two other participants had a similar impression that waste does not get separated on campus, however, that did not demotivate them to continue separating. In contrast, often the lack of time or not knowing where a certain item should be disposed of was a bigger reason not to separate.

All three participants stated that 70% of the time they are confident with their abilities to separate waste, however in recent years with the introduction of newer more sustainable packages, waste separation has become a harder process for them. Often, they spend more time thinking about how to separate a certain item leading them to become unsure and throw it away in the residual bin.

Overall the designs of the UT waste separation islands seem to be a bit confusing. The participants mentioned that the explanations of which items should go in each bin are not as obvious or easy to see as they would want them to be. In addition they explained that at first glance it is not easy to see which part of the description states the items that should go in the specific bin and which partly states the items that shouldn't. This often makes the participants doubt their knowledge and prevents them from separating their waste. The third participant explained that, at times they struggle with the organic waste bin since to throw an item away they would need to touch the lid which is often not clean, and therefore they get discouraged to throw their waste properly and go for the residual option.

The final section about social norms displayed the most variety in answers. The first participant explained that although the opinion regarding waste separation of people that matter to them is important to them, they do not feel any pressure from strangers. Therefore, in a public setting they do not care if a stranger thinks they disposed of their waste incorrectly. The second participant said that they do feel social pressure, and at times can see people judging them for their actions, which makes them want to separate their waste better. Finally, the third participant explained that in most cases, they do not feel the social pressure to separate as they are usually the person to judge others for their improper waste separation, and therefore tend to judge themselves a lot too.

Overall, the informal peer interviews provided valuable insights into waste separation habits, knowledge, and motivation at the UT Campus. Participants expressed concerns about waste being combined after separation, leading to demotivation for some, while others cited time constraints and uncertainty as reasons for not separating waste consistently. Confidence in waste separation abilities was moderate but affected by the complexity of new sustainable packaging. The current design of the waste separation islands was considered confusing, with unclear explanations and poor visibility of proper disposal instructions. Social norms had varying effects, with some participants feeling indifferent to strangers' opinions while others felt pressure and judgment. To improve waste management, clearer instructions, improved visibility, and addressing concerns about waste handling are recommended, along with understanding the impact of social norms on individuals' behaviors.

2.4 Discussion and Conclusion

The comprehensive review of existing literature, along with the observations, interviews, and analysis of state-of-the-art techniques, applications, and solutions, contribute to the overall understanding of essential factors that must be considered during the design of an intervention aimed at influencing behavior. The literature review highlights various challenges individuals face in proper waste separation and identifies factors that can be utilized to promote participation in waste separation practices. Motivation, convenience, and knowledge are ones that appear more throughout the literature research. Convenience is a significant factor that influences waste separation, as individuals are more likely to engage in the process if the waste separation system is easy to understand and use. The availability and accessibility of waste separation facilities also play a crucial role in motivating individuals to participate. A lack of knowledge and understanding of waste separation guidelines can hinder proper waste separation, particularly when there are frequent changes in the guidelines or when packaging materials are complex and confusing. Furthermore, feeling excluded from the waste management system can demotivate individuals from participating in waste separation, emphasizing the importance of a sense of inclusion and personal responsibility.

To enhance motivation and facilitate the waste separation process, several strategies can be employed. Placing waste separation islands strategically as constant reminders, decreasing the distance between waste separation facilities, and ensuring easily recognizable and familiar designs of waste bins can positively influence individuals' motivation. Social pressure and social modeling can also be effective in motivating individuals, as seeing others comply with waste separation rules can influence their own behavior. Educating individuals about the detrimental effects of not separating waste and using smart visuals and graphics can enhance motivation. Additionally, gamification approaches, such as reward or penalty systems, can be employed to increase motivation.

The state-of-the-art research presents existing technologies and campaigns that can further enhance waste separation practices. The previously provided examples utilize AI technology, provide real-time data, and incorporate gamification elements to engage users and simplify waste separation. These technologies have shown positive results in increasing correct waste segregation and promoting awareness; therefore, inspiration can be taken for the project at work.

In conclusion, the research will concentrate on developing a solution that considers the specific guidelines and the existing conditions at the UT campus, considering the diverse range of users within the UT community. By combining the identified techniques and insights, the objective is to design an intervention that enhances the motivation of the UT community regarding waste separation practices. The intervention will also provide crucial information about waste separation, including clarification on commonly misunderstood waste items. During the brainstorming phase, the project will explore the incorporation of gamification and nudging elements, which will be implemented in the final solution. The goal is to create an effective and engaging intervention that educates, informs and empowers the UT community to actively participate in waste separation efforts.

3 Methods and Techniques

3.1 The Creative Technology Design Process

The waste separation intervention developed for this project adheres to the Creative Technology Design Process by Mader and Eggink [23]. This design process follows a spiral model, as depicted in Figure 12, which encompasses four distinct stages: ideation, specification, realization, and evaluation. The process is characterized by a combination of divergence and convergence, allowing for iterative refinement of the design and prototype of the intervention. It is a flexible approach that involves conducting research, incorporating feedback, and engaging in prototyping to develop a functional prototype that aligns with the needs of the users and stakeholders.

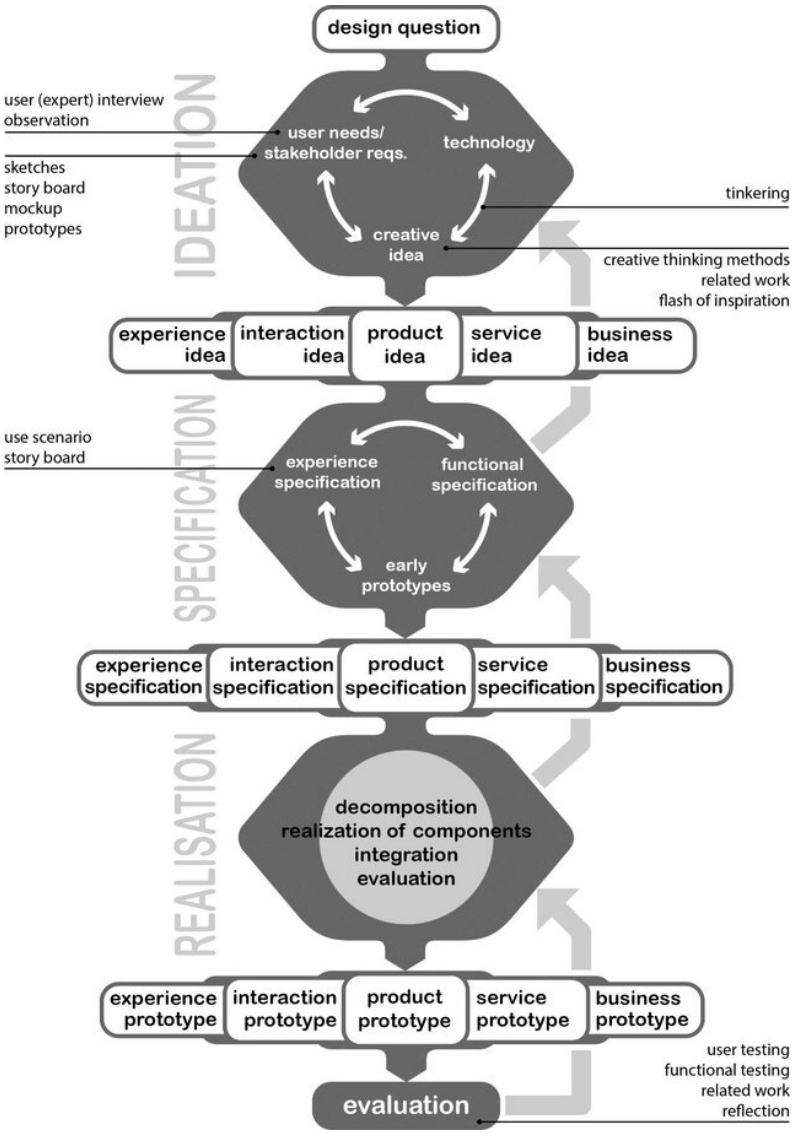


Figure 12: The Creative Technology Design Process [23]

There are various approaches to implementing the design process, however, for this project, the emphasis is placed on user-centered design, which prioritizes the user's involvement and influence in shaping the final design decisions for the product [24]. Throughout each phase of product development and the creation of the final prototype, the user's perspective is consistently taken into consideration.

Once the final prototype is developed, it undergoes testing with members of the intended user group. Their feedback is carefully collected and analyzed to identify areas for improvement in the prototype. This iterative process allows for refinements to be made based on user feedback, ensuring that the final product is better aligned with the needs and preferences of its intended users.

3.2 Ideation

The ideation phase marks the initial step in the design process. In the context of this project, the client's input determines the potential changes and interventions concerning the waste islands, while the end-users provide valuable insights into the most effective implementation methods to drive behavior change.

To execute this starting point, the project identifies the main stakeholders using the Stakeholder Salience Model (SMM) proposed by Mitchell et al [25]. The SMM assesses stakeholders based on three dimensions: legitimacy, power, and urgency. Using a Venn diagram with overlapping regions, the stakeholders are categorized into eight specific regions, each representing a stakeholder type. Figure 13 illustrates these regions with corresponding numbers and their meanings.

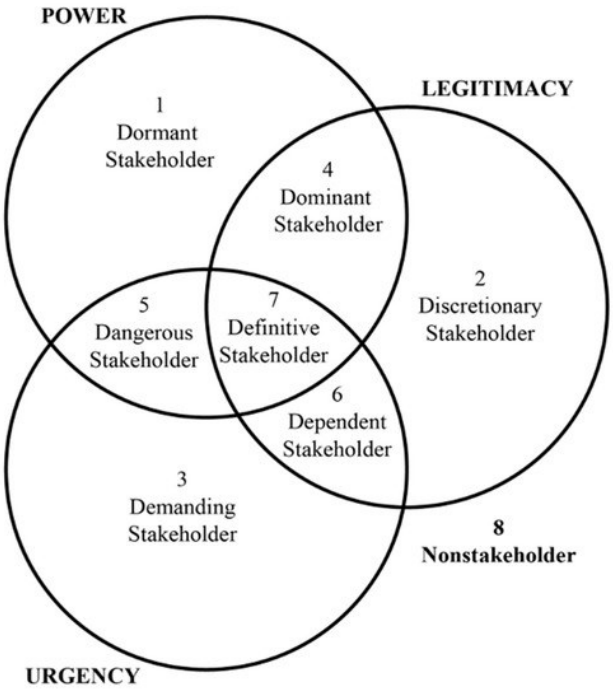


Figure 13: The Stakeholder Salience Model Venn Diagram [25]

Once the stakeholders and their requirements have been identified through background research, the subsequent step involves prioritizing these requirements. To accomplish this, the MoSCoW method [26] will be employed. According to this method, while all requirements are significant, it is necessary to prioritize them to ensure the design can be completed within the designated timeframe. The prioritization categories are: Must have, Should have, Could have, and Won't have. All requirements derived from the stakeholder analysis will be classified into these categories to establish their order of importance.

The following step is the ideation phase. In the case of this project, the ideation process commenced with two approaches: individual ideation followed by a group ideation session with Eva Barten to discuss ideas and converge on a final concept. During the idea generation phase, the State of the Art from Chapter 2 was considered a valuable source of inspiration, drawing insights from existing solutions. The initial phase of brainstorming, the individual part, employed brainwriting techniques.

Following the generation of technologies, a subsequent brainstorming session will be conducted. During this session, sketches will be created to visualize the physical representation of the ideas. Initially, the brainstorming will be done individually, and later in collaboration with the co-researcher, Eva Barten. The individual idea sketches will be combined to form a final collection of potential concepts. The selection of the final collection will heavily consider feasibility, as it is crucial to ensure that the solution can be implemented within the given time frame. Ultimately, the ideation phase concludes with the identification of a single final concept, encompassing both interaction and product ideas.

3.3 Specification

The Specification phase, which follows the Ideation phase, plays a crucial role in the design process. It begins with the creation of an experience specification, where a storyboard is developed to illustrate the user's journey and interaction with the final concept. This storyboard serves as a foundation for understanding the desired user interaction with the design. It is also translated into a Storyline with Personas, which helps identify and define interactions for different types of end-users. Personas are developed to represent these user types.

Once all the interactions are determined, a Time Sequence Diagram [27] is created to depict the interaction between different components of the product. This diagram visually represents how the various parts work together in the user experience. Following this, the functional specification phase takes place. Here, the focus is on identifying the functional and non-functional requirements of the solution, and the technical functions necessary to ensure smooth interaction and experience.

The functionalities are prioritized using the MoSCoW [26] method, which categorizes them as must-haves, should-haves, could-haves, and won't-haves. With the experience and functional specifications in place, early prototypes are developed. These prototypes are used for testing and gathering feedback from stakeholders and end-users. If any shortcomings or improvements are identified during testing, the specifications can be revised, and new prototypes can be created. This iterative process continues until all the specifications are complete and a more refined early prototype is achieved. Once the specifications and early prototypes have reached a satisfactory level, the process moves on to the Realization phase, where the product's actual creation and implementation take place.

3.4 Realization

During the realization phase, the primary focus is on decomposing the envisioned product, realizing its components, integrating them, and evaluating the prototype. The goal is to bring the envisioned product, which was conceptualized during the specification phase, to life. The requirements and functionalities identified in the previous phases serve as the foundation for the realization process.

The envisioned product is broken down into sub-parts, and suitable technological components are identified and linked to implementing the required functions of the product. Each sub-part is assessed individually to ensure its proper functionality. Once the sub-parts are confirmed to work independently, they are connected and analyzed to determine if they function properly together. If successful, they are implemented into the prototype. This phase culminates in an interaction prototype, aligning with the focus on interactive media in this research.

Another important aspect of the realization phase is conducting a functionality test to ensure all functionalities of the prototype are working effectively. This step is crucial as it allows the researcher to verify the proper functioning of the prototype before moving on to the evaluation phase with user testing. A functionality table is constructed to systematically test each functionality component of the prototype and identify any potential failures or areas for improvement. This testing

process is vital to prevent a defective prototype from impeding the subsequent user testing phase in the evaluation stage.

3.5 Evaluation

Once the prototype has been developed, evaluating its effectiveness in influencing waste separation behavior and motivating the UT community is essential. The evaluation process involves user testing to determine if the prototype successfully fulfils its primary function. To conduct the user testing, ethical approval from the UT's Ethics Committee [28] is required.

During the user test, members of the target group will interact with the system as if they were using it in a real-life setting, outside the testing environment. They will provide feedback on the effectiveness of the intervention and whether their needs are being met. They will also report any unnecessary components or missing aspects in the installation, which may uncover user needs that were not previously identified. Following the user testing, participants will be invited to participate in a short, structured interview and fill out a survey to provide further insights into their experience.

Once all phases of the evaluation are completed, the researchers will enter the reflection phase. This involves analyzing the results of the testing phases and identifying areas for improvement to achieve better outcomes. With the insights gained from the evaluation, a newer and enhanced prototype can be developed.

4 Ideation

The following chapter discusses the ideation phase of this research. The first phase is the identification of the relevant stakeholders followed by an analysis of their needs, wants, and requirements. Furthermore, a list with preliminary requirements is created, which are taken into account in the initial idea generation process. Later the concept generation process is explained beginning with the brainstorming session, followed by initial thought-out ideas and later, the final concept for this project.

4.1 Stakeholders

To design an intervention that should improve people's motivation to separate their waste correctly, identifying the stakeholders for this project and their requirements is highly important. As mentioned previously in section 3.2, the Stakeholder Salience Model is used to identify the stakeholders. This process is illustrated in Figure 14.

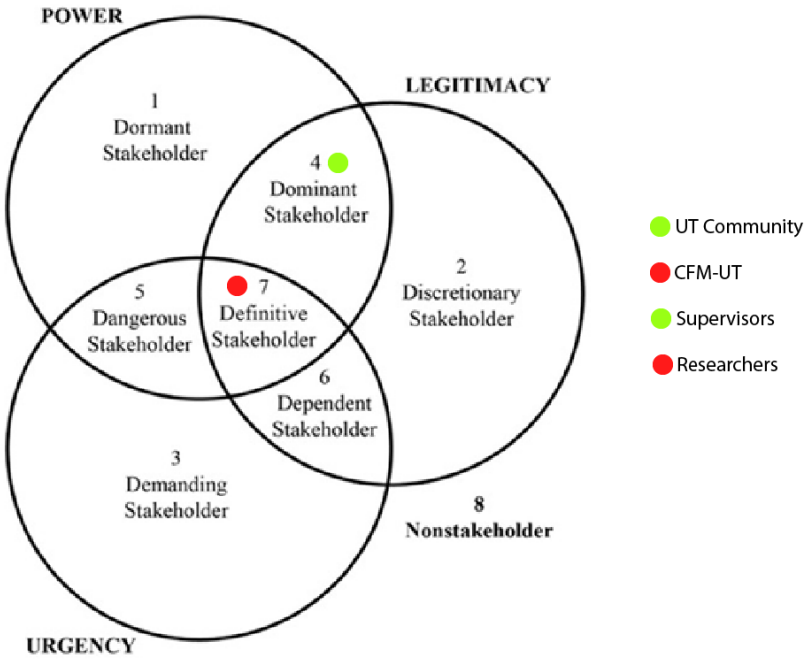


Figure 14: The Stakeholder Salience Model Venn Diagram Applied to this project.

As can be seen, each of the eight regions has a specific meaning. For instance, the definitive region, occupied by stakeholders CFM-UT and Researchers, signifies that these stakeholders possess urgency, legitimacy, and power. As a result, they hold the highest level of salience in the project. On the other hand, the dominant region is characterized by legitimacy and power but has lower levels of urgency. Stakeholders in this region, such as the UT community and Supervisors, have requirements that must be addressed at some point.

4.1.1 CFM-UT

CFM-UT is the client of this project, making them an important stakeholder. Their ultimate goal is to improve waste separation practices at the University of Twente to reach their sustainability goals set for the upcoming years. Since CFM-UT is the client of this project, they have a lot of power over the designs, functional requirements, placements, and type of interventions, as well as the decision if it will be implemented on the campus or not.

4.1.2 The UT community

The design of the waste separation intervention centers around the UT community members as they are the targeted audience. They are an important stakeholder since they directly interact with the intervention, and therefore they have power over the design and functionalities. The intervention should work for the target audience, if it does not, changes should be made accordingly.

4.1.3 The supervisors

The project supervisors are also important stakeholders who hold decision-making power over the research and play a significant role in shaping the project's direction. Their involvement is crucial, as they oversee the status of the project and approve or reject project ideas during weekly advisory meetings. Given their high level of involvement and decision-making authority, the supervisors have a considerable stake in the project's success and hold great legitimacy.

4.1.4 The designers

Finally, the designers of this project also hold an important place. Eva Barten and I influence each other throughout most of the research, and the final intervention of this project is a collaboration of

both our projects. However, we each have our designated paths, since I am focusing more on the interactive media side whereas Eva Barten specializes in the Smart technology side.

4.2 Preliminary Requirements

When designing a product, it is important to identify the stakeholders and their needs and requirements. Therefore a preliminary list of requirements was created based on the information learned from the stakeholders and the research presented in Chapter 2. This list of requirements can be seen in Table 1.

Number	Requirement	From
1	MUST design for improvement of motivation	Supervisors & Background Research
2	MUST not alter the waste islands: no change in the design of the information stickers, size, font, or design of the waste disposal holes	CFM-UT
3	MUST not relocate the waste separation islands	CFM-UT
4	MUST be easy to interact with	CFM-UT, Supervisors, Background Research, and Designers
5	MUST be time efficient	CFM-UT & Research
6	MUST educate on the unknown (frequently mistaken) waste items	Supervisors, CFM-UT & Background Research
7	MUST use human intelligence to communicate knowledge	Supervisors
8	MUST be an extension of the existing waste islands	CFM-UT & Supervisors
10	SHOULD increase proper waste separation	CFM-UT & Supervisors
11	SHOULD prevent waste from being thrown in the wrong bin	CFM-UT
12	SHOULD display waste separation outcomes	Supervisors & Designers
13	WON'T be using AI to sort waste items for the user	Supervisors & Designers

Table 1: Preliminary Requirements

The MoSCoW [26] method was used to classify the preliminary requirements in Table 1. This four-step method helps prioritise requirements by classifying them into four groups, Must, Should, Could, and Won't, from most important to least. The "Must" requirements are the most important since they are all the requirements that make the project successful. The "Should" requirements are also important for the completion of the project. However, they are not a necessity and are often flexible and can be added in later stages of the project. The "Could" requirements are nice to have but do not make a big impact if left out. Finally, the "Won't" requirements are those which have been recognized as not of priority for the timeframe of the project.

