CREATIVE TECHNOLOGY BACHELOR THESIS

UT Community Members' Education on Proper Waste Separation on Campus

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Abstract

Waste analysis conducted by Campus Facility Management (CFM) shows that only 32% of residual waste was separated correctly despite the campus having waste islands with four different waste streams: paper, organic, PMD, and residual. Therefore, education about proper waste separation in the waste islands of the University of Twente (UT) community members is necessary.

A Waste Separation Guide Service (WSGS) was designed to create a behavioural intervention based on education in the waste separation context. By selecting a button on the screen, the user acquires information on proper waste separation. The user guidance is related to the requirements for each waste stream (paper, organic, PMD, residual), the desired situation of each waste stream, and the waste management process after waste disposal. The user can select the "I am not sure" button when the user is unsure about each waste stream. The user gets questions which lead to a correct waste stream suggestion based on the user's answer.

Client evaluation showed that CFM was generally satisfied with the design and usability. User testing results with UT community members indicated that WSGS could be used as an informative solution to educate the users not only to guide the correct waste stream but also to inform why the waste should be in that specific waste stream. Hence, WSGS could help educate UT community members on proper waste separation on campus through contextual information delivery, meaningful interaction, and easy access.

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Finding a solution to improving waste separation on the UT campus was challenging. Still, it was worth tackling as I am also part of the UT community, and my friends and professors are part of it as well. Thus, the problem had more relevance to me. I express my deepest gratitude to the CFM, mainly Birgit Dragstra, UT's environment & sustainability officer. Without her support and help, I would be unable to finish the project. Her passion for improving sustainability around the UT campus impacted and inspired me.

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Table of Contents

Abstract 1
Acknowledgement 2
Table of Contents 3
List of figures and tables 6
1. Introduction 8
  1.1. Situation 8
  1.2. Challenge 9
  1.3. Outline 11
2. Background Research 12
  2.1. Definition of Pro-environmental Behaviour 12
  2.2. Determinants of Creating Behavioural Intervention of Proper Recycling Behaviour 13
  2.3. Behaviour Intervention Insights 15
  2.4. Behaviour Intervention Techniques 17
  2.5. State of the Art 18
  2.6. Discussion and Conclusion of Background Research 24
3. Methods and Techniques 28
  3.1. Ideation 28
  3.2. Specification 31
  3.3. Realisation 31
  3.4. Evaluation 31
4. Ideation 33
  4.1. Stakeholder Needs and Requirements Definition 33
    4.1.1. Stakeholder Identification and Analysis 33
      4.1.1.1. CFM (Campus Facility Management) 33
      4.1.1.2. UT Community Members 34
      4.1.1.3. Prezero 41
      4.1.1.4. Designer 41
      4.1.1.5. Supervisors 42
    4.1.2. Power versus Interest Grid 42
    4.1.3. Preliminary Requirements 43
  4.2. Preliminary Concepts 46
    4.2.1. Self-scanner of Waste (C1) 47
    4.2.2. Decision Tree of Waste Separation (C2) 48
    4.2.3. Motivate People Each Other (C3) 49
    4.2.4. Chatbot guiding Waste Separation (C4) 50

4.2.5. AR application that guides possible waste on each waste stream (C5) 51
4.3. Final Concept Decision 52
4.3.1. Concept Selection Process 52
4.3.2. Concept Finalisation Process 54
5. Specification 56
5.1. Personas 56
5.1.1. Persona 1: Dutch Student 57
5.1.2. Persona 2: International Student 58
5.1.3. Persona 3: Assistant Professor 59
5.2 Visualisation Requirements 59
5.2.1 Functional Requirements 60
5.2.1.1. Waste stream analysis 63
5.2.2 Non-functional Requirements 68
5.3. Storyboard 69
5.4. Visual Components 73
6. Realisation 74
6.1. Tools 74
6.2. Prototype 74
6.2.1. Working Process 74
6.2.2. User Interface Design 76
6.2.3. User Interaction Design 82
6.3. Evaluating Prototype based on Functional Requirements 82
6.3.1. Suggested Changes to the Prototype 85
7. Evaluation 86
7.1. Client evaluation 86
7.1.1. Evaluation Set up 86
7.1.2. Evaluation Results 86
7.2. User Testing with the UT Community Members 87
7.1.1. Evaluation Set up 87
7.1.2. Evaluation Results 88
7.3. Evaluation based on Non-functional Requirements 89
7.4. Evaluation Conclusion 91
8. Discussion 92
8.1. Discussion 92
8.2. Limitations 93
8.3. Recommendations 93

8.4. Prototype Improvement 94
9. Conclusion 95
Appendices 98
Appendix A: Questions for determining proper BCT 98
Appendix B: BCT evaluation 99
Appendix C: Example Waste List regarding four waste streams, provided by CFM, confirmed by Prezero (updated 17-06-2022) 102
Appendix D: Observation session interview questions 104
Appendix E: Storyboard of WSGS 105
Appendix F: User Interaction Design overview of WSGS 106
Appendix G: Semi-structured interview questions for CFM meeting 107
Appendix H: Survey questions for the UT community members 108
Appendix I: Observation Session Note Structure 111
Appendix J: Informed Consent Form 112
Appendix K. Waste disposal results after the use of WSGS 115
References 117