4.3 Concept generation

After conducting the stakeholder analysis and understanding the preliminary requirements, the following section considers these requirements and discusses the generation of concepts for this project. The concept generation process was split into several sections, first starting with brainstorming and the techniques used to generate ideas, followed by the discussion of preliminary concepts, and finally, the final concept and its details.

4.3.1 Brainstorming

Brainstorming is an important part of every project. To start with, this project's brainstorming was done in two ways, first individual brainstorming, and later together with Eva Barten group brainstorming was done to discuss the ideas and come to a final idea. When generating ideas the State of the Art from Chapter 2 was considered since existing solutions are a great source of inspiration. The

fits phase of brainstorming, the individual part, was conducted using brainwriting techniques. Brainwriting [29] is a technique that utilizes writing down the ideas anonymously. It is particularly useful to generate a greater number of ideas and helps group members who are more introverted to feel more comfortable with sharing their ideas. For this project, Eva Barten and I each came up with several broad concepts, or elements which help reach certain requirements and wrote them down. Later the second part of the brainstorming started which was the combination of the ideas generated using the Brainwriting technique which resulted in 11 combined project concepts as can be seen in Table 2.

1	The Tamagotchi concept
2	Holle Bolle Gijs
3	Fill the bar - reward system
4	The arcade - blinking lights and sounds - reward system
5	Sound design - persuasive sounds - if you threw it correctly or incorrectly happy/sad sound -> AH example
6	Talking to the trashcan – “Hey I have a problematic item” - maybe select on a screen - then LEDs or an avatar on the screen will show where to throw it
7	LEDs strips to show how full the trash cans are
8	Liquid disposer next to a trash can
9	Basketball trash can
10	Trash Can that shoots your trash back at you (maybe not physically but on the screen you get an animation of a buddy banana throwing in your face)
11	The screen shows you an animation about where your trash goes, depending on which waste stream you put your trash in

Table 2: Table with the 11 ideas

4.3.2 Five Preliminary Concepts

Following the brainstorming sessions, a total of 10 project concepts were formulated. These concepts were presented to the supervisors overseeing this project, leading to the further refinement of ideas and the selection of five new concepts. The following chapters explain the five preliminary concepts.

4.3.2.1 BinBuddies

The first idea is called BinBuddies and an illustration of this idea can be seen in Figure 15. Essentially BinBuddies are four little creatures whose design is inspired by the colors and designs of the waste islands. The BinBuddies are displayed on a screen above the waste islands and in an idle state float around the screen and communicate where to throw away unknown waste items through the use of speech bubbles. When a waste item is thrown away in the corresponding bin, the BinBuddy related to that bin makes an interaction such as a happy dance, or thanks the users for feeding it. The idea is to encourage the UT community to keep the BinBuddies alive by feeding them correctly separated waste. If incorrect waste is thrown away in the bin, the BinBuddy corresponding to that bin makes a sad or sick expression. Throughout the days the creatures grow in relation to how much waste (their food) is in the waste bins, and to better visualize this, a health bar is shown under each creature to show their progress.

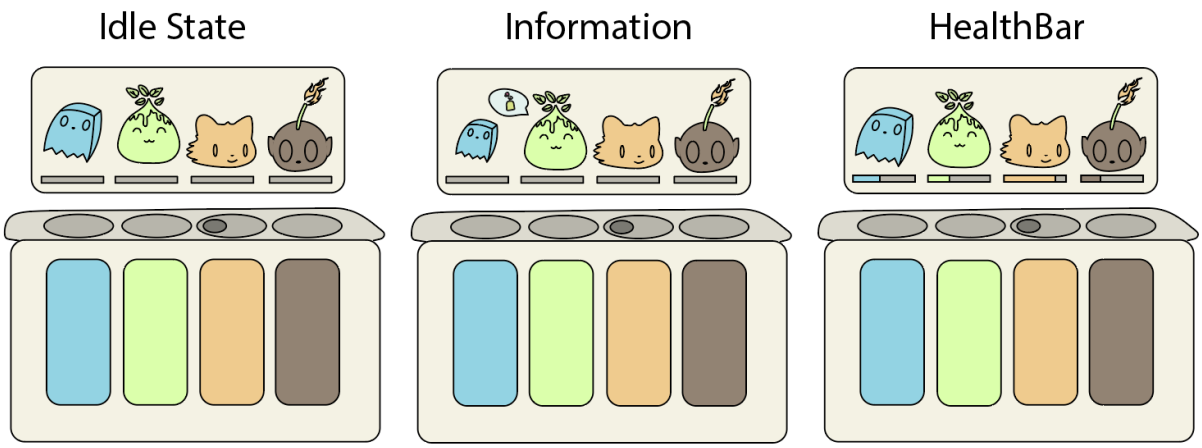


Figure 15: BinBuddies

4.3.2.2 Communicating waste islands

The second idea is a communicating waste island. The idea is to create a waste bin that knows how to separate waste correctly, and a cartoon-like owl visualizes it, as can be seen in Figure 16. In the Idle state of the installation, the unknown waste items would be communicated by the cartoon owl displaying “fun facts”. In the interaction state, when a user walks past and they are unsure about where to separate their waste, they can simply talk to the waste island and ask questions such as “Hey do you know where I can throw away my dirty salad packaging”, and the waste island will indicate the right bin by the use of the owl pointing towards the right waste bin.

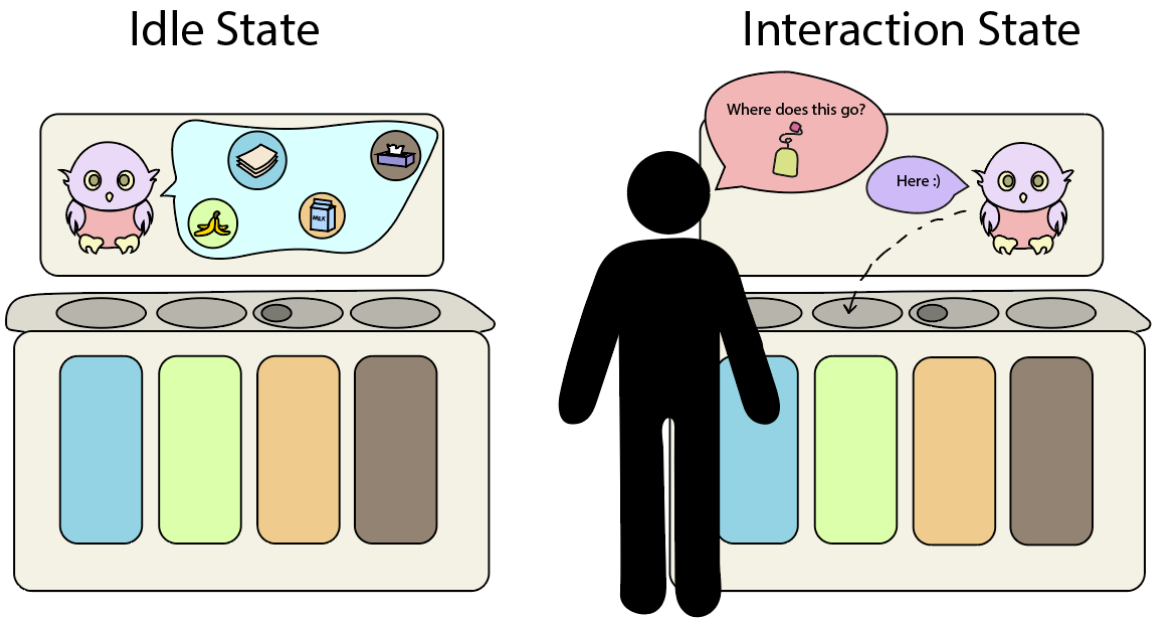


Figure 16: Communicating waste islands

4.3.2.3 LED strips and sound design

The third idea steps away from the creature's on-screen communication ideas and goes in a slightly different direction. The waste islands are altered slightly by adding an LED strip to show the amount of waste in each bin. When an item is thrown away in the waste bins a positive sound is played from the waste bins. The sound gets higher and happier the more waste is disposed of in the corresponding bin. A screen will be used to show the different unknown items which should go in each waste bin.

The sounds played from each bin will vary, to encourage people to separate their waste. This idea can be seen in Figure 17.

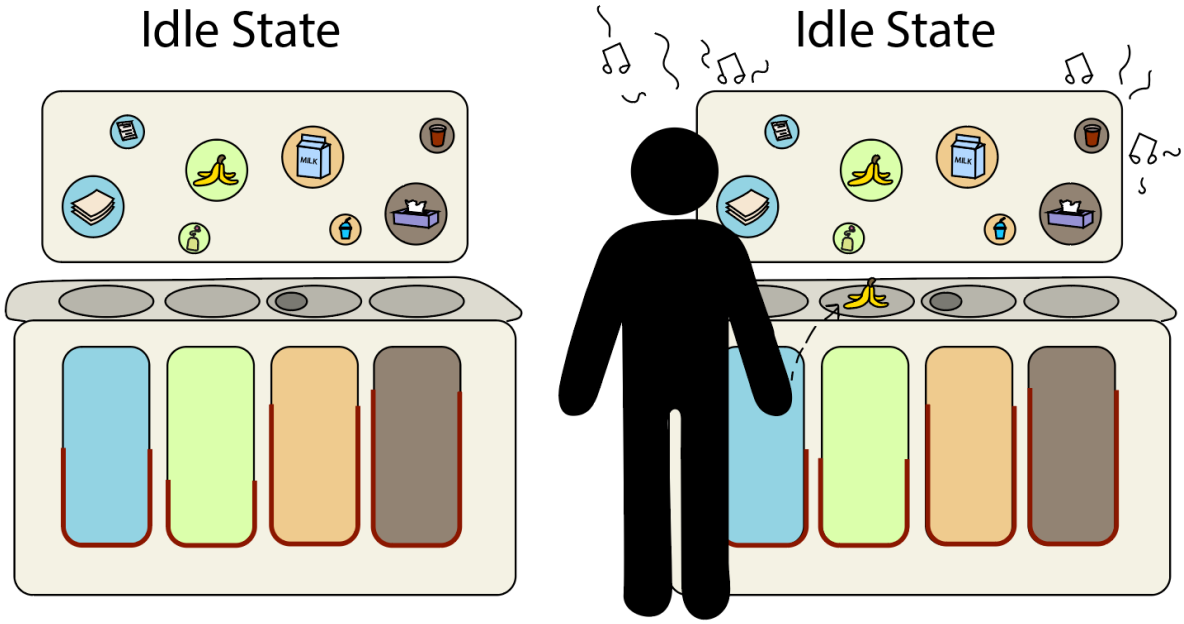


Figure 17: LED strips and sound design

4.3.2.4 Gamification

The fourth idea makes use of a reward and gamification system. A screen is connected to the waste islands. In its idle state the installation displays floating commonly misplaced items and which bin they should go in. A game state is activated when a user interacts with the waste islands by throwing away a waste item in one of the bins. In the game state, a game similar to Tetris is activated and a shape falls. The shapes are color coded per separation bin and fall roughly “on top” of the right bin. This is aimed to visualize the amounts of waste in the bins. The goal of the game element is to engage the users more with waste separation. The gamification idea can be seen in Figure 18.

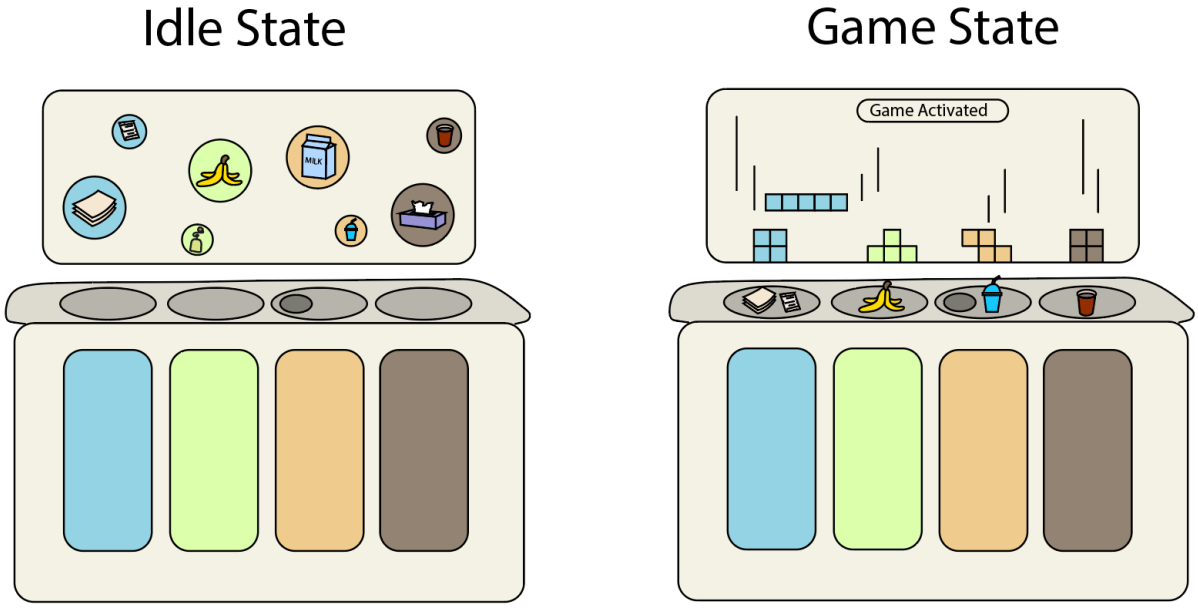


Figure 18: Gamification

4.3.2.5 Animation

Another idea is in the form of animation, as seen in Figure 19. Again, a screen is connected to the waste separation islands. In the idle state, the unknown items float and fall down into the correct waste separation bins. When an interaction with the bin is made, an animation is played of what happens when the waste bin is full and how the waste is taken care of. To make the animation vary, different animations can be shown depending on whether a bin is contaminated or if it is separated well, and how much improper separation would be needed to consider a bin contaminated.

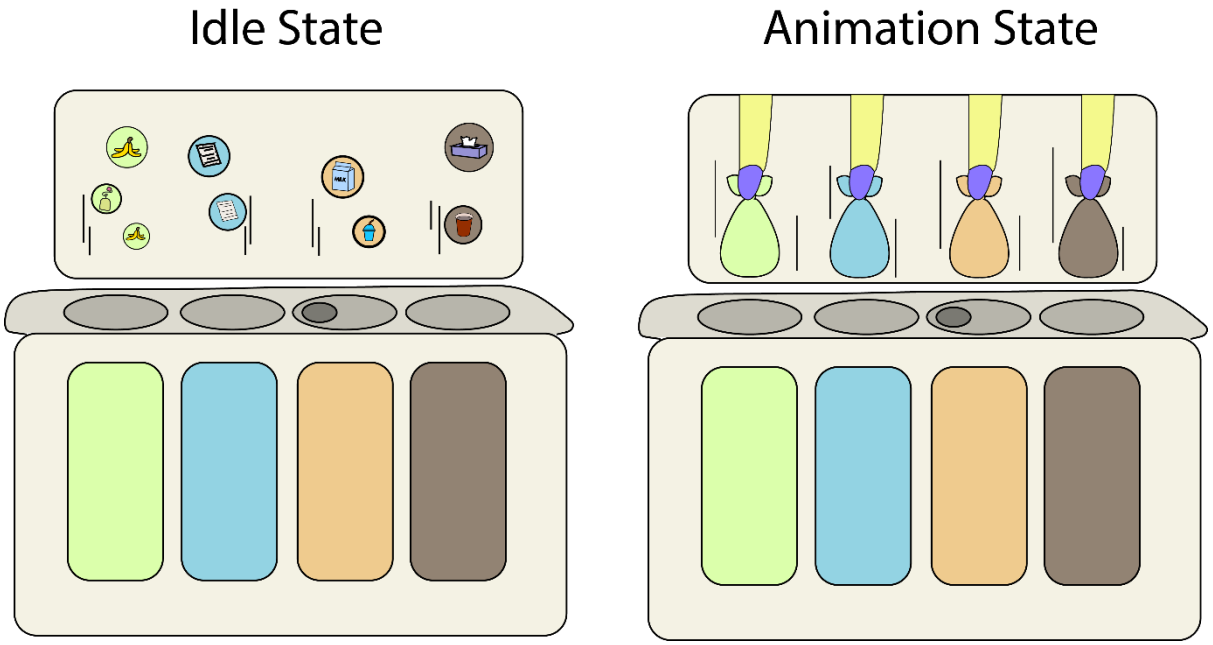


Figure 19: Animation

4.3.3 SWOT analysis

After careful consideration and consultation with the supervisors regarding all five preliminary ideas, two were chosen to be best fitting with the preliminary requirements. To assess the ideas the SWOT Analysis [30] method was used. A SWOT analysis is a method that uses a four-sided scale of Strengths, Weaknesses, Opportunities, and Threats to analyze an idea. The two selected ideas were the BinBuddies idea of chapter 4.3.2.1 and the Gamification idea of chapter 4.3.2.4. A SWOT analysis was performed for each idea, and the results can be seen in Table 3 for the BinBuddies idea and Table 4 for the Gamification idea.

BinBuddies	
Strengths	Weaknesses
• The BinBuddies catch the attention • Fun Factor	• The Idle state screen may be confusing • Communication of unknown items is weak
Opportunities	Threats
• Improvement of the idle state by making options more clear • An introduction of a “fun fact” aspect to add in the future once more knowledge is available about the commonly misplaced items. • Add animations of the BinBuddies which for example Spin all 4 at once to catch the attention to the bins	• Users could “feel bad” for one of the BinBuddies and try to feed it more to grow its size, but that could result in improper waste separation • Understanding if an item is correctly disposed of or not is not feasible

Table 3: SWOT Analysis of BinBuddies idea

Gamification (Tetris)	
Strengths	Weaknesses
• Explanatory and simple Idle state • Fun factor • The game factor	• Can not interact with the game state • Users may feel disappointed that they can not interact more with the game, making them discouraged to participate or alter their behavior
Opportunities	Threats
• Make the game state interactive	• Understanding if an item is correctly disposed of or not is not feasible

Table 4: SWOT Analysis of Gamification Idea

After conducting the SWOT analysis, several conclusions were drawn. It was found that the BinBuddies concept was the most suitable option as it encourages community involvement in waste separation by taking care of the BinBuddies, while also serving as an eye-catching addition to the waste separation islands. However, the weakness of the BinBuddies idea was in communicating the types of waste that should be disposed of in each bin. In contrast, the gamification idea had a clearer communication method visible from a distance, potentially attracting a wider audience beyond those who only interact with the waste islands. While the gamification idea lacked a concrete game element, it had the potential to enchance engagement. To address these issues, the strengths of both concepts were combined to create a final idea that minimized weaknesses and maximized strengths.

4.4 Final Concept

By combining the two previously analyzed ideas, the final idea was created and can be seen in Figure 20.

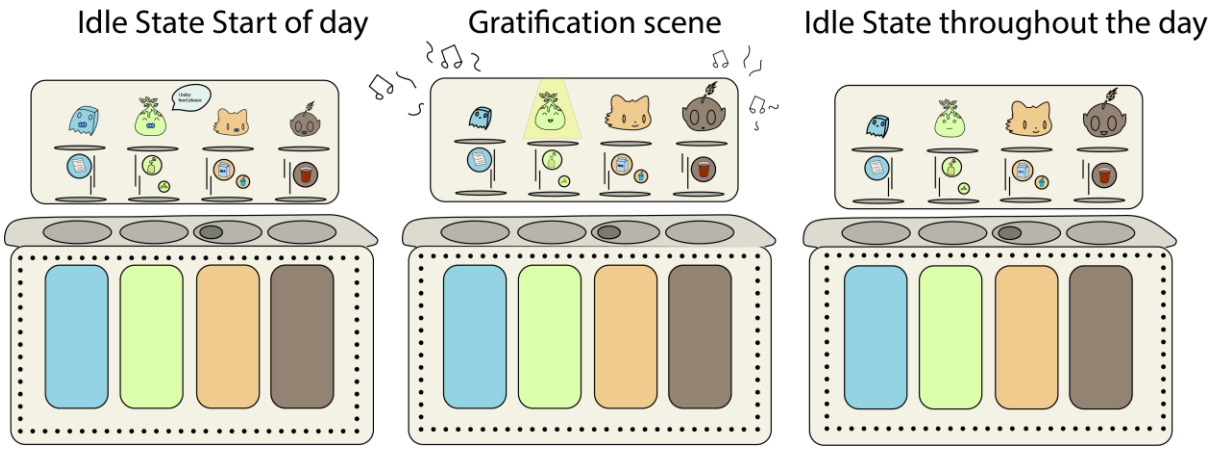


Figure 20: BinBuddies Final idea

The final concept has three states. The first is the idle state. The idle state is an active state which changes its appearance throughout the day. In the idle state at the beginning of the day, the four BinBuddies are seen as small. Under each BinBuddy there is a teleport system from which unknown items for each bin float and fall into the correct bin. This is how the unknown items are shown. LEDs are placed around the bin which are activated when a user approaches the system, letting the system know that a user is present. The goal of this idea is to keep the BinBuddies alive and happy. When a UT community member interacts with the BinBuddies by throwing away an item into one of the bins, the corresponding BinBuddy will receive a spotlight and will make a sound during which it will have a few seconds to display its gratitude for being fed. The gratification scene is made in such a way that if more waste is being thrown away in different bins at the same time, the BinBuddies will be able to

show their gratification simultaneously and not overshadow each other or take too long to respond. Throughout the day, the changing idle state can be seen as the size and mood of the BinBuddies change, and some are seen as happier and bigger than the others. The size of the BinBuddies represents how much waste there is in that specific bin.

4.4.1 Requirements Check

After the final concept is thought through, it is important to check if it adheres to the requirements that were constructed from the background research and communications with the client and the supervisors. From these discussions, Table 5 was created where it can be seen that the final concept adheres to all the preliminary requirements and is therefore fitting to the project of improving waste separation at the University of Twente campus.

Number	Requirement	Check
1	MUST design for improvement of motivation	X
2	MUST not alter the waste islands: no change in the design of the information stickers, size, font, or design of the waste disposal holes	X
3	MUST not relocate the waste separation islands	X
4	MUST be easy to interact with	X
5	MUST be time efficient	X
6	MUST educate on the unknown (frequently mistaken) waste items	X
7	MUST use human intelligence to communicate knowledge	X
8	MUST be an extension of the existing waste islands	X
9	MUST have communication with other waste separation islands	X
10	SHOULD increase proper waste separation	X
11	SHOULD prevent waste from being thrown in the wrong bin	X
12	SHOULD display waste separation outcomes	X
13	WON'T be using AI to sort waste items for the user	X

Table 5: Requirements Checked concerning the Final Concept

5 Specification

During the specification phase of the research, the final concept is further developed and refined to provide a more detailed and comprehensive understanding. This involves translating all stakeholder requirements into functional and non-functional specifications. This process ensures that the final product is both appealing and practical for the targeted user. Additionally, multiple personas are established to represent a typical user of the end product. Following the persona identification, concept storylines are drafted, outlining all the functionalities of the final concept. Lastly, a storyboard is designed to visually depict the interaction with the final product.

5.1 Personas

To understand the needs and interactions of the user with the final product, three different personas were created. To create the persona cards the in-browser program Figma [31] was used, and to create the persona faces the AI face generation website "This person does not exist" [32] was used. The three personas require to be relevant to the project and final product and represent a broad scale of possible users. For this project, three user types were specified: Climate aware, Not Climate Aware, and Indifferent. These personas were chosen since they represent the three most important types of possible installation users.

5.1.1 Persona 1 – Climate aware

The first persona, see Figure 21, is an international student from Australia who came to study Electrical Engineering Master at the University of Twente. From a young age Shawn has been passionate about the climate and throughout his bachelor's in Australia, he became more invested in climate actions. Due to this, he is already quite aware of waste separation practices. In addition since his move to the Netherlands, he has joined the UT GreenHub student environment where he is learning about local waste separation practices.

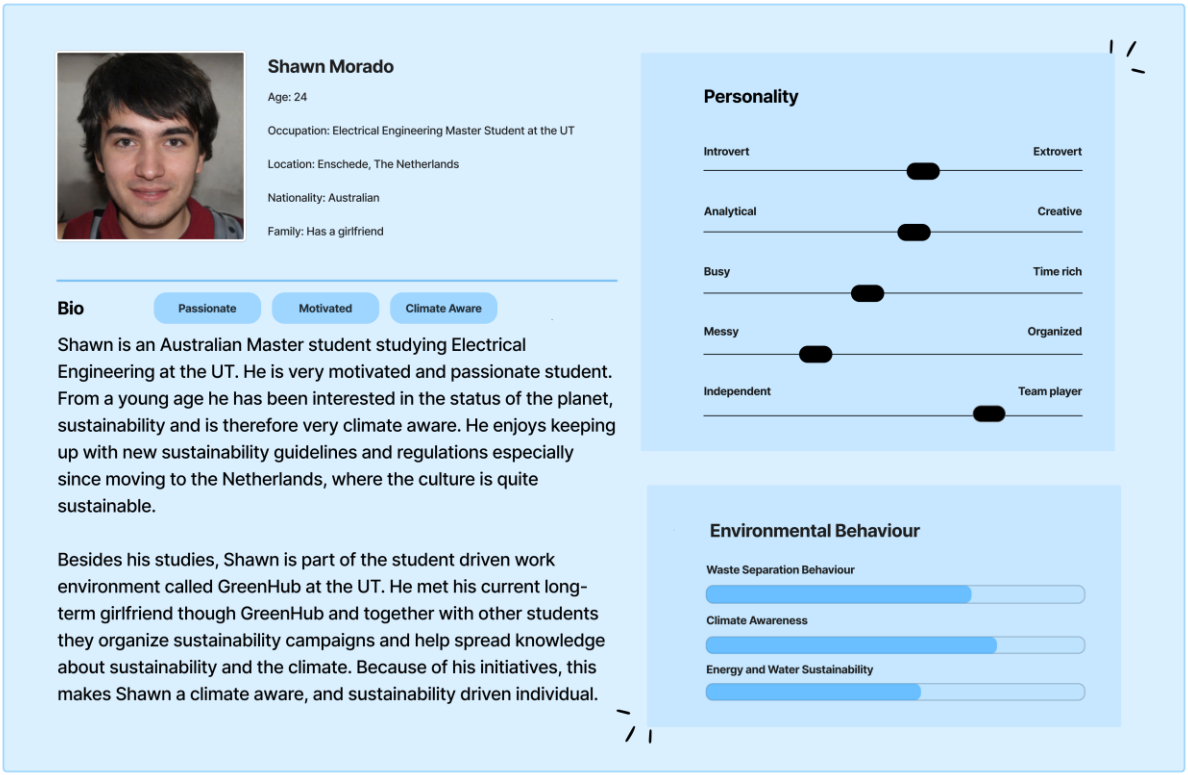


Figure 21: Persona 1 - Shawn Morado, Climate Aware

5.1.2 Persona 2 – Not Climate Aware

The second created persona for this project, see Figure 22, is a German Industrial Design Bachelor student in her 2nd year. Sarah is not particularly interested in climate actions and waste separation as they believe it takes too much time and is not a priority in her life. This presents a valid character type for this project since the goal is that the product encourages people of all types to interact with it and as a result separate their waste correctly.

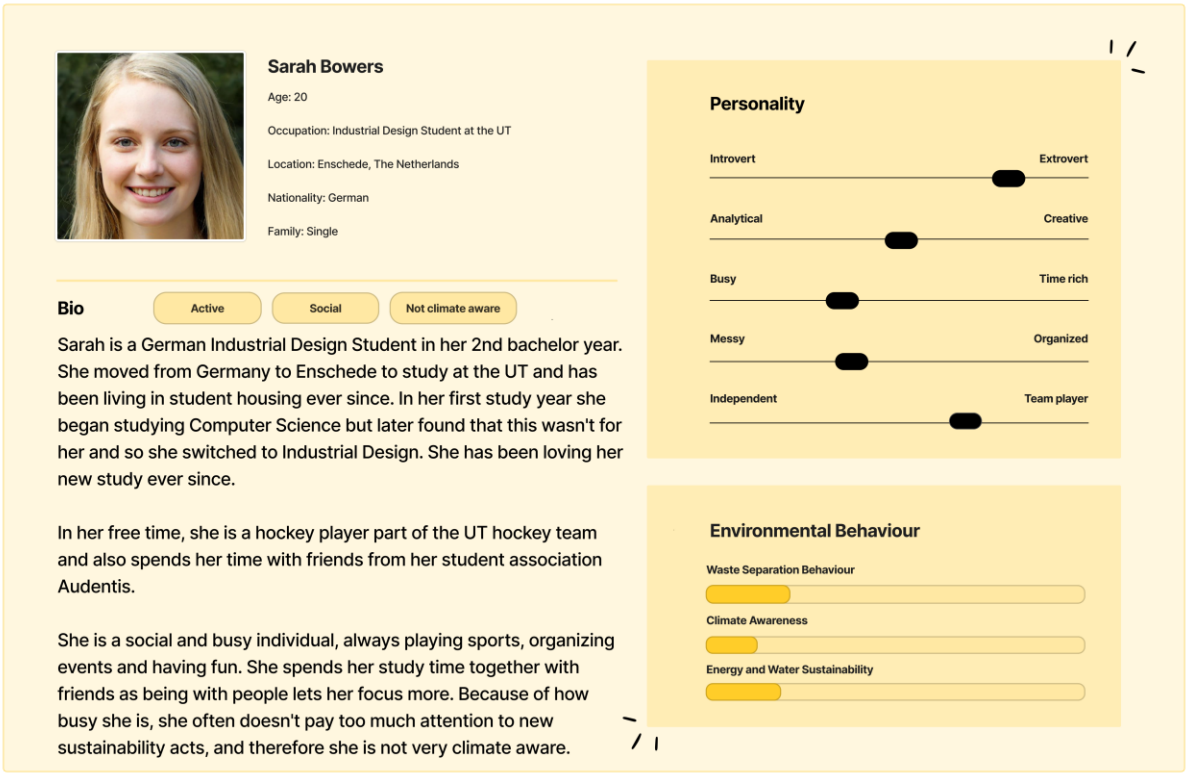


Figure 22: Persona 2 - Sarah Bowers, Not Climate Aware

5.1.3 Persona 3 – Climate Indifferent

The final persona, see Figure 23, is of the third character type: Indifferent to climate awareness. The following type of persona is those who do not fully care about their climate actions, and therefore do not prioritise climate actions. The third persona is a representative of such type of person. She is a busy working woman, and due to her lifestyle, she does not pay great attention to her climate footprint.

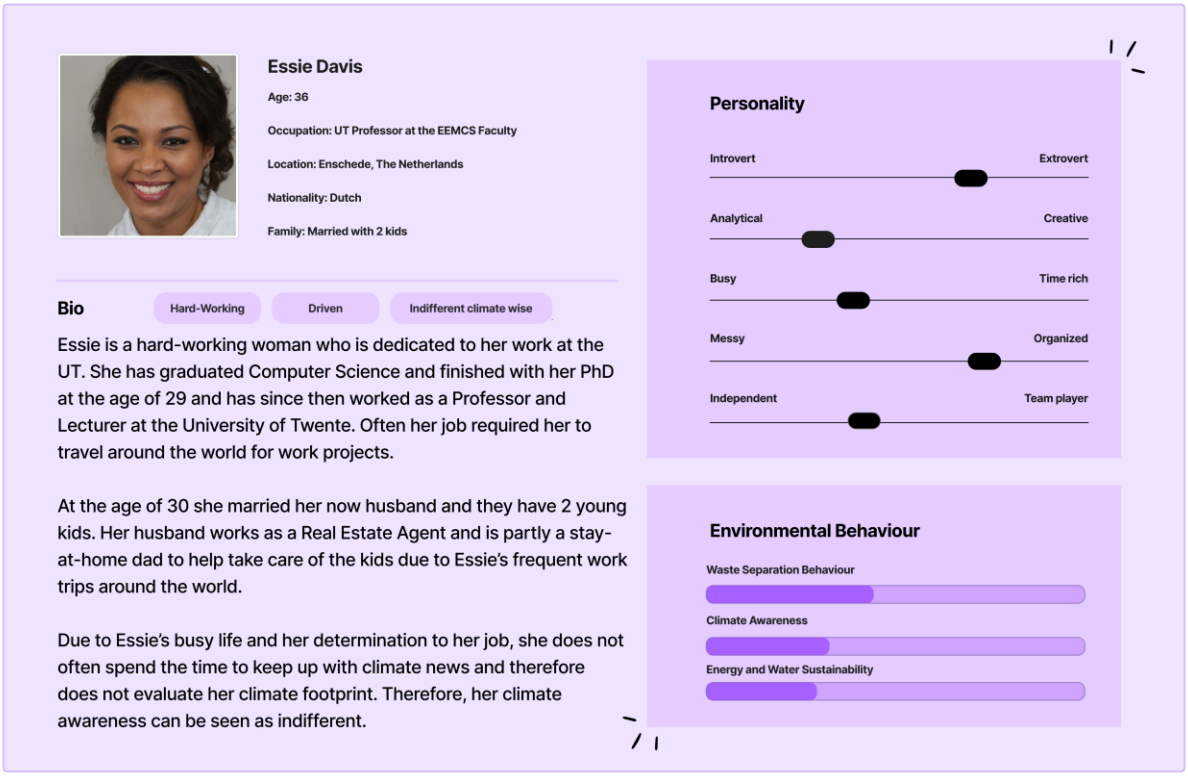


Figure 23: Persona 3 - Essie Davis, Climate Indifferent

5.2 Storylines

To provide a comprehensive understanding of the various interaction options available with the final product, the use of storylines was employed. These storylines incorporate different interaction possibilities, allowing for a clearer overview of the factors to be considered concerning the interactive components and showcasing the product's viability. Each storyline is divided into scenes, enabling a thorough examination of each component in isolation, and facilitating the detailed planning of all the steps required for the interactions.

It should be noted that the following storylines were written together with Eva Barten, the Smart Technology student working on this project, therefore the storylines are almost identical with the differences in the use of different personas based on our individual papers.

5.2.1 Story 1: Product is seen, and waste is disposed of.

5.2.1.1 Scenario 1: Waste is disposed of correctly.

Scene 1: Shawn is studying in the Vrijhof library on a Tuesday morning. It is 10:15 AM. He has three exams next week, so he decided to sit in the library to focus on studying for the exams. He has his exam books laid out on the table and is making summaries of the exam components.

Scene 2: He just drank the coffee he got from the vending machine and wants to dispose of the paper cup the coffee came in so that it does not take up unnecessary space in his working space. He stands up quietly without disturbing anyone and walks towards one of the waste islands. When walking towards the nearest waste island and from 10 meters afar he sees something out of the ordinary. A display is hanging above the waste island. He is very curious, so he starts walking faster toward the waste island.

Scene 3: The screen gets clearer as Shawn walks closer to the bin. He is 7 meters from the bin. There are four small cartoon creatures and bubbles that are raining down. He can not see what exactly

is in the bubbles. He sees someone standing in front of the system, watching them look at the screen and throw a dirty salad container into the residual bin. He is confused why the plastic is thrown into the residual instead of the PD. He walks closer to the bin.

Scene 4: He stands half a meter in front of the system and looks at the display. There are four cute creatures that are small and a bit sad looking. He wonders why they are sad. He sees the bubbles underneath the creatures. There are icons in the bubbles that depict certain types of waste. He sees that above the residual bin, a bubble falls down that illustrates a dirty plastic wrapper. Then suddenly, he gets the idea of the bubbles. They show what waste goes where.

Scene 5: A bubble filled with a paper cup falls just below the PD creature. He drops his paper cup into the PD bin. The PD creature gets a spotlight, and a speech bubble appears. The creature is thanking him for feeding it and becomes a bit happier. Shawn did already know the paper cup should go into the PD bin. However, he did have his doubts because the cups were made of paper. The system confirmed that the cup belonged in the PD bin.

Scene 6: Shawn likes the system, and the creature he fed became a little bit happier and bigger. Moreover, now he knows that the paper cups from the vending machines are supposed to go into the PD bin.

Scene 7: Shawn is done interacting with the waste bin and returns to his study desk to some further prepare for his exams.

5.2.1.2 Scenario 2: The waste is disposed of incorrectly.

Scene 1: It is 13:30 PM, and Sarah is getting ready to go to her lecture which starts in 15 minutes. She just had lunch with a few of her friends at Starbucks.

Scene 2: While walking she finishes her Starbucks coffee, which she got from the educafe, and is looking for a bin to throw her cup into. At the end of the hallway, just around 10 meters away, she sees something that looks like a garbage can, however, a display is hanging right above it. She is a little confused but walks towards the waste bin. She wants to get to the lecture room on time so she is a bit in a rush.

Scene 3: She walks closer to the bin and from 5 meters away she can see what is on the display. There are four small cartoon creatures and bubbles that are raining down. She cannot see what exactly is in the bubbles. She keeps walking towards the bin. Moreover, she sees that she has to separate her waste.

Scene 4: When she is a meter away from the waste bin she sees that there are four cute creatures that are small and a bit sad looking. Sarah feels like she does not really have time to interact with the system. She reckons that her paper cup goes into the paper bin since it is made from paper. She sees one of the bubbles showing a paper cup that is supposed to go into the PD. She is confused why that is so she throws it in the paper waste stream and continues walking to the lecture hall. She chooses to ignore the system due to time constraints and confusion.

5.2.1.3 Conclusion

From these scenarios, it can be deduced that Shawn (persona 1) is more aware of separating waste while Sarah (persona 2) does not really care for waste separation and does not take the time to do it correctly. Essie (persona 3) could react to the system in both scenarios since she is indifferent about the idea of climate change. She could either react to the system in curiosity and see what the product does and separate waste correctly. While she could also be too lazy or she could not have enough time to interact with the system and therefore separate his waste incorrectly. Furthermore, it might

be that when Shawn is stressed or does not have enough time, there might be a chance that he separates the waste wrong as well. He might not have the time to observe the bubbles and see where his waste object belongs.

5.2.2 Story 2: Product is seen, no waste is disposed of.

Scene 1: It is 10:30 AM on a Wednesday morning and Essie just told her students that they can take a break of 15 minutes. She is giving her usual lecture to the first-year Computer Science students. Since she has some time before she wants to continue the lecture, she decides to take a short walk to get a coffee from one of the machines.

Scene 2: When walking in the hallway she sees one of the waste islands at the end of the hallway. It is a 10-meter walk to the waste bin. She observes that there is a display that hangs above the waste islands.

Scene 3: As Essie walks closer to the bin the screen gets clearer. She is 7 meters from the bin. There are four small cartoon creatures and bubbles that are raining down. She cannot see what exactly is in the bubbles, so she decides to explore the waste bin and see what the display shows.

Scene 4: She stands half a meter in front of the system and looks at the display. There are four creatures that are small and a bit sad looking. She wonders why they are sad. She sees the bubbles underneath the creatures. There are icons in the bubbles that depict certain types of waste. She observes the system for a couple of seconds and looks at the waste bubbles and in which bin they are going. After a short while, she decides to continue her walk to the coffee machine.