List of figures and tables

Figure 1. Waste streams at UT 9
Figure 2. EvoEco: measure the weight of the waste and show the infographic. 19
Figure 3. Twente Milieu app: provide waste calendar, reminder, report, and correct waste separation method. 19
Figure 4. Waste island with a sticker in the library at UT 20
Figure 5. Bin-e: contactless automated waste segregation bin with an app that tracks the bin's waste. 20
Figure 6. Tetra-bin: a street-side waste bin that motivates people to put their waste in the bin instead of littering on the street 21
Figure 7. Mamamatiks: a vending machine which releases food for stray animals when people recycle plastic bottles 22
Figure 8. Examples of voting bins. (a) voting bin to recycle plastic bottles, Wecup; (b) voting bin to recycle cigarettes, Hubbub 23
Figure 9. Smiley bins by Envirobin 23
Figure 10., Examples of recycling usint incentives. (a) McDonald’s Stockholm Recycling Campaign; (b), recycling vending machines, Enviroank; (c) deposit vending machines for plastic bottles in the Netherlands 24
Figure 11. Creative Technology design process 28
Figure 12. Power versus interest grid 30
Figure 13. Waste island with a sticker in the library 36
Figure 14. Power versus interest grid of improving waste separation on Campus project 42
Figure 15. Mind map to help concept generation 46
Figure 16. Behaviour intervention process through knowledge 46
Figure 17. self-scanner of waste (C1) 47
Figure 18. Decision tree for waste separation (C2) 48
Figure 19. The screen shows the possible wastes that are thrown away in a particular bin, and the video that people throwing away the correct waste in the bin (C3) 49
Figure 20. Chatbot guiding waste separation (C4) 50
Figure 21. AR application that guides possible waste on each waste stream (C5) 51
Figure 22. Chosen concept: decision tree with a selection of waste 53
Figure 23. Finalised concept: Interactive screen that asks questions about waste and guides proper waste separation 54
Figure 24. User persona: Dutch student Karolina 57
Figure 25. User persona: International student: Michael 58
Figure 26. User persona: Assistant professor 59
Figure 27. Weggooiwijzer symbols 67
Figure 28. Decision tree for waste separation guiding questions 68
Figure 29. (From left) Scene 1: waste created at lunch, Scene 2: Select the 'press me' button on the screen 70
Figure 30. (From Left) Scene 3: select wooden cutlery in the residual waste section, Scene 4: requirements of the residual waste stream and the recycling process after waste disposal, Scene 5: dispose of waste in the residual waste bin 70
Figure 31. Scene 6: select the PMD waste stream in the PMD waste section, Scene 7: display information regarding PMD waste, S8: find symbol in the yogurt pack, S9: dispose of the yogurt pack in the PMD bin 71
Figure 32. Scene 10: select the “Click if you are not sure” button. Scene 11: First question: does it have symbols? Scene 12: Second question: Is it related to eating food? Scene 13: Third question: Which type of waste is it? Scene 14: display information regarding organic waste, Scene 15: dispose of the waste in the organic waste bin, Scene 16: finish waste disposal with support of WSGS 72

Figure 33. Colour palette of the prototype......73
Figure 34. design cycle of the prototype 74
Figure 35. Initial main screen design......75
Figure 36. Initial question screen design 76
Figure 37. Main selection screen design......77
Figure 38. (Left) Waste stream requirements of the residual waste stream, (Right) bubble describing the requirement detail. 78
Figure 39. (Left) After the waste management process of the residual waste stream, (right) UT's goal regarding the residual waste stream......79
Figure 40. "I am not sure" button first question: "Is your waste related to food?"......79
Figure 41. "I am not sure" button second question: "Is your waste...? Food packaging, disposable products, or food leftover 80
Figure 42. "I am not sure" button third question: Is your packaging waste...? Tetra pack, can, sauce, sugar packaging, chips bag, pringles can, plastic bottle, containers, yoghurt packaging, candy bard, small snacks, or none of them. 80
Figure 43. The final screen of "I am not sure button": (a) PMD Waste stream; (b) recycling process of PMD waste stream; (c) UT's goal regarding PMD waste stream 81
Figure 44. Result screen in case the user selects "None of them". 81
Figure 45. Animation of the user interaction of WSGS 82
Figure 46. (Left)User testing setup in Technohal, (Right) Tablet(iPad) for user testing 87
Figure 47. Content evaluation of WSGS 88
Figure 48. Usability evaluation of WSGS 89

Table 1. CFM (Campus Facility Management)'s expectations and preliminary user requirements......34
Table 2. Ideas discussed during focus group discussions......38
Table 3. UT community members' expectations and preliminary user requirements 40
Table 4. Prezero's expectations and preliminary user requirement 41
Table 5. Designer's expectation and preliminary user requirement......42
Table 6. Supervisors' expectation and preliminary user requirement......42
Table 7. User requirements of the project......44
Table 8. Advantages and disadvantages of three concepts with preliminary requirements fulfilment 52
Table 9. Functional requirements of WSGS......60
Table 10. Non-functional requirements of WSGS 69
Table 11. Functional requirements fulfilment 83
Table 12. Non-functional requirements fulfilment......90

1. Introduction

1.1. Situation

For several years, various efforts have been made to mitigate the effects of global warming across countries. For example, the Paris agreement in 2016 was made, which urged global corporations to reduce greenhouse gases to avoid fatal climate change by limiting global warming to well below two °C and pursuing efforts to limit it to 1.5°C [1]. To meet the goal of the Paris agreement, the European Union (EU) set the goal to lower greenhouse gas emissions by at least 55% by 2030 to become climate neutral by 2050 [2]. The Dutch government also aimed to reduce the Netherlands' greenhouse gas emissions by 49% by 2030[3].

There are several approaches to lessen the effect of the climate crisis. Waste separation is one of the essential strategies for decelerating climate change, as proper waste separation decreases carbon emissions generated by landfills. An increase in waste separation enables fast landfill recovery, thereby slowing down the effects of climate change [4]. Thus, increasing the recycling rate is essential to slow the effects of climate change.

EU's target for recycling is at least 55% of municipal waste by 2025 and 60% by 2030 [5]. The Netherlands is also one of the leading countries regarding the recycling rate. According to European Environment Policy, 57% of waste was recycled in the Netherlands in 2019, the 5th highest in the EU [6]. However, the recycling rate in the Netherlands from 2004 to 2016 only increased by 6% [7]. If this tendency remains, it is less likely to achieve 60%, which is the goal of the EU. Therefore, various actions should be started to tackle the waste separation issue.

Improving waste separation has been a goal of several institutions in the Netherlands. For instance, the University of Twente (UT) has created waste disposal places at central locations in different buildings to separate waste in and around offices and teaching rooms. Campus Facility Management (CFM) named this waste separation place waste islands. There are four waste bins in the waste islands: Paper, PMD (plastic, metal, and drink containers), Fruit & Vegetable waste, and Residual waste. The waste bag in each waste island is gathered by an external company [8], and the waste bin content is either recycled or used for energy generation [9]. Waste islands are used to create a circular ecosystem on campus.