Scene 5: Essie gets her coffee, returns to her lecture hall, and continues to teach the nice pupils about Computer Science.

5.2.2.1 Conclusion

The two other personas would probably react differently to the system than Essie. The persona that cares more for the environment will probably be more enthusiastic about the product and would want to spend more time interacting with it while the indifferent persona might not want to interact with the system at all when there is no need for it.

5.2.3 Story 3: Product is overlooked, waste is disposed of.

5.2.3.1 Scenario 1: waste is disposed of correctly.

Scene 1: On a quiet Wednesday morning around 11:00 AM, Shawn is seen studying at the Bastille building at the UT campus. It is at the end of his module, and he is studying hard to prepare for his upcoming exams. He's working on a tight schedule to finish with revisions and practicing practice exams in time.

Scene 2: Around 12:30 PM he takes a lunch break by going to the nearby grocery store called the Coop and purchasing a sandwich and a refreshing iced tea drink. After which he returns to his seat at the Bastille to finish his lunch. When he finishes his lunch, he decided to clean up his work area so there are no more distractions around and so he could get back to work as per his schedule.

Scene 3: Shawn begins to gather all the waste from his desk and group them per category to make it easier for himself when throwing away his waste. He then grabs his phone and proceeds to check his calendar and his to-do list, whilst walking towards the nearest waste separation island.

Scene 4: Shawn approaches the nearest waste bin and notices a screen placed by the waste islands that turns on and displays four creatures called BinBuddies, above each waste bin. Shawn became a bit confused as to what is the purpose of these creatures and decided to proceed to throw

away his waste as he had prepared it. Shawn is aware of the waste separation guidelines at the Unveracity of Twente and therefore he performed correct waste separation, even without observing the screen with the BinBuddies.

Scene 5: Quickly he checks his phone and sees the time and that he is behind on his schedule. He decides to turn back and return to his study place, leaving the waste islands and missing the reactions of the creatures (BinBuddies) to his disposed waste.

5.2.3.2 Scenario 2: Waste is disposed of incorrectly.

Scene 1: It is 17:30 on a Thursday and Sarah is getting ready to go to hockey training. Her last lecture of the day just ended, and her practice starts at 18:00 so Sarah is in a rush to get home from the Horst to Campuslaan, to grab her gear and head to the Sport Centre at the UT Campus.

Scene 2: After grabbing her gear, she realized she didn't have time to eat dinner before practice and so she ran out to the near grocery store called the Coop and purchased a few Bio healthy muesli bars. She then proceeded to eat a few of them on her walk back to the Sports Centre. Her training was starting in 5 minutes so she slightly panicked and looked around for a waste bin she could throw away her wrappers in.

Scene 3: While walking around the Sports Centre, she saw a waste bin and approached it. She is about a meter away, and a screen turned on from above the waste bins and displayed four cute creatures called BinBuddies. Confused about the screen and in a rush to not be late for training, Sarah looked at her waste and threw her packaging into the paper bin as it seemed to be made from paper, where in reality it was a mix of paper and plastic and should have therefore been thrown away in the PD bin. At the corner of her eye, she notices the creature above the paper bin reacting to her throwing her waste in the paper bin, however, she chooses to ignore it and rush to training.

5.2.3.3 Conclusion

From these scenarios, it can be concluded that Shawn (persona 1) is more aware of correct waste separation while Sarah (persona 2) is not as aware and does not necessarily care about it. In the situation of Essie (persona 3) who is indifferent regarding climate awareness and waste separation, both scenarios could have been performed mostly depending on the waste to be separated. Since both Shawn and Sarah chose to overlook the system due to being in a rush or general time constraints Essie could've also performed the same. In the situation that both Shawn and Sarah have more time on their hands, it is expected that Shawn shows more interest in the system in contrast to Sarah since Shawn is in general more climate aware and passionate about performing correct waste separation.

5.2.4 Story 4: Product is seen, the product is abused.

Scene 1: Sarah and a few of her friends are sitting in the Bastille lounge area enjoying snacks and chatting about recent events and plans for parties they would want to attend. Throughout that time, they have gone through a few bags of chips and cookies alongside fruits and chocolate. Around 18:00 they decide that it is time for them to leave and go home and so they gather all their waste and hand it to Sarah to find the nearest waste separation island and throughout the waste.

Scene 2: After walking around a bit, Sarah sees the waste separation islands and begins to approach it. From a distance she can see that there is a screen present beside the waste bins and interested in it she walks quicker to the waste bins. She sees that on the screen there are four creatures with different sizes visible and each one is hovering on top of a different waste bin. She then understands that these creatures represent the waste bins.

Scene 3: After a few seconds of observing the creatures, she notices that the paper and the organic bin creatures seem sadder than the PD and Residual waste. Confused about why that is, she proceeds to throw away some of the waste into the PD waste bin. She then sees a spotlight appear on top of the PD creature, and the creature becomes bigger and happier whilst it thanks her for her waste (feeding it). After this interaction, Sarah understood the purpose of the waste bin creatures.

Scene 4: Sarah felt bad for the organic and paper bin and so she decided to feed them too by throwing the rest of her waste into those two bins. At first, she threw away all her organic waste in the organic bin, and all her paper waste in the paper bin, which was correct and as a result of being fed, the creatures were happier. Still, they were not as happy as the PD and residual. She then decided to tear up one of her plastic bag waste and throw it into the paper bin to make the paper creature happier.

Scene 5: At first the paper creature was getting happier, and Sarah got excited that she was feeding it and making it happy, however after 10 seconds of being constantly fed, the paper creature started to become sick. Sarah was confused. The paper creature had become sick and sadder looking since the system was aware that the system may have been abused. Sarah felt bad for her overfeeding actions and proceeded to throw her remaining PD waste into the PD bin and return to her friends to gather her belongings and go home.

5.2.4.1 Conclusion

From this scenario, it can be seen that Sarah (persona 2), is not very climate aware and does not fully pay attention to proper waste separation. Therefore she misused the system for “her own” fun benefit by feeding the creatures incorrect waste in order to make them happier. In order to attempt to counteract this action, the system responded by making the creature sad, therefore the exact opposite of what Sarah wanted to achieve, which then resulted in Sarah disposing of her waste correctly. When it comes to Shawn (Persona 1) or Essie (persona 3), Shawn would most likely not perform such misuse since he is more climate aware and waste separation cautious and would not purposely separate wrongly for the benefit of one creature over another. When it comes to Essie, this could go both ways. Possibly due to curiosity, Essie could behave similarly to Sarah, however, she could also potentially pay more attention to the regulations and use the waste islands as they are supposed to be used.

5.3 Time Sequence Diagram

A Time Sequence Diagram (TSD) [27] is a type of diagram that visually represents the user's actions and their interaction with various elements of the product in a clear sequence. For this project four different TSDs were created using the tool Adobe Illustrator [33], based on the Storylines explained in chapter 5.2. The diagrams consist of three interconnected components: the user, the screen, and the waste island, each playing a role in the overall interaction process.

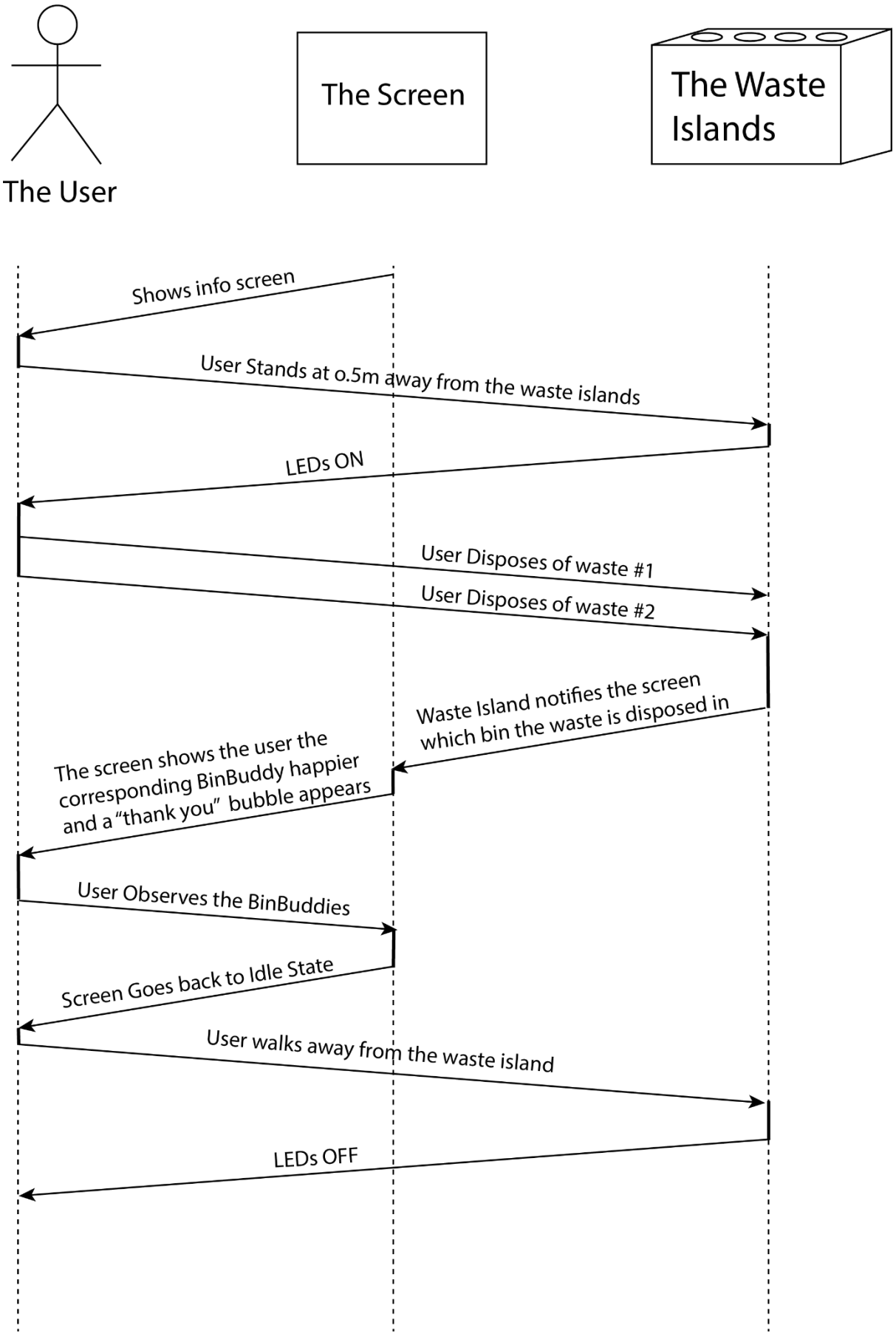


Figure 24: TSD of: Product is seen, and waste is disposed.

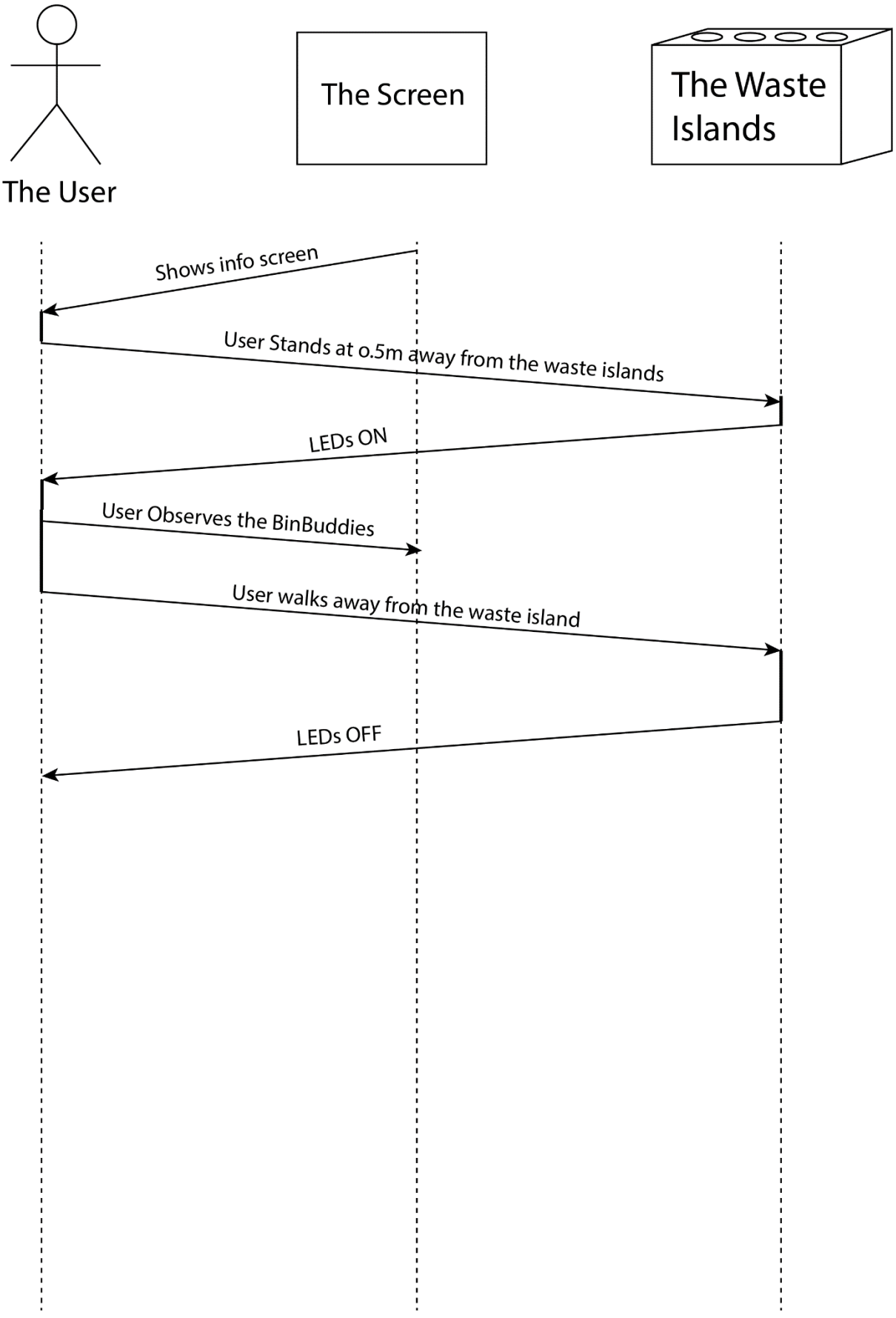


Figure 25: TSD of: Product is seen, no waste is disposed.

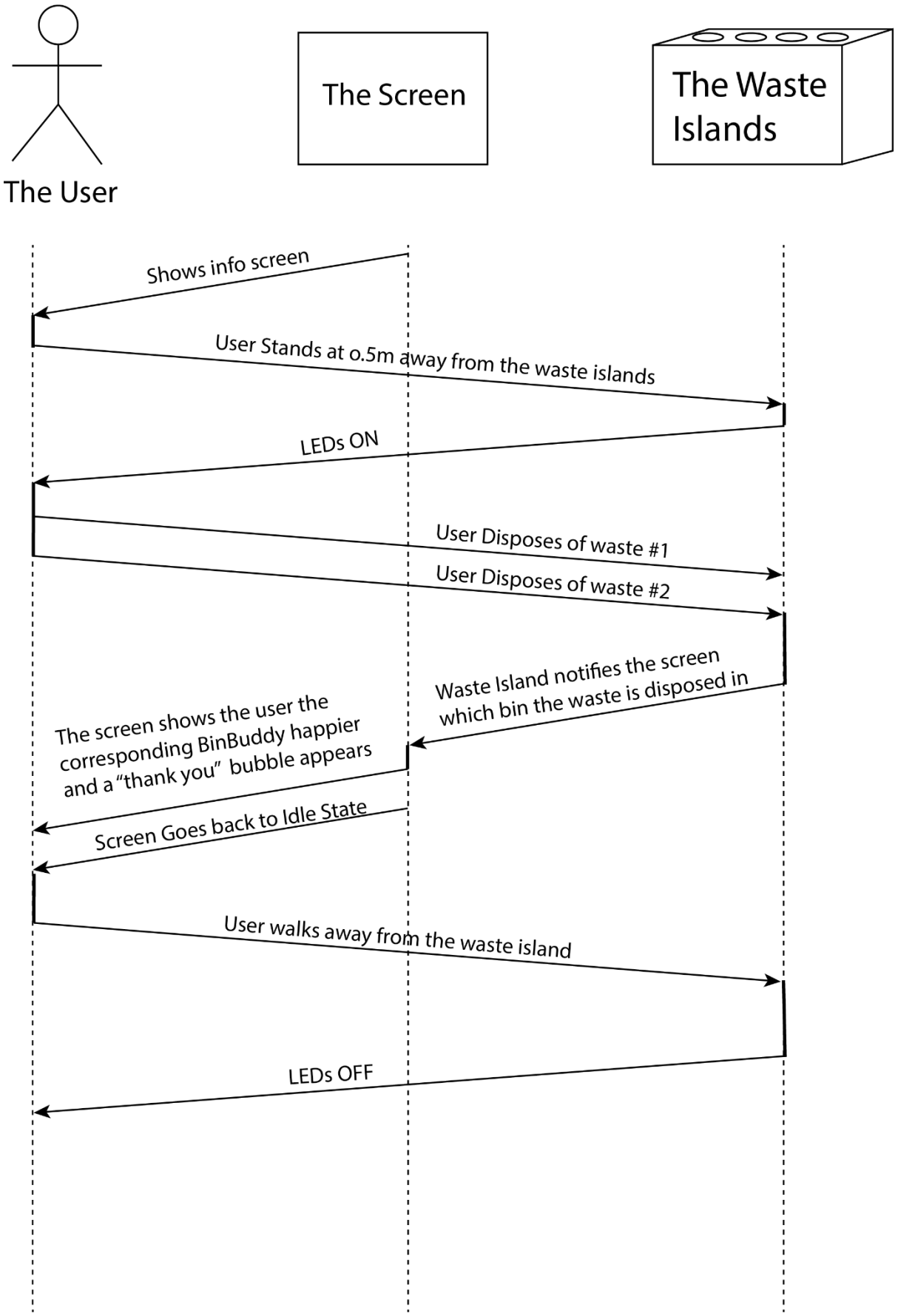


Figure 26: TSD of: Product is overlooked, waste is disposed.

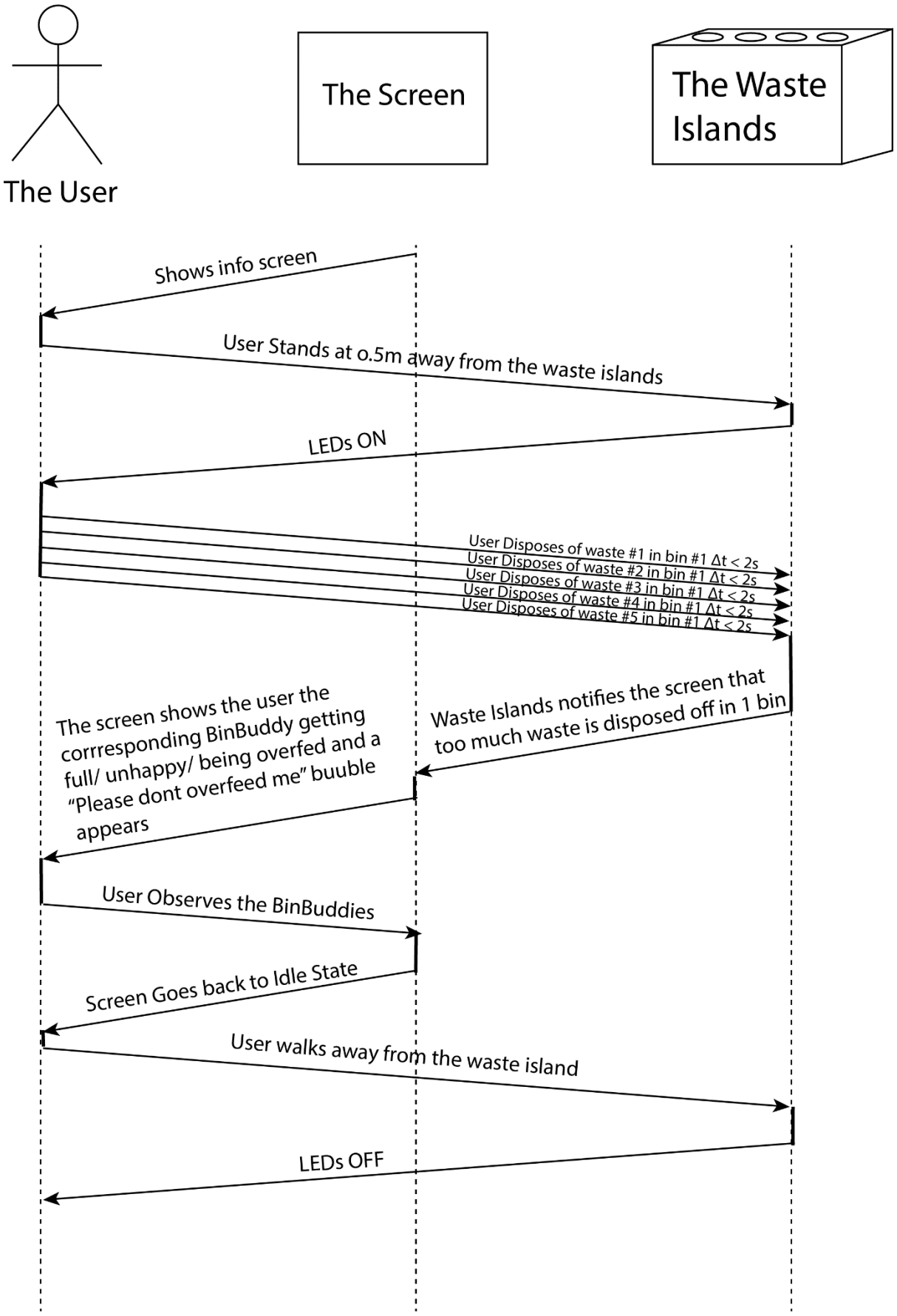


Figure 27: TSD of: Product is seen, product is abused.

5.4 Visualization Requirements

5.4.1 Functional Requirements

The functional requirements outline the specific tasks and functionalities that the product is expected to perform. The functional requirements for this project can be seen in Table 6.

Number	Requirement	MoSCoW Priority
1	Changes state based on the bin that waste is thrown in	Must
2	Notices when the system is abused and reacts accordingly	Must
3	Reverts back to idle state when not in use	Must

Table 6: Functional Requirements

5.4.2 Non-functional Requirements

The non-functional requirements specify the way the product should accomplish its functions. These requirements focus on factors such as performance, usability, security, and other aspects that contribute to the overall effectiveness and quality of the product. Table 7 shows the non-functional requirements.

Number	Requirement	MoSCoW Priority
1	Be visually appealing such that it attracts users.	Must
2	The imagery used is clear and understandable for all users	Must
3	Text is clearly readable and understandable for every user	Must
4	Use the UT house-style colors.	Must
5	The images used are coherent and similar in style	Should
6	Motivate users to separate their waste better	Must
7	Educate users about waste separation of difficult items	Should
8	Not have a high or too low screen brightness	Should

Table 7: Non-functional requirements

5.5. Storyboard

A storyboard is created to help visualize the storyline and interactions between the user and the system. The storyboard seen in Figure 28 depicts interaction one where the product is seen and waste is disposed of. The storyboards for Interactions two, three and four can be seen in Appendix III on Figure 45, Figure 46 and Figure 47.

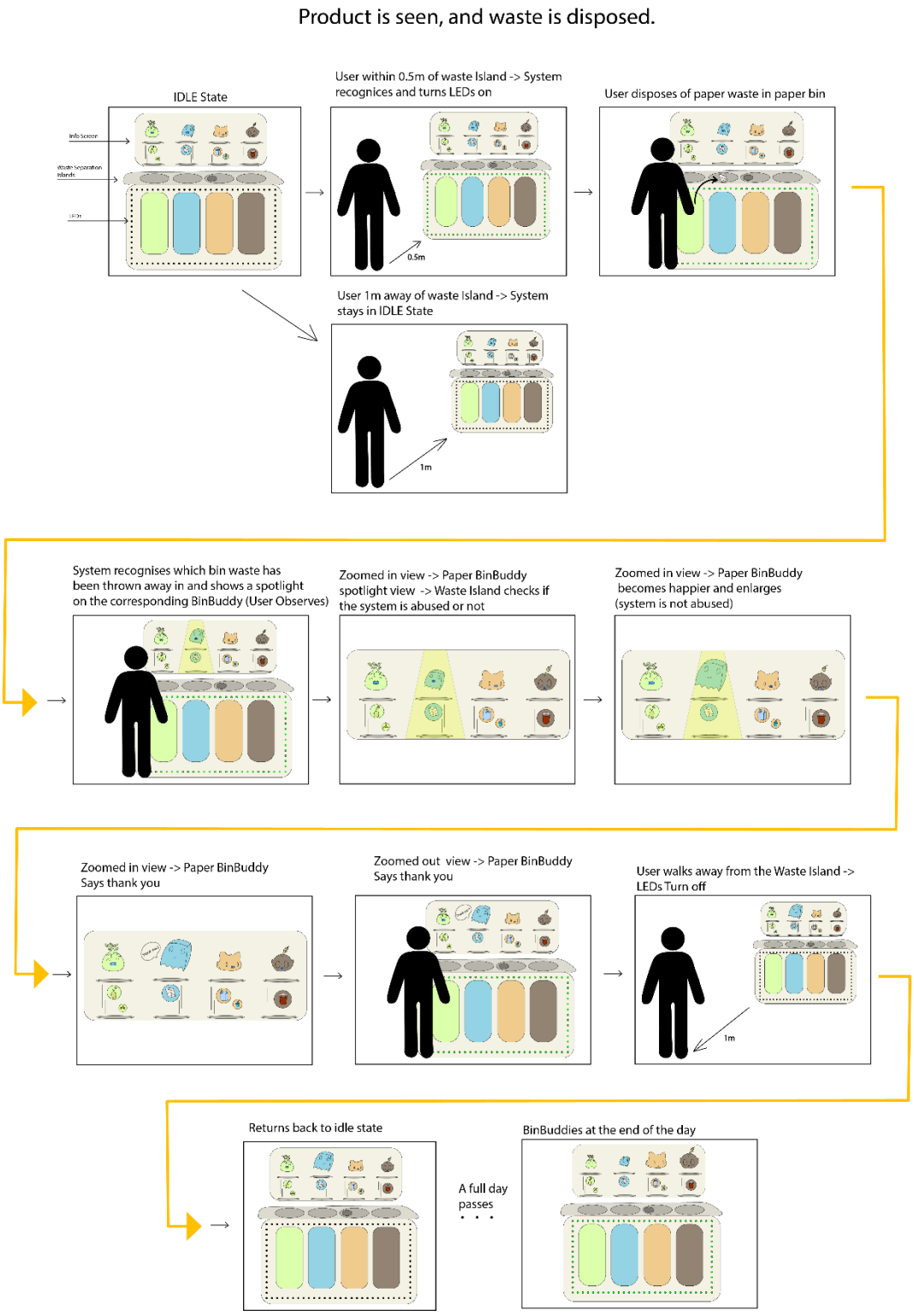


Figure 28: Storyboard Interaction 1

5.6 Visualisation components

The visual aspects of an installation play a vital role in effectively conveying its purpose to the user. To accomplish this, the visual components are categorized into several key elements: colors, icon style, and measurements.

5.6.1 Colours

Choosing the right colors to use for the installation is of great importance. Considering that this installation is designed for the University of Twente, it felt fitting to use the University of Twente house-style colors as a base. Figure 29 visualizes these colors.

Figure 29: UT House Style Colours [34]

When selecting colors that fit the UT house style all the above colors are suitable. However, colors also are considered to have underlying meanings, and some can be considered more meaningful to the project in mind than others.

5.6.1.1 Background

Given that the primary visuals of the final concept are presented on a large screen positioned behind the existing waste islands, the choice of background color holds significant importance. It is crucial that the background color does not overwhelm the installation, detract from its objectives, or negatively impact the users' emotions. The background of the installation needs to remain neutral, allowing the displayed items to be clearly visible without overpowering the visuals on the screen. Consequently, two main colors were considered for the background: Black and White. Several criteria were employed to determine the most suitable option, including the symbolic meanings of the colors and their compatibility with the University of Twente's surroundings and the waste islands.

According to Kendra Cherry [35] Black is associated with nobility, mystery, coldness, and power. Additionally, it carries an emotional association with sadness. Conversely, White is linked to notions of truth, impartiality, freshness, cleanliness, youth, and modernity [35]. When comparing these two colors for the background of the installation, the “UT_Wit” White appears to be the more fitting choice. Considering its alignment with the University of Twente's surroundings, where the existing waste islands have a white base, selecting white for the screen background creates a cohesive and harmonious extension of the islands. Figure 30 aims to visualize this choice.

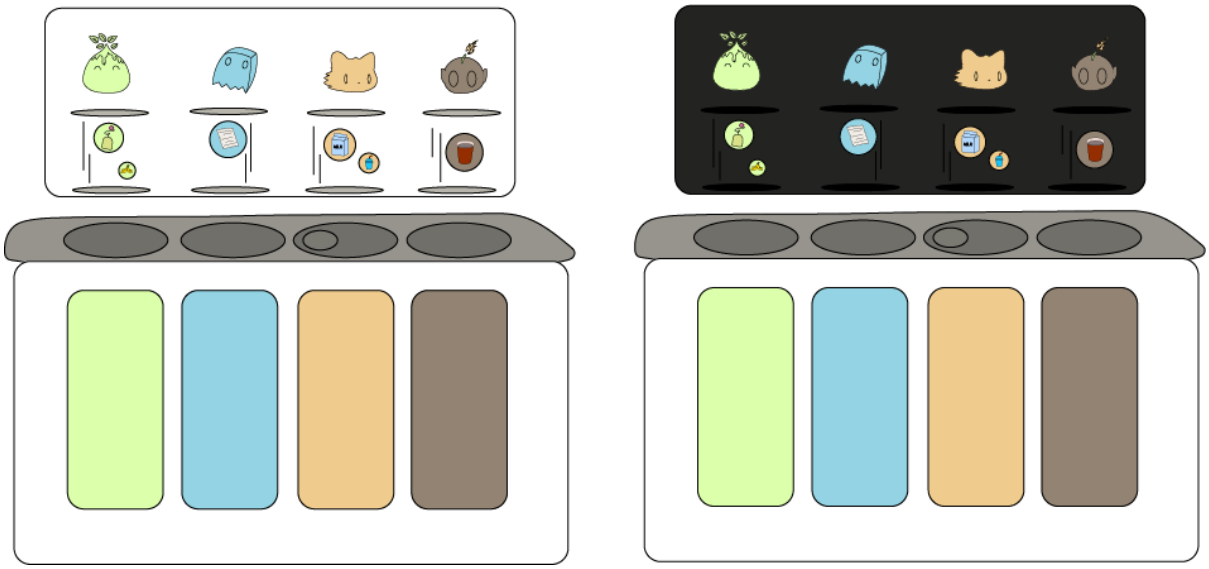


Figure 30: Black or White background

5.6.1.1 Colors for Elements

Next, it is essential to select colors for the four creatures known as BinBuddies, which symbolize the different waste streams. The University of Twente has already designated specific colors for each waste stream: Blue for Paper, Green for Organic, Orange for Plastic and Drink Cartons (PD), and Gray for Residual waste. Figure 1 illustrates the original UT waste islands and their corresponding colors. To ensure easy association between the BinBuddies and their respective waste streams, it is decided to closely align the BinBuddy colors with the predefined color scheme. Therefore, the base colors chosen from the UT House Style Colors are as follows: "UT_Donkerblauw" for the Paper BinBuddy, "UT_Groen" and "UT_Olijfgroen" for the Organic BinBuddy, "UT_Oranje" for the PD BinBuddy, and "UT_Koudgrijs" for the Residual BinBuddy.

Since these colors offer various opacity shades, they allow for the visualization of depth and dimension when illustrating the BinBuddy creatures. The Organic BinBuddy is assigned two colors because the vibrant green of "UT_Groen" combined with the natural tone of "UT_Olijfgroen" creates a more authentic appearance, better suited for representing organic waste. This combined color was created using the website called “Coolors” [36] as well as a visualization of the chosen color pallet seen in Figure 31.

Figure 31: Chosen Colour Pallet

The same colors were chosen for the portals located beneath each BinBuddy and for special effects, such as confetti colors representing the BinBuddies' reactions. The decision for the portals was made as such to maintain consistency across the illustrations and to facilitate easy differentiation

of waste items, indicating where each item belongs. Additionally, this choice creates the illusion that the waste items generated by the BinBuddies directly fall into the corresponding waste streams of the waste island.

5.6.2 Style BinBuddies

After choosing the colors which are to be used for the installation, the next important aspect is to choose the style of the BinBuddies creatures. The two main parts of the creatures are their bodies and their faces.

5.6.2.1 Style Bodies

During the ideation phase, the purpose of the BinBuddies was determined to be avatars representing each waste bin. As such, they needed to embody the essence of the corresponding bin. Given that these avatars would take the form of creatures, it was concluded that a completely realistic appearance would not be suitable for this project. Adding a face to a realistic object could seem unnatural and unsettling.

Thus, it was decided that the creatures should be depicted in an artistic style. However, there were various artistic approaches to consider for creating the BinBuddies. This is illustrated in Figure 32, which showcases the different artistic styles explored for their design.

Figure 32: Different Artistic Styles

The visualization of a trash bag on the far left appears to be the most realistic, resembling an actual trash bag. However, considering the style and overall atmosphere of the installation, this realistic representation does not align well and will not be utilized. Moving toward the center, the second visualization presents a sketchier version of a trash bag. While it deviates from strict realism, it still retains a significant level of detail and proximity to reality. Consequently, it does not fully fit with the installation's aesthetic and is not the preferred choice. On the far right, the third visualization stands out as the most suitable for the installation. It strikes a balance between artistry and abstraction, effectively capturing the essence of a trash bag while incorporating a cleaner and more simplified design. This style choice proves advantageous, particularly when considering that the creatures in the installation will not only possess bodies but also facial expressions. The cleaner space allows for better visibility and expression of the faces. Furthermore, this visualization complements the current design of the waste islands and the drawings exhibited there. Hence, the third visualization aligns most closely with the installation's intended style and overall concept.

5.6.2.1 Style Faces

As previously mentioned, the creatures in the project would possess faces to convey their emotional state to the user. Since the chosen style is cartoon-like, it is essential for the faces of the creatures to

be in line with this aesthetic. Consequently, a decision was made to keep the faces as simple as possible, utilizing basic shapes such as circles for the eyes and lines for the mouth. Figure 33 provides examples of facial expressions that can serve as inspiration. After observing various methods of expressing emotions, the preferred options were identified and highlighted within the yellow boxes.

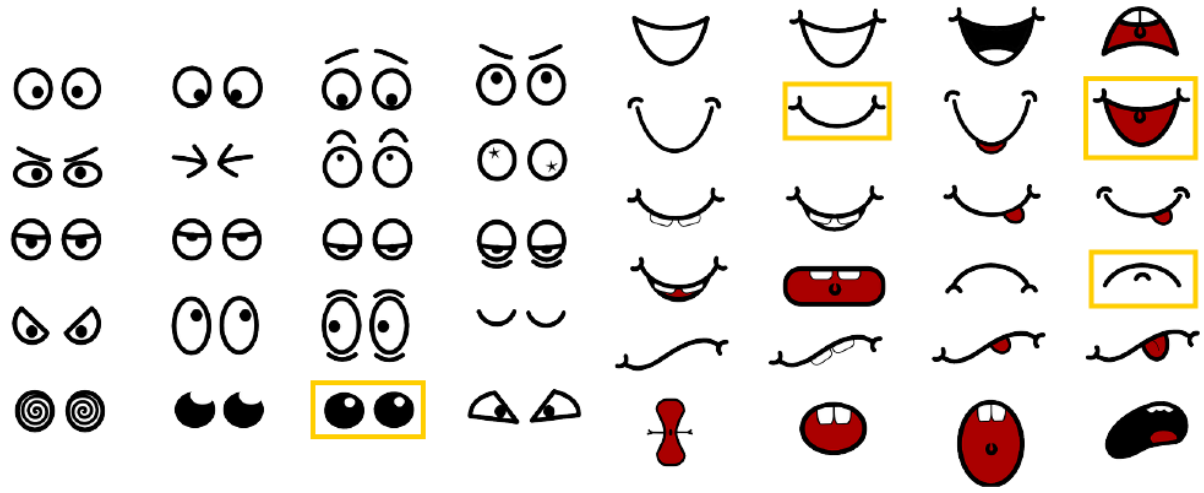


Figure 33: Cartoon Facial Expressions

5.6.3 Style Icons

In Figure 20, the unknown waste items are represented by bubbles containing images or illustrations of those items, which flow through the portals. However, several considerations must be taken into account to effectively portray these items, including the design of the bubbles and the style of the images or illustrations. To ensure consistency, the previously defined colors used for the BinBuddies will also be applied to the bubbles. Six different bubble options were experimented with for each waste stream, as shown in Figure 34. The objective of these bubbles is to convey depth and align with the BinBuddies' appearance and the illusion of the portals. After careful observation and comparison of the potential colors, the sixth gradient option was selected. This particular option creates a focal point in the center where the waste item pictures or illustrations are placed, directing attention towards them. Moreover, it provides a more three-dimensional and dynamic appearance, resembling flowing bubbles that harmonize with the overall installation.

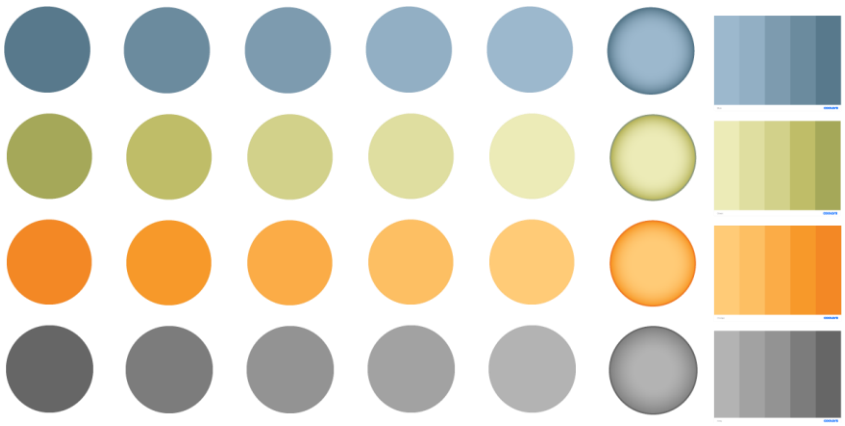


Figure 34: Bubbles Colour Pallet

After finalizing the selection of the bubbles, the next crucial step is to determine the style of the images inside them and whether to use actual images or illustrations. Since the primary objective of these displayed items is to assist users in correctly disposing of waste, they are unsure about, it is

crucial that the images closely depict everyday waste items. Therefore, using actual images is a preferable choice over illustrations as can be seen in Figure 35. Additionally, utilizing images allows for easier future updates of the unknown waste items by the client. The images used for this project were acquired through the PNG picture platform PNGWING [37].

Figure 35: Bubbles with Images

While the realistic style of images may not perfectly align with the illustrated style of the rest of the installation, the predominant concern is ensuring that users can easily recognize items they are uncertain about and determine their proper disposal. The emphasis lies in facilitating user understanding rather than solely pursuing an aesthetic appeal. It is vital that the unknown items are depicted with a high level of accuracy to assist users in their decision-making process.

6. Realization

The realization phase is dedicated to transforming the concept that was conceived during the ideation phase and defined during the specification phase into a tangible product. The initial step involves identifying all the individual components that require design and implementation. Subsequently, a detailed explanation of how these components have been brought to life is provided. This is then followed by an evaluation of their compliance with the functional and non-functional requirements identified in Chapter 5.