After placing waste islands in several buildings, more sustainability actions with the UT community have been proposed by Shaping 2030 [10]. It states that the UT targets to reduce carbon footprint by at least 15% by implementing sustainable solutions on campus in food, water, waste, travel, and energy use [10]. The 2021 UT waste plan [11] was made as part of the SEE (Sustainability, Energy &

Environment) Programme [12]. The main goal of this waste plan is “to prevent, reduce, and improve waste (recycling)” [11, p.4]. The waste plan also describes the current waste disposal situation at UT. Waste analysis conducted by CFM in January 2020 showed that only 32% of the collected residual waste on campus was disposed of correctly; the remaining 68% was paper, organic or PMD waste [11]. Waste analysis of collected PMD waste showed that only 77,8% was disposed of correctly; the remaining 22,2% was paper, organic, or residual waste [11]. This result indicates that UT needs to find a way to encourage people to separate their waste in the correct bin of the waste islands to increase recycling rates. Figure 1 [9] shows the UT waste stream in 2019.

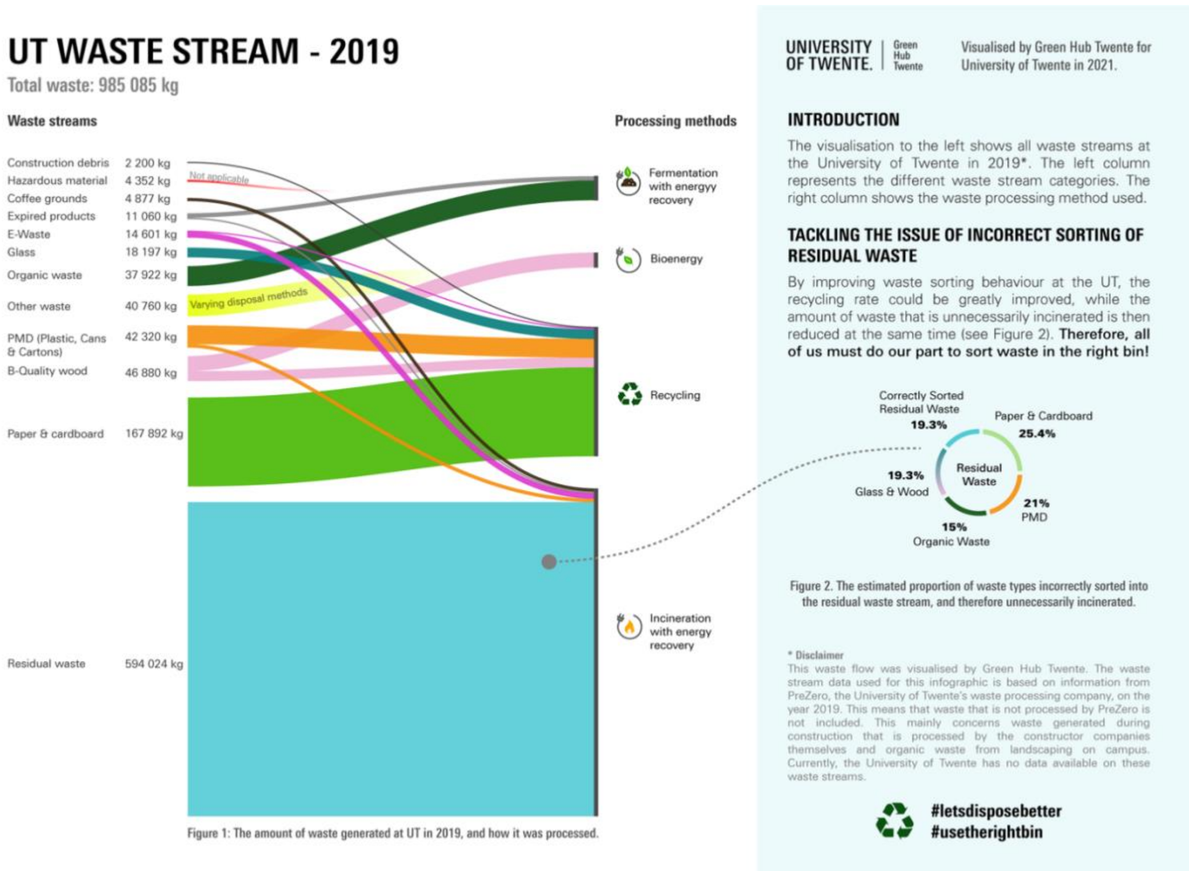

Figure 1. *Waste streams at UT*

1.2. Challenge

The main problem is that information about correct waste separation is not adequately delivered in the context of waste disposal in front of the waste islands. First, waste management contractors of student housing and campus are different. The first one is the Twente Milieu[1], and the second one is Prezero[2]. Most people are not aware of it, and they are separating waste according to the rules they follow in households. However, the waste on campus and at home is different, as waste created in the university is considered industrial waste. It creates confusion when people need to look for the correct information. Secondly, searching for the correct waste separation information takes too much time. On the university website [9], it is not elaborated in detail. Suppose they search for the information either on Twente Milieu or Prezero. In that case, they provide only static information that needs to be actively translated by a user, which creates additional steps and time. In addition, some waste bins have a sticker providing the information in text. It is difficult to catch up with the information within a few seconds, which is the usual waste separation moment. The inconvenience of accessing information and the unclarity of information on the waste island bins creates idleness of getting correct information about proper waste separation and throwing waste in the residual waste bin. Improving waste separation is vital to accomplishing the goal of the waste plan. Therefore, the challenge would be providing the correct information to people and stimulating the continuation of proper waste disposal. Based on the challenge, the main research question for this research is:

RQ: "How to educate UT community members to separate their waste properly in the UT waste islands?"

Several facets should be examined to find a detailed answer to the above question. First, the definition of pro-environmental behaviour should be discussed to determine the origin of recycling behaviour. Next, the determinants for the behaviour of proper waste disposal should be taken into consideration. These factors will give various insights into how the user of the UT waste islands could be influenced to do appropriate waste disposal behaviour. This entails the first sub-question:

Sub-RQ 1: "What factors form pro-environmental behaviour, specifically recycling behaviour?"

Furthermore, the information provision (behaviour intervention) is essential to elicit proper waste disposal behaviour at the UT waste islands. Hence, the second sub-question is focused on the delivery of information (behaviour intervention) in the context of waste disposal behaviour:

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[1] https://www.twentemilieu.nl/ (Last visited 13-09-2021)

[2] https://www.prezero.nl/ (Last visited 13-09-2021)

Sub-RQ 2: “What behaviour interventions are used to effectively deliver the instruction to the people when separating their waste?”

Thirdly, this research will focus on the mode of information delivery (behavioural intervention). Delivery of the correct information with the accurate method through various means. Hence, adequate delivery of information in the context of waste disposal in the UT waste islands will be done by answering the third sub-question, which is also considered a design question:

Sub-RQ 3: “What ICT-based behavioural intervention could be used to educate the UT community to separate their waste properly at the UT waste islands?”

Answering the sub-questions will ultimately form the multifaceted answer to the main research question. This answer will be used to create an ICT-based solution that will educate UT community members about proper waste separation in the context of waste disposal in front of the UT waste islands.

1.3. Outline

This research is composed of nine chapters. The first chapter introduces the problem in the paper's context, challenge, and primary goal with research questions. The second chapter investigates the related literature and projects by literature review and state of the art. The third chapter introduces the methods and techniques used in this research. The fourth chapter is the ideation phase which focuses on the preliminary requirements and idea generation. The fifth chapter is the specification phase, which elaborates on a final concept with functional and non-functional requirements. In the sixth chapter, a prototype is built with conditions decided in the previous chapter. The seventh chapter describes the evaluation by stakeholders and evaluates whether requirements are met. The eighth chapter discusses the implication of the research results, limitations, and recommendations. The final chapter concludes the entire research.

2. Background Research

Various ways of improving waste separation by behavioural intervention should be examined to understand the problem and possible solutions. Therefore, the main goal of this chapter is to give an insight into different behavioural interventions that could affect people separate their waste correctly.

This section is composed of six parts. First, the definition of pro-environmental behaviour will be discussed to profile what characteristics make people pro-environmental. Secondly, the determinants for the behaviour of proper waste disposal will be taken into consideration. Thirdly, how different behaviour interventions can create pro-recycling behaviour will be examined, and insights will be gathered. And then, other behaviour change techniques will be discussed and evaluated based on previous findings. Different solutions for waste disposal will also be investigated through state of the art. Lastly, the conclusion and discussion will be drawn from the background research.

2.1. Definition of Pro-environmental Behaviour

Pro-environmental behaviour is an action that positively impacts the environment because human behaviour has a significant impact on the environment. According to Altan [13], human behaviour is one of the critical factors in global warming. Also, Byerly *et al*. [14] state that individual consumption and lifestyle choices significantly affect climate change. Therefore, changing human behaviour pro-environmentally is essential. Pro-environmental behaviour is defined as reducing the environmental impact in different domains (e.g., energy consumption, water usage, waste reduction, transportation). It is a "deliberate action that can reduce adverse impact upon the environment" [15, p.3]. Pro-environmental behaviour is described, in other words, as pro-ecological behaviours, environmentally significant behaviours, green consumer behaviour, ecological behaviour, ecologically responsible behaviours, environmentally-supportive behaviour, responsible environmental behaviours, and environmentally friendly behaviour [15]. Also, Pro-environmental individuals who behave environmentally accountable are described as holding pro-environmental attitudes, acknowledging the impact of their actions, feeling helpful in the environmental domain, and expressing concern about the ecosystem [16]. Pro-environmental individuals are aware of the environmental impact of their activities. Therefore, they try to reduce their actions' environmental impact, including recycling behaviour.

2.2. Determinants of Creating Behavioural Intervention of Proper Recycling Behaviour

Four determinants influencing recycling behaviour are moral motivation, moral obligation (created by social norms and pressure), knowledge, and socio-demographic factors. Van der Werff *et al.* [17] found that there is a higher chance to do more recycling when people recognise the problem caused by recycling, feel motivated by thinking that their action can help reduce a waste problem and feel a moral obligation to recycle. This finding shows that there are two ways that ethics impacts recycling behaviour: morality creates motivation and obligation. First, moral motivation is one of the determinants that provoke recycling behaviour. According to Markowitz *et al*. [18], pro-environmental behaviour could be evoked by altruism. And the pro-environmental behaviour could even be prompted by an "impure" form of generosity, according to Briguglio [19]. It is related to the pro-environmental individuals' identity mentioned previously. As they feel helpful in changing the environmental crisis positively, they tend to be more involved in activities that could mitigate the effect of global warming.

People recycle as they can contribute to society while getting personal benefits, translated as good feelings. It explains "why people are still participating in environmental behaviour even where there are no legal, financial or social pressures to do so"[19]. Therefore, pro-environmental value is adhered to by cooperating with recycling, and individuals benefit from feeling good [19]. However, Xu, Zhang, and Ling [20] found that people have moral balance sheets that make them less pro-environmental in other areas by being active in certain regions by thinking that they have contributed to society already enough. While people feel good by doing pro-environmental behaviour in other areas (e.g., energy consumption, meat consumption), they calculate the benefit of their actions and adjust their moral balance sheet. Therefore, moral motivation should carefully be created not to make a significant deduction from the moral balance sheets.

Secondly, moral obligation is considered a factor in recycling behaviour. And this is created by peer pressure and acknowledging social norms. Byerly *et al*. [14, p.159] found that people usually care about others' behaviour and are "not strictly self-interested". Also, according to Xu, Zhang, and Ling [20, p.221], people try to maintain behaviour consistency to avoid criticism by spectators such as family, friends, colleagues, or the public who see them as "two-faced". So, if they consider themselves "environmentalists", they aim to continuously follow an environmental goal to reinforce their identity [20]. Depending on how people recognise their social identity affects their behaviour choices. While peer pressure makes people morally obligated, acknowledging social norms is also related to moral obligation. According to Jansson and Dorrepaal [21], social norms are recognised differently depending on how community members internalise their values. It is essential to ensure that people are engaged in the community and absorb the social norms. It is supported by Briguglio [19], finding that social norms could make a difference when community members recognise them. Depending on how individuals feel, the sense of community creates a positive difference in the recycling era [19].