6.1 Identification of Sub-parts

To create and evaluate the final prototype effectively, it is crucial to deconstruct it into its constituent parts that together constitute the complete design. With this objective in mind, the design was categorized into two distinct aspects: The Visuals and Nudging.

1. The Visuals

   The visual component is dedicated to presenting various types of waste to users and displaying the BinBuddies. Additionally, this part incorporates nudging techniques via the expressions of the BinBuddies to communicate and guide users on proper waste disposal effectively. Its primary objective is to inform users on the screen about the correct ways to dispose of their waste.

2. Nudging

   The nudging component comprises aspects that aim to influence user motivation, without the user necessarily being aware that their behavior is being influenced. This is done via the BinBuddies.

6.2 Realization of Sub-parts

After the identification of the sub-parts, the realization stage can begin. Each sub-part is discussed in terms of its implementation, including the methods, tools, systems, and research conducted for its realization.

6.2.1 Visuals

The visualization part of the product is the largest one therefore different aspects need to be considered. Firstly, the visuals were created using the tools Adobe Illustrator 2022 [33] and Adobe After Effects 2022[38]. Both tools are graphic-driven software and have all the necessary tools to design the images used for the bin buddies and the video displaying the unknown items.

Figure 36 shows the full view on the screen, including the four different BinBuddies and their respective portals. This view is seen throughout the day and individuals walking past can observe the moving bubbles through each portal. These elements were realized based on the color and style choices made in Chapter 5. The chosen style is clear and simple. The images are clear and can be seen from a distance or when just walking by the installation.

Figure 36: Visualization of the full screen view

During user interactions with the system, the BinBuddies can express different facial expressions, including happiness, neutrality, sadness, and nausea, depending on their current stage. At the beginning of the day, the BinBuddies start off in a sad state and progressively become happier when the users use the system. However, if the system is abused and too many waste items are disposed of simultaneously in the same bin, the BinBuddy will display a nauseous expression. This indicates to users that the BinBuddy is full and requests them not to overfeed it via a speech bubble. Figure 37 displays the facial expressions of the organic BinBuddy. The rest of the BinBuddies have similar expressions and the visualizations of those can be found in Appendix IV in Figure 48.

Figure 37: Organic BinBuddy Expressions

6.2.2 Nudging

The concept of nudging played a significant role in the previous solutions and technologies discussed in the background research. Consequently, this project's intervention also incorporates nudging techniques. The screens utilize various nudging techniques to encourage users to actively engage with the system and effectively sort their waste. The following techniques were used:

1. Graphics Simplification
   To enhance clarity and ease of use, the visuals have been simplified to ensure that all waste items are easily recognizable. Additionally, the emotions of BinBuddie are prominently displayed and easily identifiable. This enables users to quickly identify waste items they intend to discard when they see corresponding representations on the video. As a result, the process of waste disposal becomes clearer and more straightforward for the users.

2. Performance Simplification
   The system allows users to choose whether or not to interact with the installation. It is not mandatory for users to observe the reactions of the BinBuddies, allowing them the option to simply walk away if they prefer not to engage. This approach ensures that the installation remains accessible and avoids unnecessary complexity. However, for users who do wish to interact, they have two options available. They can either watch the video loop to gain knowledge about waste separation or actively participate by disposing of their waste and observing the reactions of the BinBuddies.

3. Social norms
   The inclusion of emotions displayed by the BinBuddies serves a crucial purpose: to establish a connection between the users and the creatures. The intention is to evoke a sense of empathy and a feeling of concern for the BinBuddies. This emotional connection is intended to motivate users to actively participate in waste separation, driven by their willingness to alleviate any distress experienced by the BinBuddies. By fostering this emotional bond, users are more likely to be motivated and willingly engage in proper waste separation practices.

4. Convenience
   The simplification of waste disposal actions through the use of screens makes the process more convenient for potential users. By continuously playing the video loop showcasing unknown items, users gain knowledge about waste separation without the need for additional actions. This effectively implements the nudge of convenience by eliminating unnecessary steps. Moreover, prominently displaying the BinBuddies on the screen captures the attention of potential users, encouraging them to engage with the screen. This strategic placement of the BinBuddies serves as an effective means to attract users and increase their interaction with the system.

6.3 Functional Requirements Review

Following the integration of all components into the design, the system underwent evaluation based on the functional requirements outlined in the previous chapter (Chapter 5). It is important that the system adheres to the essential "must" requirements. Table 8 demonstrates that all requirements have been successfully fulfilled, indicating that the system meets the desired criteria.

Number	Requirement	MoSCoW Priority	Is it met?
1	Changes state based on the bin that waste is thrown in	Must	Yes
2	Notices when the system is abused and reacts accordingly	Must	Yes
3	Reverts back to idle state when not in use	Must	Yes

Table 8: Functional Requirements Review

7 Evaluation

The Evaluation phase is the final part of the Creative Technology design process, wherein the product developed during the realization phase is thoroughly tested and the non-functional requirements are assessed. User testing was employed to evaluate all aspects of the product. The user testing was done physically in the Zilverling building near the Smart XP in June 2023. A total of 20 participants were recruited for the user testing sessions, which spanned over two days.

Following the first day of testing, several modifications were made to the prototype based on the feedback received. The updated prototype was then tested on the second day. Throughout both testing days, participants were provided with a set of clean waste items, carefully selected to include both easy and challenging items. The easy items represented waste materials that are consistently disposed of in the same way across the majority of waste separation regulations (such as a banana peel), while the challenging items were considered less familiar (such as a paper cup or a metal can). Additionally, some items were labeled as "dirty" to simulate a realistic experimental setting.

7.1 Set-up

The evaluation setup for this project can be seen in Figure 38. The evaluation was done in 2 areas. The first area is a hallway located outside area 2 which is a room. In the first area, the screen and the waste islands together with the waste items was set up. The screen is placed right above the waste island to make the system as collected as possible. Area 1 is also where the participants would begin the user testing. During the user testing, the researchers would stand around the installation while the participant would interact with it. The goals were to observe the interactions without interfering or interrupting the interaction. After the participant is done with disposing of the provided waste items, they are brought to area 2, which is a quieter room where one of the researchers would perform a short interview and a survey with the participant while the other researcher would re-collect the waste items and prepare the installation for the next participant.

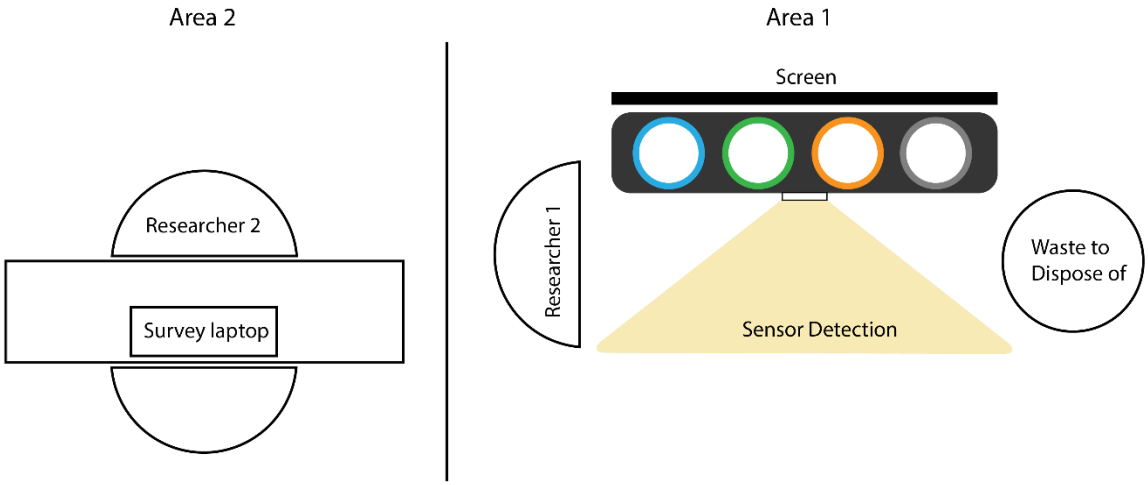


Figure 38: The evaluation Set-up

7.2 Procedure

The user testing procedure was as follows:

1. The participant is provided with the ethical consent form and an information brochure available in Appendix V and VI. They are requested to read the information brochure and encouraged to ask any questions they may have. Subsequently, the participant is asked to complete and sign the consent form. Following this, they are given a brief explanation of their task, which involves disposing of waste in the waste island, followed by completing a short survey and a short interview.
2. The participant takes the waste and disposes it on the waste island.
3. When the participant is finished, they are interviewed and are given the survey, which they fill in each question honestly.
4. Once the survey has been completed, the participant is given the opportunity to provide any feedback or comments they wish regarding the prototype or their overall experience.
5. The participant is thanked for their assistance and contribution to the research. The researchers then prepare the set-up for the next participant.

7.3 Results

Chapter 7.1 evaluated the prototype using a semi-structured interview followed by a survey. The following section dives into the results of both the interviews and the survey.

7.3.1 Survey Results

Several aspects were evaluated regarding the visual aspect of the installation. These aspects encompassed the attractiveness of the screen, the clarity of the visuals, and their ability to convey knowledge and motivate better waste separation. In total 18 questions were asked of which 13 were about the requirements and can be found in Table 9. The rest of the questions were regarding informed consent which was required to be answered with a yes in order to proceed with the survey as well as general remarks questions at the end of the survey. The general remarks answers will be evaluated at a later stage.

Number	Questions
1	The screen is easy to understand.
2	The screen looks appealing.
3	The screen gave informative feedback.
4	Items in the bubbles were easy to recognize.
5	Items in the bubbles looked realistic.
6	The text was readable.
7	The video of the waste items was clear.
8	The video of the waste items helped separate waste.
9	The goal of the BinBuddies is understood.
10	Sympathy is felt for the BinBuddies.
11	The installation engaged and captured attention.
12	The installation taught me how to separate waste better.
13	The installation was easy to interact with

Table 9: Survey Questions

The following graph shows the results of the 13 questions found in the list above. For each question the participants could answer with a scale of 1 to 5 as follows: 1 – strongly disagree, 2 –

disagree, 3 – neutral, 4 – agree, and 5 – strongly agree. Figure 39 depicts a bar chart with the average answers provided for each question.

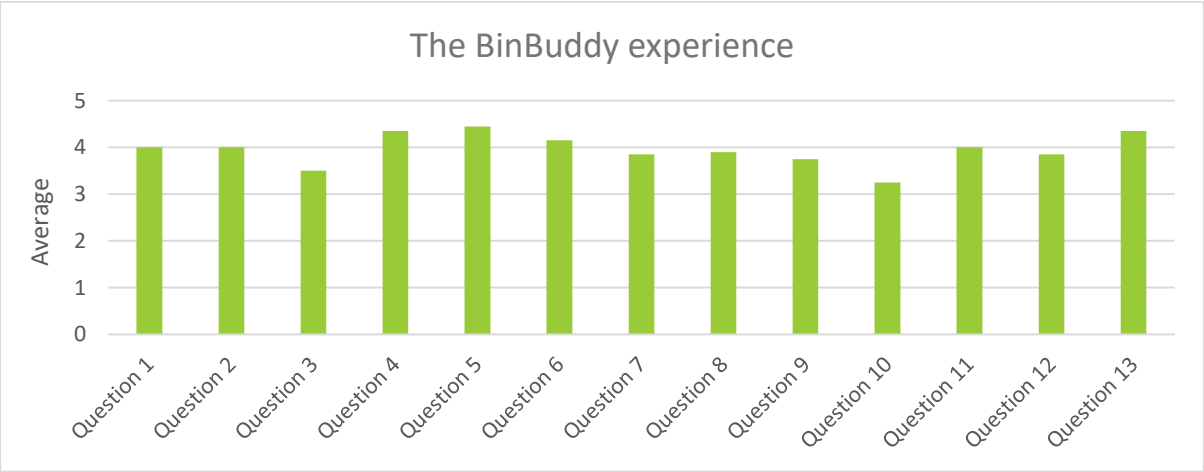


Figure 39: Bar Chart graph depicting the average answer per question in the survey.

The bar chart depicting the survey results reveals a largely positive response across the majority of questions. Participants expressed that the installation was visually appealing and cohesive, effectively capturing their attention and encouraging interaction. However, it is worth noting that Question 3 and Question 10 received lower scores.

One possible explanation for the lower score on Question 3 is related to the feedback mechanism provided to participants. Although immediate feedback was intended, technical issues such as screen bugs and delayed or premature responses from the system may have caused confusion among some participants. As a result, the timing of the feedback might have differed from their expectations, potentially impacting their overall experience. Regarding Question 10, the confusion expressed by some participants during the survey completion suggests that the question itself may have been unclear. Although efforts were made to address the confusion by providing explanations, it is possible that the initial confusion still influenced their answers.

7.3.2 Interview Results

The interview part of the evaluation process was designed to be relatively open, allowing participants to express their thoughts freely. It comprised three questions, and participants were encouraged to provide their best possible answers. Table 10 displays the questions and their goals.

Number	Question	Question goal
1	How do you think the installation effected your motivation to separate waste in the short term?	This question seeks to grasp the participants' initial (short-term) observations about the installation and how it impacts their motivation immediately after interacting with it.
2	How do you think the installation will affect your motivation to separate waste in the long term?	This question aims to grasp how participants perceive the product when encountering it daily as the typical trash bin on campus. How would this scenario influence their motivation?
3	How do you feel your knowledge is about waste separation after interacting with the installation?	This question aims to determine whether participants' knowledge about waste separation improved after interacting with the installation. Participants are encouraged to share their opinions on the video showcasing commonly

		unknown items and whether they learned anything from it.

Table 10: Interview Questions and their Goals

The interview, just like the survey took place over two days, with adjustments made to the prototype based on the evaluations from day 1. The refined prototype was then tested on day 2.

Following the interviews, the answers were categorized to comprehensively understand the outcomes. Each positive answer was assigned a score of 1. Negative answers received a score of 0, and neutral responses that often also provided suggestions for improvement were categorized as 0.5. The average score was subsequently calculated, and the findings were visually presented in two graphs, as shown in Figure 40 and Figure 41.

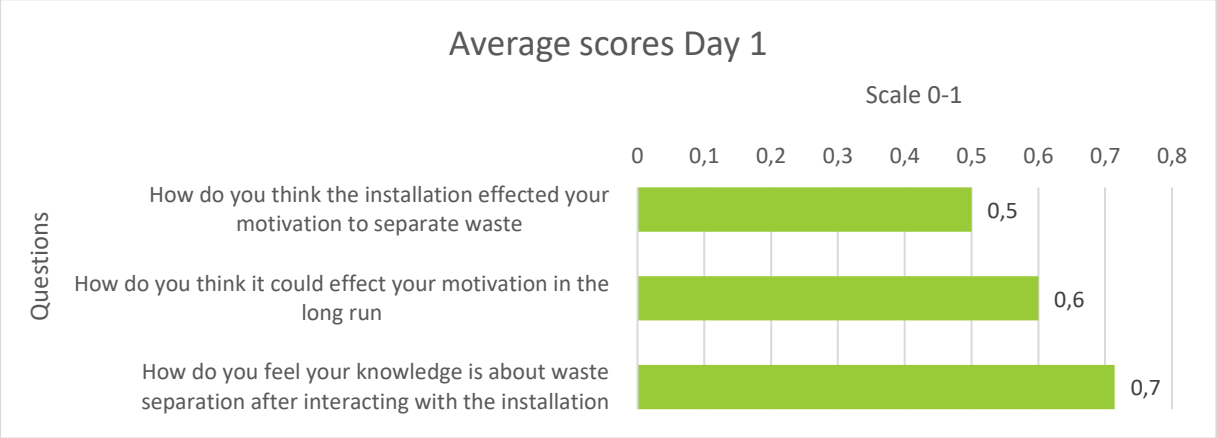


Figure 40: Average Interview Scores Day 1

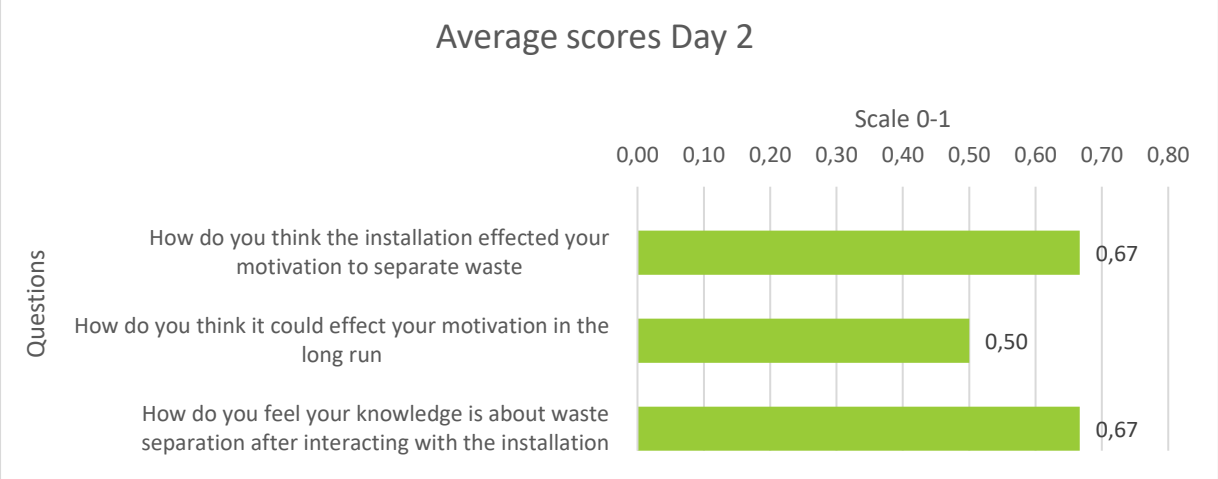


Figure 41: Average Interview Scores Day 2

7.3.2.1 Short term and Long term Motivation

The outcomes from day 1 provided valuable insights into the prototype, highlighting certain faults that were overlooked during its creation. Examining the scores for each question, it became evident that the immediate motivation experienced by participants after interacting with the installation received a score of 0.5. It is important to note that motivation and influence are generally long-term processes, so this score can be considered mediocre. Similarly, when participants were asked about their long-term motivation and how it would be affected, a score of 0.6 was awarded. Many participants expressed that the installation initially made the waste separation process more interesting, but their interest would diminish over time without further interaction.

One aspect that participants enjoyed was the immediate feedback provided by the BinBuddies through sound effects and speech bubbles. However, it was not always clear to the participants which BinBuddy was thanking them, therefore for the second evaluations day, a Confetti visual effect was added as well as the screen was brought closer to the waste islands, and the LEDs were placed on the screen itself, to further emphasize this immediate feedback. With this modification, it was observed that the short-term motivation of participants improved on the second day, resulting in a score of 0.67. However, the scores for long-term motivation still remained relatively low even after the adjustments. Participants explained that they believed these interactions would become "boring" over time or that they would simply become accustomed to them, diminishing their impact. Similar responses were given regarding the BinBuddies themselves. While they were initially appealing avatars, participants felt that more interaction would be necessary to maintain their interest and motivation in the long run.

7.3.2.2 Knowledge

The knowledge aspect of the installation received relatively positive feedback from participants. Prticipants gave high scores for the video elements on the first and second day, with a score of 0.7 on the first day and 0.67 on the second day. The concept of flowing bubbles containing unknown items was well-received. However, there is always room for improvement.

Participants mentioned that the speed at which the video was displayed felt too slow, resulting in a lengthy waiting time for the item they were unsure of to appear. It was suggested that the speed of the video should be increased to provide a more efficient and engaging experience. Furthermore, participants expressed that in the long run, the items displayed should be able to change. Currently, the items can be learned over time, and participants felt that introducing new items as unknown or misclassified would enhance the learning experience and maintain interest and engagement in the installation.