Thirdly, knowledge about waste separation affects recycling behaviour. Lack of knowledge demotivates people to do proper waste disposal, while enrichment of knowledge motivates people to join in recycling. Three knowledge elements affect recycling. First is the correct recycling method. Providing a recycling information programme to people [20] or explaining the reason for recycling and the recycling technique through a flyer or a leaflet [17] could encourage recycling behaviour. The second is environmental impact awareness. As mentioned in the pro-environmental individual identity, when people know the impact on the environment of their actions, they are more likely to recycle [15]. The last is about acknowledging the effect of the waste management system. According to the research of Hao, Zhang, and Morse [22], it is found that people are not willing to participate in recycling if their effort is neglected (i.e. They found that their waste was not separated in the collection and transportation process even though the waste was put in different bins). Therefore, it is essential to be transparent about waste management to people. This knowledge could be presented as an outcome of waste management. Hence, people should be educated about the correct method, the impact of recycling on the environment, and the results of waste separation to improve recycling rates. While people absorb the knowledge, this also affects their pro-environmental identity.

Lastly, social-demographic factors can influence recycling behaviour. Izagirre-Olaizola *et al.* [23] found that students who believe their contribution can change the environment better, who acknowledge the current environmental crisis well, and who are female have a higher chance of recycling. Markowitz *et al.* [18] also found that younger people are open to more pro-environmental behaviour, including recycling, as pro-environmental behaviour involves trying new and innovative products. Environmental individuals are usually female, more youthful, wealthy and educated than non-PEIs [18]. However, it is found that gender factors could be neglected if other factors (income, education, age, community involvement) are identified [20].

Hence, while people feel good about recycling, they also consider the consistency of their pro-environmental behaviour and calculate their moral benefits from their moral balance sheets. If they think of the other's gaze in the community, they try to maintain their consistency of environmental action and are more pro-environmental when they consider themselves "environmentalists". Sensing community social norms is essential to keep their behaviour. Also, knowledge should be delivered considering different elements, which are correct recycling methods, the environmental impact, and the result of their action. And this knowledge attainment affects creating or keeping their pro-environmental identity.

Lastly, other socio-demographic factors should be considered. However, gender could be carefully considered after other socio-demographic factors are examined.

2.3. Behaviour Intervention Insights

Based on three main factors that determine recycling behaviour: moral motivation, moral obligation, and knowledge, three interventions were examined that gave meaningful insights: convenience, charges, and communication. Socio-demographic factors are excluded as the other factors have more impact on provoking recycling behaviour. The first behaviour intervention is convenience. Convenience could increase participation in recycling. Briguglio [19] and Hao *et al*. [22] state that the recycling rate could increase when there are more accessible collection points and garbage collection happens more frequently. However, when the disposal of mixed waste is convenient, it could inhibit recycling cooperation [19]. Xu, Zhang, and Ling [20] argue that if people find their pro-environmental behaviour easier, they are less likely to participate in following pro-environmental behaviour. For example, suppose people don't have to think about how to separate waste and can dump it in a single bin. In that case, they feel fewer demands about environmental policies or campaigns to enhance their knowledge about waste separation. Therefore, convenience should be carefully created not to harm their internal motivation to know more about waste separation or feel good by doing waste separation. This is also related to pro-environmental individuals' willingness to keep their environment identity and higher motivation to maintain the consistency of behaviour. Hence, motivating people to continue recycling is more effective by letting them self-segregate waste. Meanwhile, Briguglio [19] states that time and space are constraints when asking for cooperation in recycling. This should also be considered when creating convenience-based behaviour interventions.

Secondly, charges could be a possible intervention to enhance recycling behaviour, though this also suppresses the moral benefits. The research argues that waste separation could be less motivated when people think they can monetise their pollution behaviour field [19][20]. The study found that the possible reason could be the rebound effect of the monetary inducement [20]. For example, while peoples' environmental identity increases their exposure to environmental information, people use more plastic as the price is getting lower and single-action bias, which is that people are already feeling less guilty about their not-environmentally behaviour after they did one single pro-environmental action. [20]. So, when it does not come from self-motivation, it decreases moral motivation, which triggers a negative spillover that reduces the pro-environmental action [20]. Their cause to separate waste is to get incentives, not from their environmental awareness and acknowledgement of the importance of waste separation. Still, if charges are used to create behavioural intervention, it should be constructed as positive feedback to be more effective. Providing incentives is a better option rather than a penalty for polluting the environment by more taxes. The argument about incentives can be found in the paper about the reflection on the mandatory regulation system of Zhengzhou city, which is that a reward system should be implemented instead of a penalty [22]. However, it is also complicated to confirm whether incentives for recycling can increase recycling behaviour. Negative spillover can be triggered if the behaviour is formed by external causes, such as coercion or monetary inducement by the government or different organisations [20]. Also, it is found that financial incentives can suppress the benefits that can be given by cooperating of own accord [19]. Thus, several arguments conclude that monetising behaviour cannot be a complete solution. But if it is chosen, giving a reward is better than a penalty.

The third is communication. Communication can help create environmental awareness that can lead to pro-environmental behaviour by providing the knowledge that can be used to do the proper waste separation. And it should be delivered within the context of behaviour. First, social norms are essential in the communication [14]. Because "people follow what others do, considering their self-benefit from recycling behaviour" [19]. Messenger (via neighbours) is also essential, as when neighbours deliver information in the community, recycling increases [14]. This finding supports that social norms within the community are delivered via community members.

In contrast, media-based communication is not as efficient as face-to-face. It means small group communication works better. Because it could be simply neglected as people don't take information actively [19]. Contextual behaviour intervention also creates peer pressure and acknowledges social norms. If the bin is in a place where other peers can see it, people tend to do the proper waste separation. Therefore, behavioural intervention is effective in a contextual environment (such as in front of a waste island).

Meanwhile, Byerly *et al*. [14] state that recycling can be encouraged by adding bins for recycled goods alongside waste cans and offering curbside pickup on the same day as waste pickup, changing defaults. It is an example of contextual behavioural intervention. The importance of contextual behavioural intervention can be found in research conducted in Maastricht [24]. The researchers tried to encourage students' recycling behaviour in the waste separation bin in the cafeteria by providing an information triangle on the table in the canteen. However, it did not show a significant difference compared to before. This research got feedback from students that the intervention should be where actual decision-making takes place, which means that the context and timing of providing the information should be considered. Also, the intervention was mainly focused on knowledge, while other determinants of intention, attitude, and subjective norms were not considered in the research [24]. Byerly *et al*. [14] support the importance of contextual behavioural intervention by the argument that contextual variables mediate behaviour through "automatic, unconscious cognitive processes" while traditional behavioural intervention, such as financial incentives and education, which "target-controlled, conscious deliberation".

One essential insight is about the gap between intention and actual behaviour. According to Byerly *et al*. [14], how the interventions are framed and communicated is necessary for people and incentives, information, and persuasion. It is supported by the conclusion of Izagirre-Olaizola *et al*. [23] and Kasapoğlu and Turan [25] that there is a big gap between students' intention to be environmentally responsible and actual behaviours. This research supports Markowitz *et al*. [18] findings that people's environmental values are insufficient to predict cooperation. The intention does not always lead to the actual behaviour. This research shows that knowledge delivery and other determinants like moral motivation or moral obligation should be considered to reduce the gap between intention and actual behaviour.

So far, three primary behavioural interventions have been discussed, leading to some insights. First, conveying the conveniences or charges should not be designed to lessen peoples' moral motivation as it could mitigate people's pro-environmental individual identity. Secondly, communication should be done within context rather than spreading information widely through mass-media channels to ensure they take the lead and absorb it properly. Lastly, knowledge and other factors like moral motivation or moral obligation should be considered to match the intention and their actual behaviour.

2.4. Behaviour Intervention Techniques

To deliver a successful behaviour intervention, different techniques should be explored. For exploration, Behaviour Change Technique (BCT) taxonomy(v1); hierarchically-clustered techniques [26] was examined, and possible techniques that could be useful for future research were selected and discussed. The selection was based on the questions related to behavioural intervention determinants: moral motivation, moral obligation, knowledge, behavioural interventions that were examined: convenience, charges, and communication (see Appendix A). Considering the questions, behaviour intervention techniques were explored and examined with determinants of recycling behaviour and behaviour intervention insights. The behavioural intervention methods were selected and evaluated (see Appendix B).

Most interventions were selected based on communication of knowledge. Because of possible consequences or results of the waste management system, other factors like moral motivation or moral obligations are influenced by knowing the correct recycling method. Also, giving positive feedback is essential. Feedback on outcomes of behaviour (2.7), identification of self as a role model (13.1), reward approximation (14.4), rewarding completion (14.5), situation-specific reward (14.6), and vicarious consequences (16.3) are behaviour change techniques that give positive feedback to users. Positive feedback also affects increasing moral motivation and obligation, which are other determinants of recycling behaviour. Convenience is not found enough regarding behaviour change techniques, although restructuring the physical environment (12.1) or the social environment (12.2) are possible behaviour change techniques that could increase the convenience of recycling. However, they do not consider time, which is one of the constraints in creating the convenience [19].

After reviewing the behaviour change techniques, different solutions were explored. These will be helpful to create a behavioural intervention for the future. In this research, instruction on performing a behaviour (4.1) will be the primary technique used based on a credible source (9.1). Monitoring of behaviour by others without feedback (2.1) was applied as an observation session regarding the user's interaction with the current waste island. Other techniques related to feedback will be combined or used to design efficient input for users.

2.5. State of the Art

Exploring the solutions already developed and tested in the market and society is essential to implement an effective envisioned behavioural intervention. To research the interesting examples, some criteria are set up. First, the intervention should be related to recycling behaviour, either education or encouragement of recycling. The findings are not limited to information provision but focus on a behaviour intervention strategy. Secondly, technology adaptation is examined. Thirdly, it is checked whether the solution is contextual or non-contextual.

Additionally, the previous section's determinants and behavioural intervention strategies are considered. So far, different types of solutions have been implemented. These are categorised into several aims: knowledge provision, automation, and encouraging recycling behaviour with indirect drivers such as playfulness, opinion expression, aesthetics, or benefits. And the solutions are analysed with the following questions: What is it? How does it work? What kind of insights can be taken out of the solution? How can it be adapted to future projects? Based on the aims, solutions are discussed and analysed.

Figure 2. *EvoEco: measure the weight of the waste and show the infographic.*

First, some solutions aim to provide information regarding waste disposal. The data is either focused on the proper waste separation or the environmental impact of recycling. EvoEco [27] is an interactive waste bin which provides the correct waste separation method on the screen, measures the weight of waste and shows the estimated savings that can be made by recycling (see Figure 2 [27][28]). Users get positive feedback when they throw away waste in the can. And knowledge is provided in visuals. While the bin is not used, a video regarding correct waste separation is shown repeatedly. This looped video lets the user stop by the bin and educate them. When considering the determinants, it encourages the users' moral motivation by providing positive feedback. The feedback makes people think about the benefits of recycling. And this is a contextual behavioural intervention as the intervention happens during waste disposal.

Figure 3. *Twente Milieu app: provide waste calendar, reminder, report, and correct waste separation method.*

Other solutions that focus on the information provided are in the form of a sticker and an application. Twente Milieu app is an application that was developed for the residents of Almelo, Borne, Enschede, Hengelo, Hof van Twente, Losser, Oldenzaal, and Wierden (see Figure 3[29]). The application offers a waste calendar, reminder, report, and correct waste separation method. It enables residents to do proper waste disposal. Since users can check the information via their smartphones, information seems to be easily accessible. However, app development is taking a long time. Also, if the application is not deployed and managed well, users' feedback about the application is not positive [30][31]. If fewer users have installed the app, then the app's effectiveness is difficult to determine. Even though the app works well, it still has disadvantages because it takes a long time to search the information on the place to separate waste and focuses on showing the data rather than education.

Figure 4. *Waste island with a sticker in the library at UT*

A sticker is another type of information provision. An example is the waste island located in the library at the University of Twente [32] (see Figure 4). The correct information regarding waste disposal is provided. However, this information is written in text, and it is difficult to read. Even if the information is provided in context, the knowledge delivery method is essential, so it should be easy to understand and catch the user's attention.

Figure 5. *Bin-e: contactless automated waste segregation bin with an app that tracks the bin's waste.*

Secondly, automation is also an option for facilitating the recycling process. Bin-e [33] is a contactless automated waste segregation bin with an app that tracks the bin's waste. The app enables users to efficiently manage waste collection (see Figure 5 [33]). The bin is opened automatically when a user comes close to the bin, and the bin will segregate the waste based on the item's material. It provides a waste management service, so the user does not have to think about where the waste should go. The bin only deals with recycled materials (paper, glass, metal, plastic) and no residual waste. Therefore, it does not apply to the current waste island at the University of Twente. Also, if automation could be a solution, it would be more efficient to implement the automated waste segregation system in the waste management company and let people dump the waste in a single bin. However, the main goal of encouraging people to recycle is to let them be aware of the environmental problem and the impact of the activity rather than only the efficiency of waste management. Also, the current state of the art regarding automation of waste sorting is focused on recycled materials [34]. Therefore, it is going to be challenging to implement residual waste sorting.