7.3.3 Observations

During the user testing several observations were noted about the interactions of the participants together with the installation:

- Some participants did not notice the screen since they focused on the waste separation act itself.
- Participants felt some pressure to separate waste correctly because of the evaluation setting.
- Participants would often not stand directly in front of the waste bin, which would result in the waste bin not being activated and that would interfere with the responses the BinBuddies provided.
- For people with shorter attention spans, the installation seemed to be harder to keep them focused, especially the video with the unknown waste items.
- Most participants did not notice the “thank you” speech bubble but only the sound and the confetti.
- Some participants did not pay attention to the screen at all and only noticed the sound effects and would notice the screen only after disposing of their waste items.
- Individuals who were simply passing by the installation (not participants) showed interest in the BinBuddies and the video displaying the unknown waste items.

In addition, participants could provide their general remarks and comments both in the survey as well as during the interviews. The following list displays these comments:

- “Staying in front of the waste bin would be a problem if you are just moving by”.

- “The sound accompanying the thank you message was more motivating for me than the actual characters saying thank you. I think this was because it was always notable also if I didn't look at the screen that moment”.
- “The screen was (at the moment) very pixellated and as such was a bit hard to view. My focus was mostly on the trash and the trashcan, it was hard to split my focus in three to also look at the screen, maybe in the case that I have my own trash I would not think about the item I have at hand as much.”
- “The approving sound for all items is confusing. I won't know whether it is right or wrong what I put in where. Also, the LED lights integrated on the side is not really visible when you stand in front of it. It would help more if it is lined on the top.”
- “It would be better to have the installation more integrated into the waste bin as now you will have to look down from the screen and are more focused on the trash. Also, the process of throwing away trash will last longer if you don’t know where you need to throw your stuff and you’ll have to have to wait till the item appears on the screen”.
- “I expected to hear an error sound.”
- “The BinBuddies were not very impactful on the installation for me.”
- “I really like the idea and found the creatures pretty motivating.”
- “It may be harder to catch the attention of people with shorter attention spans/people who are too impatient to wait and see what goes where.
- “The LEDs and the sounds were very nice.”
- “The different images were very interesting; I was able to find many items I wasn’t sure about”.
- “I think the creatures saying thank you make it more interesting and less boring”.

7.4 Non-functional requirements evaluation

Based on the evaluation results, the satisfaction of non-functional requirements can be assessed. Table 11 demonstrates that nearly all requirements have been met successfully. However, requirement number 6 presented some challenges in terms of satisfaction. This can be attributed to several factors previously mentioned. As discussed earlier, motivation, is a complex aspect that can be influenced over the long term, making it difficult to test during the evaluation process, which had a limited duration. Additionally, the motivation scores indicated a positive impact on individuals’ motivation in the short run with the scores increasing from 0.5 for day 1 to 0.67 for day 2. However, for the long-term motivation, the scores slightly decreased from 0.6 on day 1 to 0.5 on day 2. Various suggestions were proposed to enhance this requirement, necessitating careful attention to address the identified issues and improve on them for the future.

Number	Requirement	MoSCoW Priority	Is it met?
1	Be visually appealing such that it attracts users.	Must	Yes
2	Imagery used is clear and understandable for all users	Must	Yes
3	Text is clearly readable and understandable for every user	Must	Yes
4	Use the UT house-style colours.	Must	Yes
5	The images used are coherent and similar in style	Must	Yes
6	Motivate users to separate their waste better	Must	Partly

7	Educate users about waste separation of difficult items	Should	Yes
8	Not have a high or too low scree brightness	Should	Yes

Table 11: Non-Functional Requirements check

7.5 Conclusion

The evaluation process has demonstrated overall success, as the prototype proved capable of influencing participants' motivation to a certain extent and effectively educating them about unknown waste items and proper disposal methods. However, in order to further enhance the prototype's ability to positively impact users' motivation to separate waste, several changes need to be implemented. These improvements are essential for optimizing the prototype's performance and achieving even better results in motivating users toward waste separation.

8 Discussion

After conducting extensive research, as well as completing the realization and evaluation phases of this project, it is essential to discuss the results. Based on the evaluation, it can be concluded that the interactive installation is a moderately successful product. The product was generally well-received, and it has demonstrated its ability to positively influence motivation.

The visual aspects of the installation were particularly effective in capturing users' attention and encouraging better waste separation practices. The BinBuddies feature received positive feedback overall, as participants found the immediate feedback from the BinBuddies to be motivating. Including the unknown items video also yielded positive outcomes, as it improved participants' knowledge about the proper disposal of challenging waste items.

However, it is crucial to note that certain improvements are necessary for this product to achieve long-term success. To better evaluate the effectiveness of the product, it should undergo a series of long-term testing and waste analysis to determine if users' motivation is sustained over time.

By conducting such long-term evaluations, it will be possible to assess the durability of the product's impact and identify areas where further enhancements can be made. This will ultimately contribute to refining the product and ensuring its long-term effectiveness.

9 Future Work

While the interactive installation has demonstrated partial success, there are several areas that can be improved upon: the screen, the interactions, and the evaluation process.

Starting with the screen, it is crucial to address the image quality of the BinBuddies. Currently, integrating videos and multiple images into PyGame[39], the Python library used by Eva Barten for the integration of the visual elements, has resulted in lower-quality pictures. Exploring alternative methods to resolve this issue would be essential to enhance the visual appeal of the BinBuddies. Additionally, based on user feedback, incorporating more animations for the BinBuddies' reactions, such as animations between the changing expressions from sad to happy, would make the emotions more visible and engaging for users.

Regarding the video of waste items, participants indicated that the speed of the video was too slow. Reducing the overall playtime from 30 seconds to roughly 20 seconds would be a viable solution to maintain user engagement while providing sufficient exposure for each item. Alternatively, instead of items simply falling into the trash bin portal, they could circulate the screen, allowing more visibility and creating a better understanding of which items belong in each waste stream bin. Integrating a screen on top of the waste island, where items can stack and unstack every 30 seconds, would also accomplish this goal effectively. Furthermore, expanding the variety of items in the video would be

beneficial and can be achieved by making changes in Adobe After Effects based on a table specifying the playtime of each item. This table can be seen in Appendix VII under Table 12.

From the user evaluations, it was learned that enhancing interaction is crucial to maintain user interest. An example of how to achieve this could be by adding a button on the side of the screen that displays demographics and the overall sustainability progress of the University of Twente. The demographics screen would provide users with a sense of impact and motivation toward waste separation. As this interaction is voluntary, it would not inconvenience users who prefer not to engage with the installation to that extent.

The evaluation process can also be improved. The current power supply of the installation is a laptop, therefore implementing a different power supply, considering the installation's future implementation throughout the University of Twente, is necessary. Conducting a before and after evaluation would be valuable to assess the impact of the prototype on participants' motivation by comparing waste separation evaluations without the installation versus with the installation. Additionally, adding a line guideline on the floor would help ensure that the LEDs remain consistently turned on, addressing issues related to sensor reaction time. Considering the incorporation of more sensors can also contribute to resolving this problem.

By addressing these improvements in the screen, interactions, and evaluation process, the interactive installation can be refined to maximize its impact and long-term success in motivating proper waste separation behavior.

10 Conclusion

CFM-UT, the client for this project, made a discovery regarding the improper waste disposal practices within the UT community. After conducting a comprehensive waste analysis, the results were far from satisfactory. The analysis revealed that the residual waste bin consisted of 32% PMD, 18% organic waste, and 18% paper waste, leaving a mere 32% as actual residual waste. This situation contradicts the sustainability and recycling objectives set by the UT for the future. Consequently, the primary objective of this project was to identify an appropriate solution to address this issue and develop an intervention that would foster improved motivation for waste separation, thereby positively influencing waste separation behavior.

To tackle this issue, a research question was formulated with the objective of finding a solution utilizing interactive media. Extensive background research was conducted, exploring various reasons behind motivational challenges in waste separation and examining theories for improvement. The primary factors identified as obstacles to waste separation motivation were convenience, knowledge, and social setting. It was discovered that positive motivation could be influenced through gamification designs, social nudging, and simplification techniques. Through interviews conducted with the client and several peers, it was confirmed that these three challenges were indeed valid. Although the client had proposed some solutions to address certain aspects of these problems, they had not proven to be as effective as desired. Drawing inspiration from both the client's existing solutions and state of the art, the ideation phase of this project was guided.

During the ideation phase, the stakeholders were identified, and their requirements were carefully considered. Building upon these requirements, a brainstorming session was conducted, leading to the generation of the final idea. The ultimate concept entailed the creation of a screen as an extension of the existing waste islands. This screen would showcase four unique creatures known as the BinBuddies, each representing an avatar for a waste stream. Below each creature, a video featuring waste items is played. The purpose of this installation is to enhance the waste separation process at the UT by fostering motivation among the UT community while subtly educating them about waste separation.

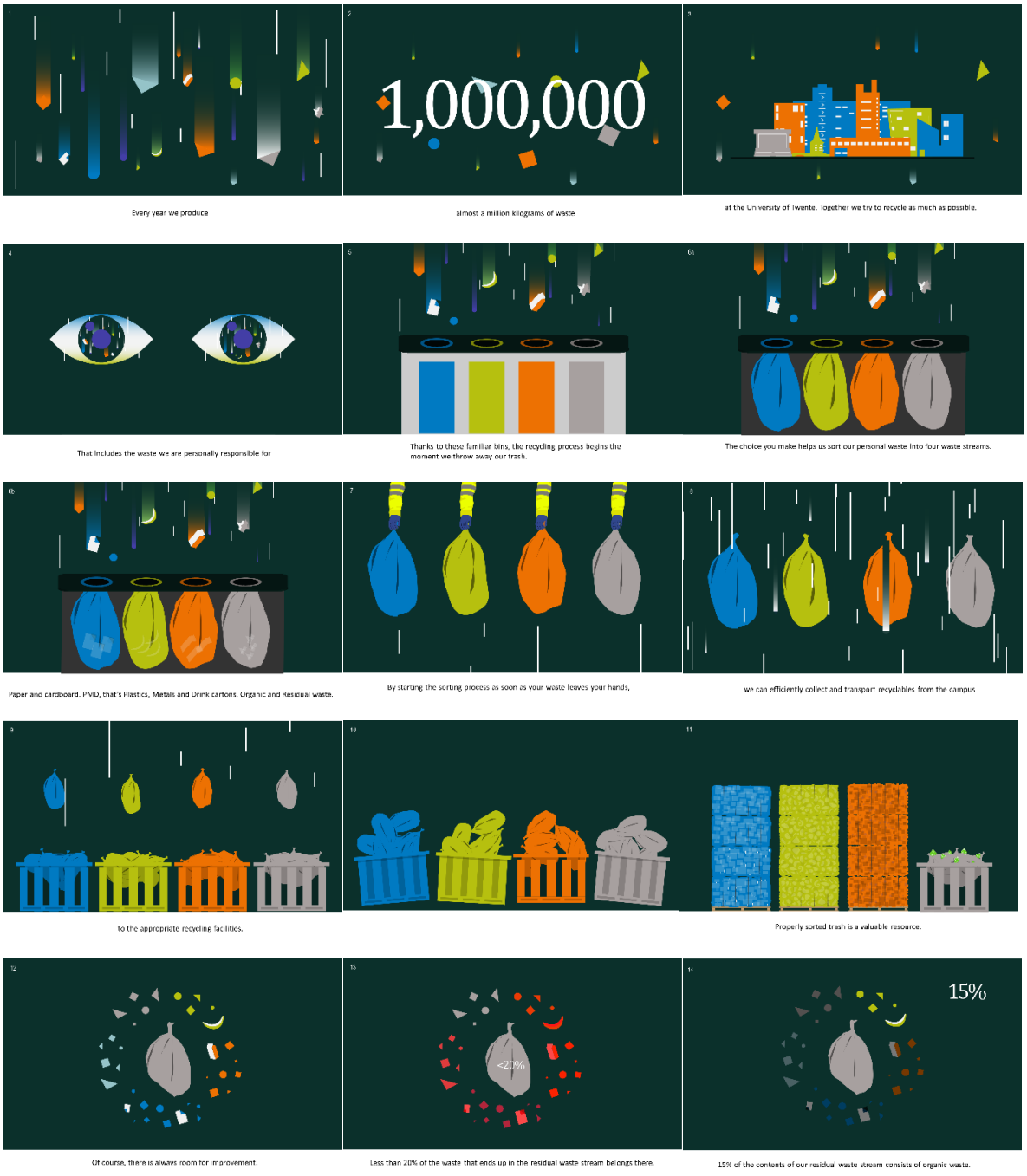
During the realization phase, two primary components of the installation were identified: the visual aspects and the nudging aspects. With these components in mind, steps were undertaken to bring the prototype to life, documenting each stage to ensure the reproducibility of the project. A functional prototype was developed and subsequently tested to verify the fulfillment of all requirements.

During the evaluation phase, the prototype was tested with the assistance of voluntary participants. These participants were given the opportunity to test the prototype using provided waste materials and were asked to respond to interview questions and complete a survey. The evaluation process revealed that the product, overall, achieved initial success but would require further refinement to ensure long-term effectiveness. Feedback from the evaluation indicated that the knowledge aspect of the prototype was highly appreciated by the participants. However, the motivational aspect would benefit from further revisions and enhancements to better engage and inspire users. The evaluation results provided valuable insights, highlighting areas for improvement and guiding the direction for future development of the product.

Ultimately, the research question "How can interactive media be employed to influence the motivation of the UT community towards proper waste separation at the UT campus?" can be addressed as follows: By combining the existing waste islands with interactive media on the screen, users are effectively motivated to separate their waste correctly. Furthermore, the video and smart visuals increase individuals' understanding of commonly unknown waste items, thus encouraging proper waste disposal behavior. Additionally, the product has the ability to influence motivation even when users are not actively interacting with it but rather by merely observing the installation. This passive engagement enhances users' knowledge and, in turn, their motivation to participate in proper waste separation practices.

Appendix I

GreenHub animated Video storyboards.



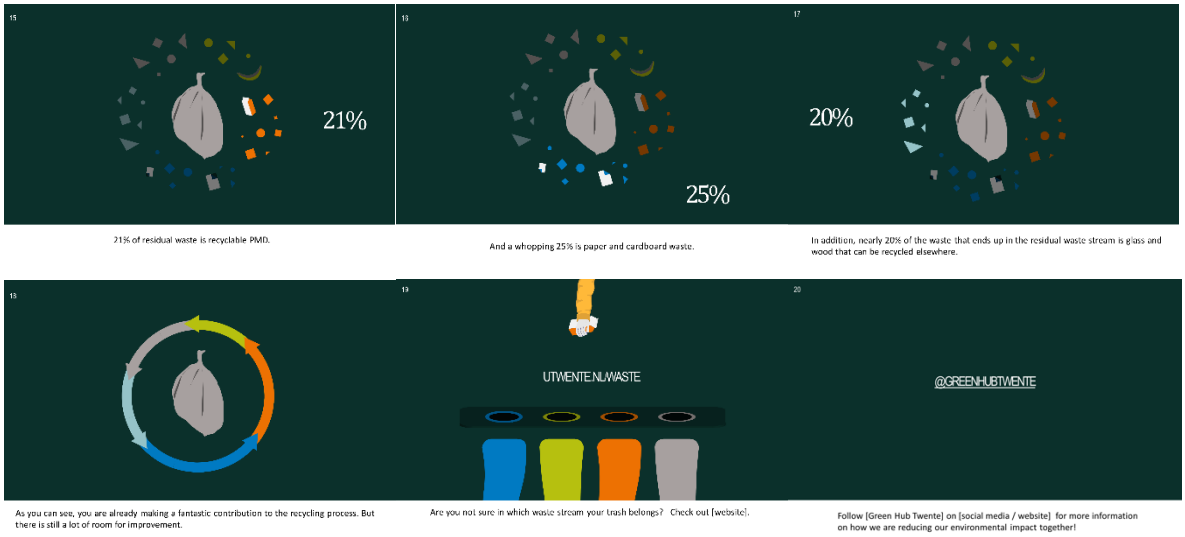


Figure 42: GreenHub Twente Animation Story Boards

Appendix II

GreenHub Information Posters.

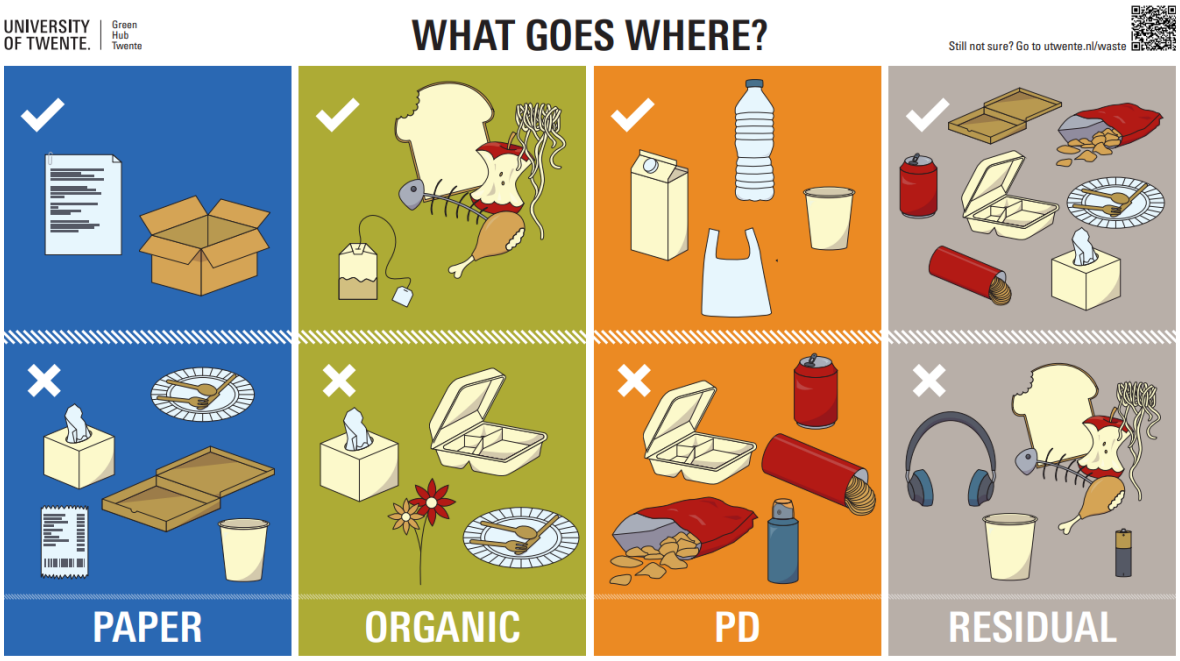


Figure 43: GreenHub Poster with pictures

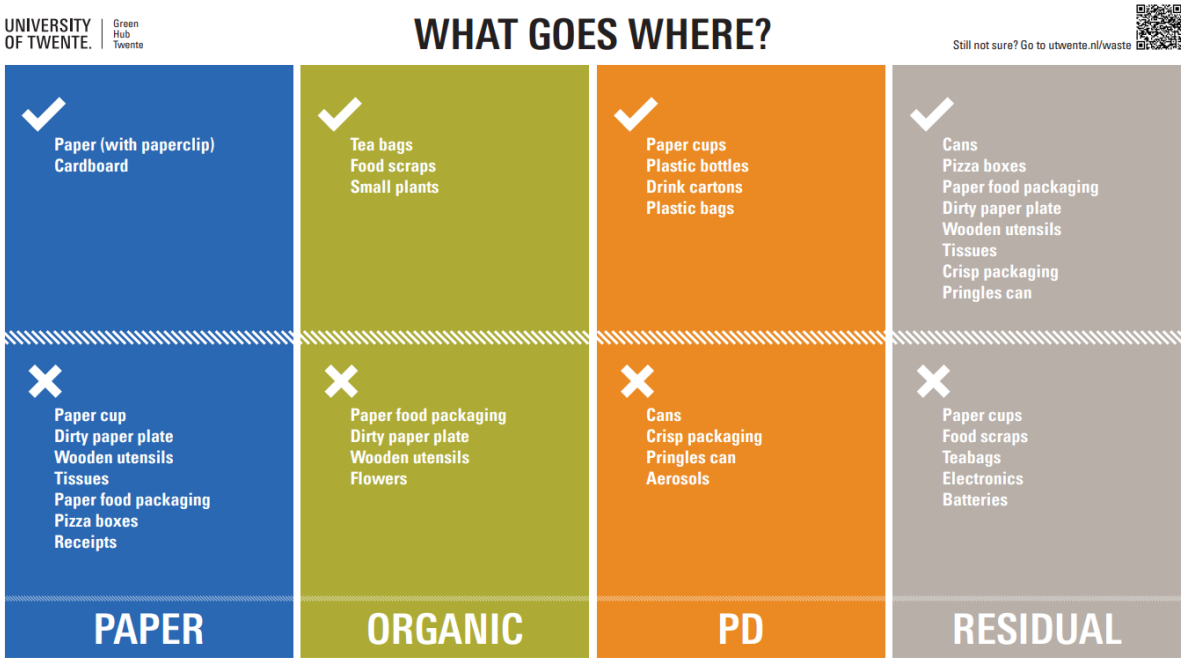


Figure 44: GreenHub Poster with Word

Appendix III

Final Product storyboards.