Figure 6. *Tetra-bin: a street-side waste bin that motivates people to put their waste in the bin instead of littering on the street*

Thirdly, some behaviour interventions encourage recycling behaviour with indirect drivers such as playfulness, opinion expression, aesthetics, or benefits. Tetra-bin [35] is an example of applying gamification for waste disposal behaviour (see Figure 6 [35]). A street-side waste bin motivates people to put their waste in the bin instead of littering it in the street. If people put trash in the container, people can see the game interaction in the led panel, like feeding a dog a bone. The Gamification approach can catch peoples' attention, and people have fun using the bin. The LED part can be used for advertisement as well.

Playfulness can lead to behaviour change. Although the bin focuses on preventing littering on the street, gamification could be one of the elements that can be considered. Nevertheless, the information provision should not be neglected.

Figure 7. *Mamamatiks: a vending machine which releases food for stray animals when people recycle plastic bottles*

Meanwhile, Mamamatiks [36] (see Figure 7) lead people to recycle by indirect motivation, which is providing food for stray dogs, as mentioned in 2.2, a moral motivation determinant that leads people to be more pro-environmental. The people's "feeling good" mind drives them to do specific actions. In this case, feeding the stray dogs is their motivation. When people recycle plastic bottles in the vending machine, the machine releases food for dogs and cats. People can also put the leftover water of their plastic water bottles in space so that animals can drink them. It combines recycling behaviour with good intentions. People can think this is a win-win situation. Although recycling is a common concept in the Netherlands, the application of indirect drivers could also be helpful for the UT community members who are high intellectuals.

(a) (b)

Figure 8. *Examples of voting bins. (a) voting bin to recycle plastic bottles, Wecup; (b) voting bin to recycle cigarettes, Hubbub*

Another concept that uses the indirect driver is voting. Wecup [37] (see Figure 8 a) and Hubbub (see Figure 8 b) created the voting bin to stimulate people to put their waste in the correct bin. In this way, people do not litter waste while they express their opinions. Voting is another way to add playfulness to the waste bin. However, these examples are also focused on littering rather than information provision.

Figure 9. *Smiley bins by Envirobin*

Aesthetics are also important in design. Smiley bin by Envirobin [38] is an example of the design's importance (see Figure 9). The design is simple, but it makes people feel happy using the bins. With an interesting design, it would be easier to attract the people to use the envisioned solution.

(a) (b) (c)

Figure 10., *Examples of recycling usint incentives. (a) McDonald's Stockholm Recycling Campaign; (b), recycling vending machines, Enviroank; (c) deposit vending machines for plastic bottles in the Netherlands*

Incentives are a well-known approach that makes people recycle. Figure 10 is an example collection of incentives. Figure 10 (a) shows McDonald's Stockholm Recycling Campaign [39] which attract people to return cans to get free food. Figure 10 (b) is recycling vending machines by Enviroank and Figure 10 (c) shows deposit vending machines for plastic bottles in the Netherlands. This is related to charges which is one of the behavioural intervention strategies. By letting users know the benefits that they could get from recycling, people are more likely to participate in recycling.

So far, different behavioural intervention examples have been explored. Through discussion, it is found that there are direct and indirect drivers that encourage or educate recycling behaviours. And it was confirmed that the importance of determinants and adapted the case of behavioural intervention approaches that have been discussed in 2.3. The knowledge should be delivered within the context and valuable when combined with the correct method and positive feedback. Not only direct drivers but also indirect drivers can be considered. Gamification, playfulness, expressing opinions, attractive design, and incentives are possible options for driving indirect motivation.

2.6. Discussion and Conclusion of Background Research

The review aimed to examine determinants of recycling behaviour and behaviour interventions and determine the most effective way to affect people to separate their waste correctly. Three main factors influence recycling behaviour (moral motivation, moral obligation, and knowledge) and three types of behaviour interventions (convenience, charges, and communication). They are intertwined, and factors are connected to different interventions. Knowledge is essential, as it provokes other factors like moral motivation and obligation.

Based on this, behaviour change techniques were chosen, and possible techniques were discussed. The primary method that will be used is instruction on how to perform a behaviour (4.1) [26] combined with a credible source (9.1) [26]. Instructing how to do proper waste separation based on reliable sources will be the primary strategy to improve waste separation on the UT campus. State of the art was focused on littering rather than motivating recycling and gave additional insights into how the solution could be designed. Theory from the literature review was confirmed through state of the art, which helped deepen understanding regarding users.

Although insights through background research helped to understand the problem and possible solutions, it has some limitations. Some research focuses on households or the public. In this case, not everyone is expected to know the importance of recycling. This project focuses on UT community members, who are expected to know the importance of recycling as they are educated. Also, most state of the art focuses on creating new bins. However, the research goal is to educate the UT community members to separate waste properly in the waste islands. Therefore, the behaviour determinants and behaviour interventions should be tailored to apply to this project.

Regarding moral motivation, it is difficult to confirm whether UT community members have it. It can be provoked by providing knowledge regarding how they contribute to the community or benefit them. Regarding moral obligation, peer pressure exists in the community as this is a university environment It could be expected that UT community members are aware of the importance of recycling as they are educated. However, as mentioned above, the intention and actual behaviour are not matched. The solution should be constructed as actual behaviour is affected by the solution, not only affecting intention. Therefore, providing a proper way to do waste separation and nudging people to get the correct information is essential. This could be enhanced by delivering playfulness, gamification, or interactivity discussed in state of the art.

Regarding knowledge, three types of knowledge could affect proper waste segregation. This knowledge should be entailed for the community as recycling rules should be based on UT rules, goals should be relatable for the community members, and the waste management process should be based on a waste management company contracted with UT. Additionally, socio-demographics could be mentioned briefly. Most populations are young, educated people. Therefore, they tend to do recycling properly.

Regarding convenience, UT provides waste bins at an accessible point. So, people do not litter usually. However, access to information regarding waste separation is not convenient. Also, detailed information is provided in Dutch or not elaborated enough. Therefore, it is not accessible for international students, who are one of the leading groups of the community.