Product is seen, no waste is disposed.

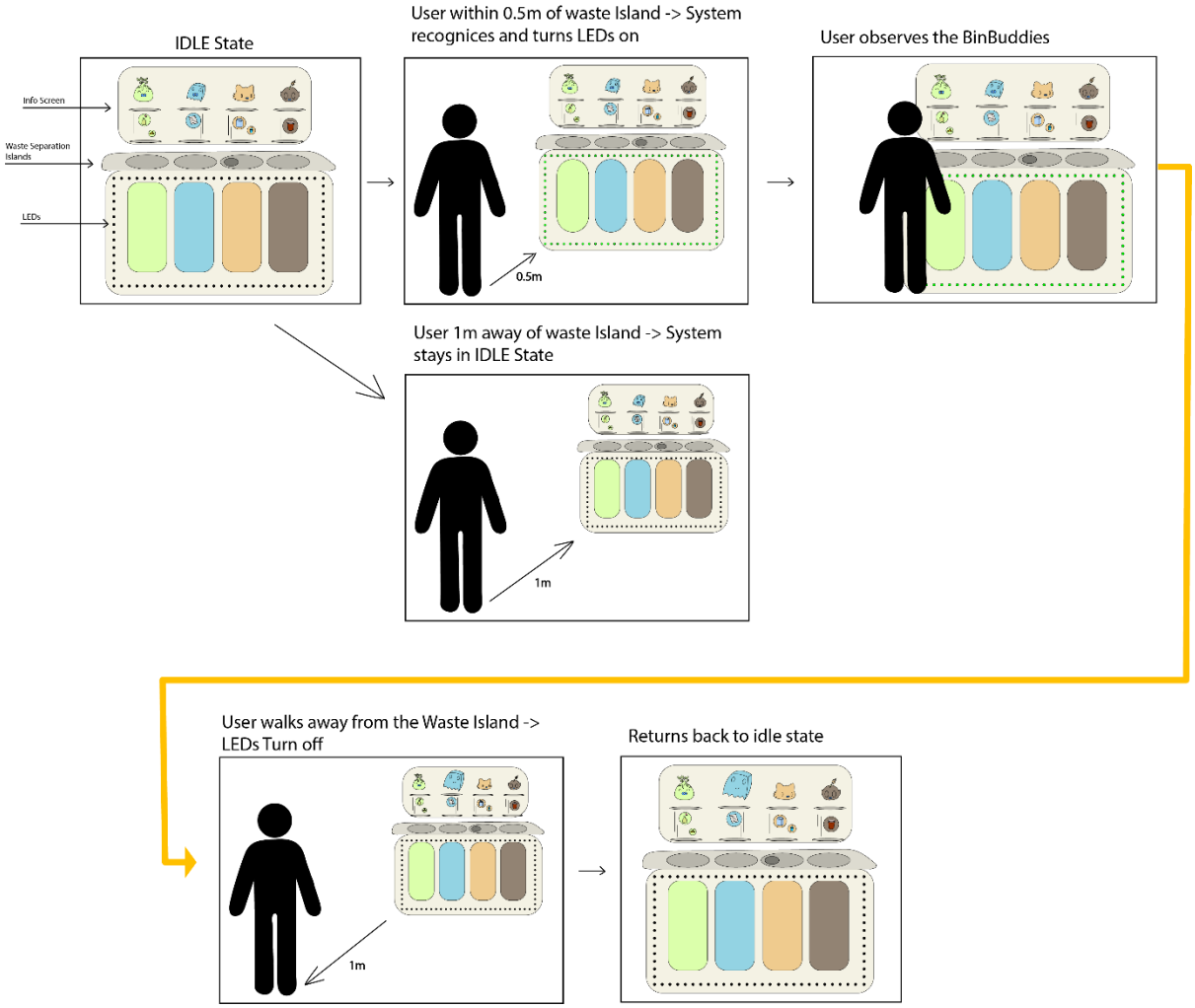


Figure 45: Storyboard Interaction 2

Product is overlooked, waste is disposed.

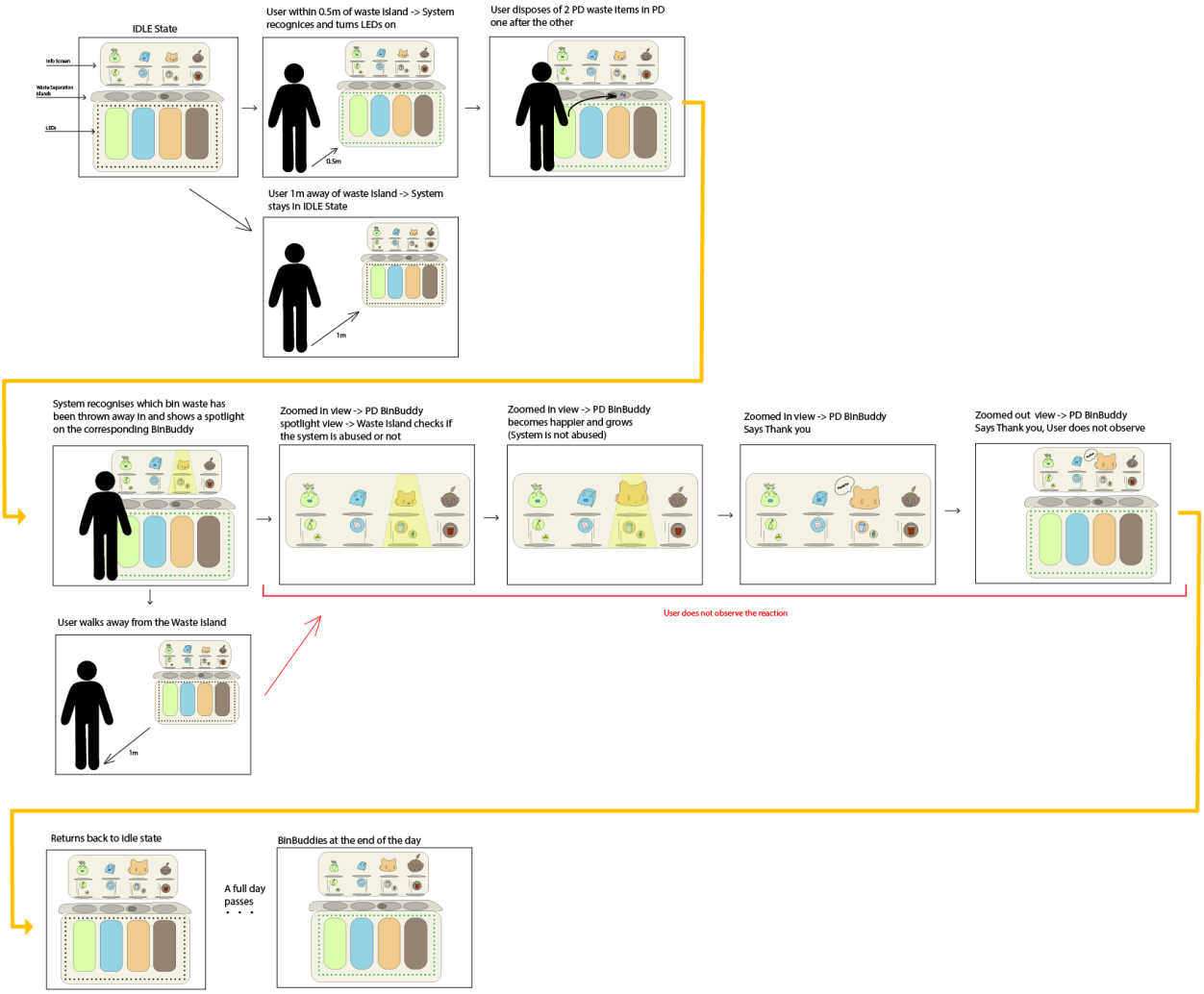


Figure 46: Storyboard Interaction 3

Product is seen, product is abused.

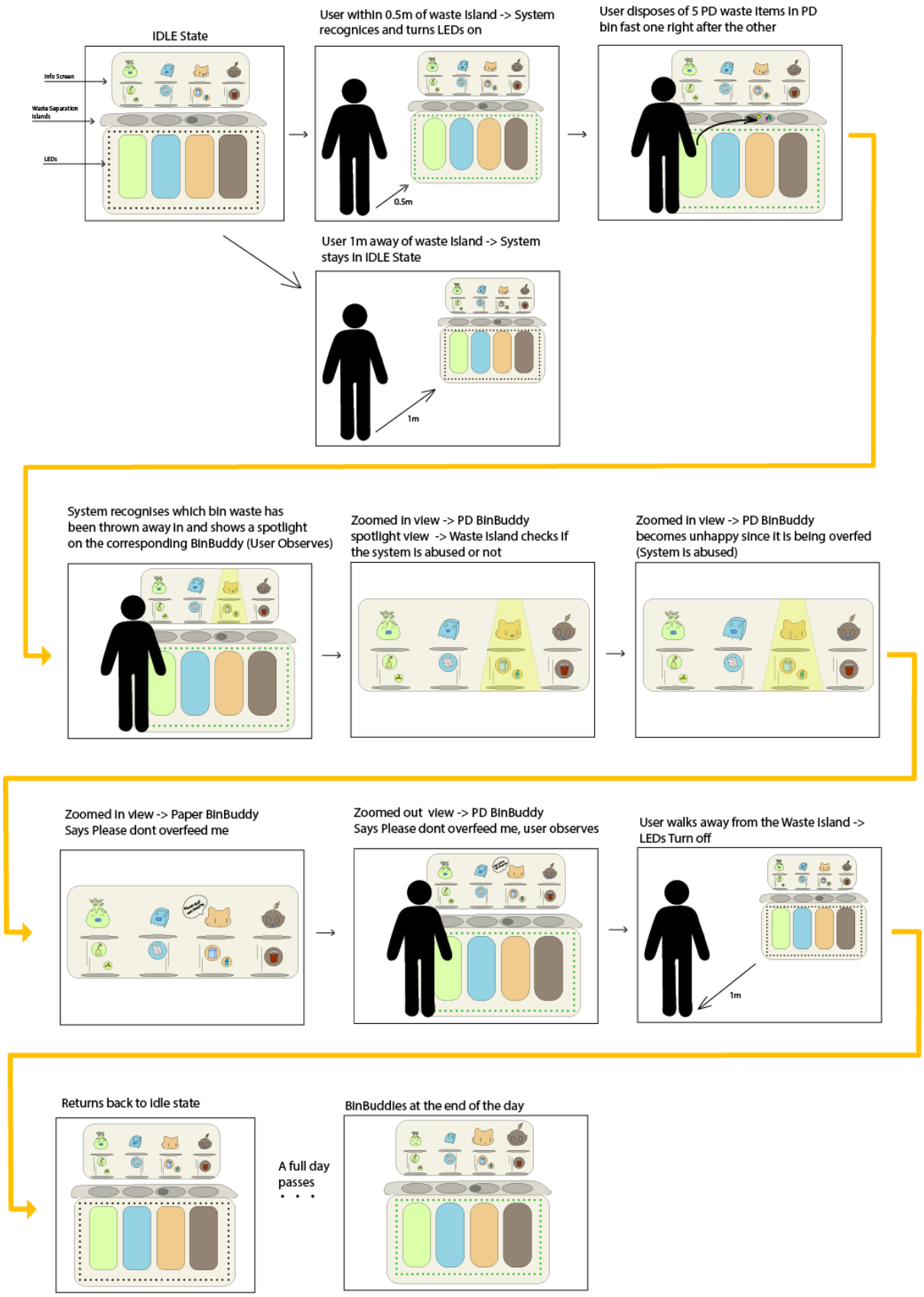


Figure 47: Storyboard Interaction 4

Appendix IV

The different facial expressions of each BinBuddy.

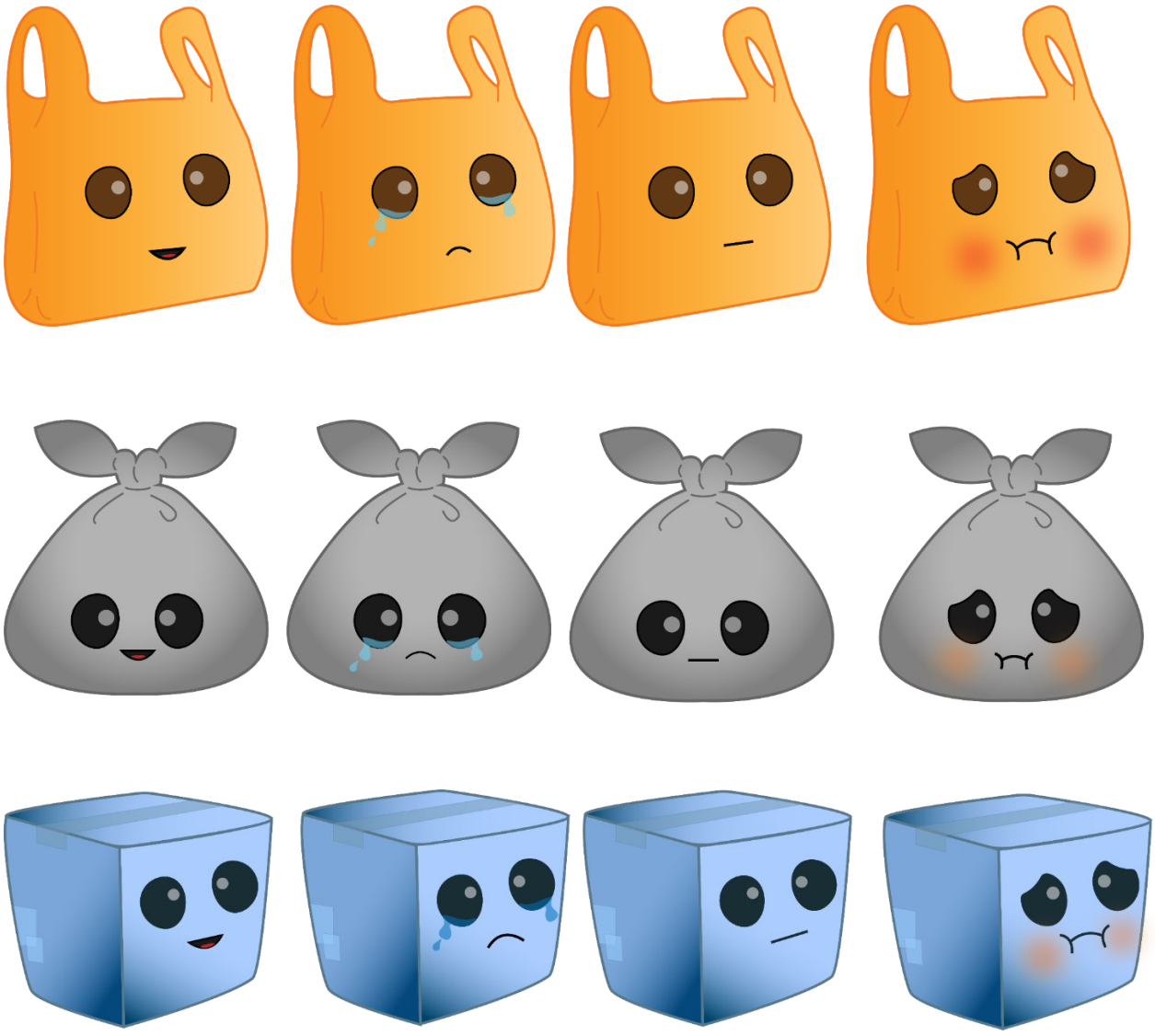


Figure 48: BinBuddies facial expressions

Appendix V

Information Brochure for Graduation Project on Waste Separation

Institution: University of Twente

Researcher information: Marina Stefanova: m.t.stefanova@student.utwente.nl & Eva Barten: e.d.f.barten@student.utwente.nl

Supervisors: Kasia Zalewska: k.zalewskakurek@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 Campus

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 are asked to test the prototype created for the final product of the Graduation Project of the researchers. You will be given a task to separate several different waste items (such as a plastic bottle, a coffee cup, an empty chips bag, a piece of paper, a napkin, empty salad box, empty sandwich bags, a banana peel, a tea bag etc.). The waste items will be cleaned prior to the user testing. To fully simulate day to day waste, clean items will be labelled “dirty” with a posted note. For those items you are asked to imagine them as being dirty and separate accordingly. Afterwards a short survey is provided to you for which you will be asked to fill out. Several questions will be asked regarding your impression and experience with the installation. A small unstructured interview will also be performed on the same topics and will be Audio recorder and transcribed into text afterwards. After the transcription the audio file will be deleted. For this research there will be no personal data used and all the recorded data will be anonymised. During the user testing, the researchers may take notes on how the participants interact with the installation and dispose of their waste, as well as perceived easiness or difficulties with separating the provided trash. You can withdraw from the research at any moment, as well as request for your data to not be used in the research. If at any point you feel uncomfortable during the research, please inform on of the researchers and the session will be stopped.

Duration: Approximately 15-20 minutes

Risks: Participants must attend the user testing session in person at the University of Twente. During the user testing we will prioritize the health and safety of all participants.

Confidentiality: Participants are not obligated to provide any personal information. The research findings will be reported in a thesis using anonymized and aggregated data. If you wish for your data to be excluded from the research, you can request at any time during the research. The contact information to make such a request is provided in this brochure, as well as in the consent form.

Appendix VI

Consent Form for Improving Waste Separation at the UT

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to take part in the user testing, interview 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 and a 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 which will be collected is saved 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.	○	○
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 for the data that I provide 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:

Marina Stefanova

m.t.stefanova@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 VII

Table displaying the animation times for when each picture is displayed on the video of unknown items.

Time	Paper	Organic	PD	Residual
0 - 5	Cardboard_1	Coffee_1	Pd_Cup_1	Chips_1
3 - 8	Clip_1	Pods_1	Milk_1	Cola_1
6 - 11	Paper_1	Soup_1	Pd_Container_1	Flowers_1
9 - 14	Cardboard_2	Salad_1	Bottle_1	Zip-Bag_1
12 -17	Clip_2	Tea_Bag_1	Plastic_foil_1	Face_mask_1
15 - 20	Paper_2	Coffee_2	Salad_Box_1	Wooden_Cutlery_1
18 - 23	Cardboard_3	Pods_2	Paper_Cup_1	Pen_1
21 - 26	Clip_3	Soup_2	Candy_1	Receipt_1
24 - 29	Paper_3	Salad_2	PD_Cup_2	Food_Container_1
27 - 32	Cardboard_4	Tea_Bag_2	Milk_2	Pringles_1
30 - 35	Clip_4	Coffee_3	PD_Box_2	Metal_foil_1
33 - 38	paper_4	Pods_3	Bottle_2	Dirty_Napkin_1
36 - 41	Cardboard_5	Soup_3	Foil_2	Paper_Plastic_1

Table 12: Animation Times and Pictures display

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