Regarding charges, creating an incentive system for waste separation will be difficult. Instead, positive feedback to improve satisfaction could be considered. Communication of knowledge should be contextual, meaning it should be provided in the context of waste disposal at the UT waste island.

Most analysed interventions were not implemented within the technology-based solutions. Instead, it is mainly based on psychological and social elements of behaviour intervention. Therefore, some technology-based solutions were discussed in state of the art.

During state of the art exploration, direct and indirect drivers that motivate or educate recycling behaviour were investigated. Those confirmed the importance of determinants. behaviour interventions discussed in 2.3 could be found in the examples. Examples gave insights into that knowledge regarding recycling should be conveyed within the context, and positive feedback and correct methods should be combined in the knowledge delivery. Also, gamification, playfulness, expressing opinions, attractive design, and incentives were discussed as possible options for driving indirect motivation.

The graduation project aims to implement ICT-based behavioural intervention to educate UT community members to separate waste properly at the UT waste island. The target group for the behavioural intervention is UT community members, mainly students, employees, academic professionals, and visitors. Higher institution members are usually considered an essential group to tackle the global environmental challenges as individual behaviour regarding resource use can prompt collective changes [13]. However, the characteristic of the community is transient. Therefore, it is difficult to form social norms together and community involvement.

Moreover, the university has an international environment, so people have grown up with different social models. Also, there are not enough case studies targeting university community members and are campus-based. Most case studies about waste separation and minimisation are discussed widely, targeting households, students, and policymakers. Future solution development should focus on how knowledge should be delivered based on the target group level.

There are three assumptions regarding the reason why people do not recycle:

1. People do not know the correct waste separation method.
2. People do not care about proper waste separation.
3. People do not trust the waste management system.

The First could be solved by providing clear information regarding waste sorting. The current education is insufficient to correctly separate waste as it is difficult to catch and understand. The second could be solved by providing facts on What UT wants to achieve regarding waste separation. Therefore, the challenge would be to ensure that people understand the reason for waste separation and be motivated to do it. The third could be solved by providing a trustworthy waste management process confirmed by a waste management company, Prezero. Therefore, giving knowledge from different domains in a contextual way is essential.

In summary, some preliminary requirements for the envisioned solution became concrete through background research. To educate UT community members to separate their waste correctly at the UT waste island, knowledge should be provided within three domains: waste separation methods, the reason for waste separation, and the waste management process. Regarding waste separation methods, the waste management company and CFM should confirm the correct information to ensure the source's reliability. Regarding the reason for waste separation, it should be relevant to community members and give moral motivation and moral obligation. The waste management process information should ensure the community members understand it and provoke moral motivation. To facilitate convenience, the envisioned solution should provide an easily accessible point for recycling. Still, it should not harm moral motivation and obligation (e.g., a fully automated recycling system, so people do not have to check whether their knowledge is correct). Charges are translated as feedback, as providing an incentive is not realistic. Positive feedback should be provided (e.g., give a compliment when the user follows the instruction). To enhance communication, contextual information delivery should be considered. Also, the information delivery should be interactive, playful, and aesthetic to attract people to catch the information. Those requirements will be considered during the ideation to create an idea.

3. Methods and Techniques

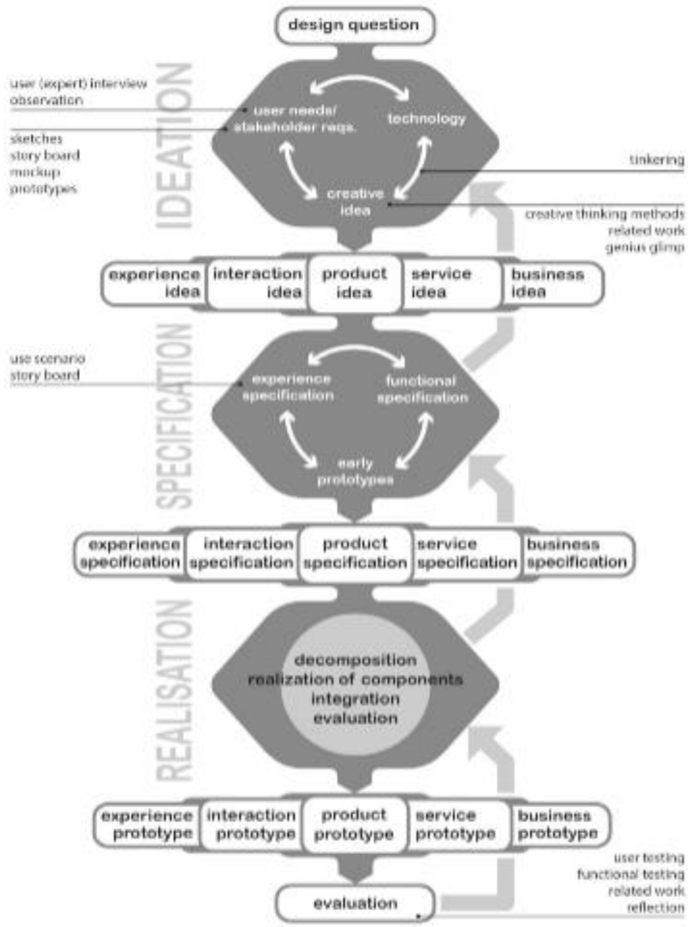


Figure 11. *Creative Technology design process*

Designing a product for educating UT community members to separate their waste properly at the UT waste islands uses the Creative Technology Design Process presented by Mader and Eggink [40]. As shown in Figure 11, the model has four phases: ideation, specification, realisation, and evaluation. This technique provides a design thinking process with a spiral-shaped model. It helps create a product based on background research through literature review and knowledge via different approaches like interviews, focus group discussions, or observation sessions. In each phase, methods and techniques used in the project are described and elaborated.

3.1. Ideation

In the ideation phase, concepts for the prototype are generated. The starting point of the ideation phase is to define a design question. In this project, the design question is “What ICT-based behavioural intervention could be used to educate the UT community to separate their waste properly at the UT waste islands?". Through the problem and context analysis and background research, it was found that the correct information regarding waste separation should be delivered to the user contextually through technology at the UT waste islands.

Information and communication technologies (ICT) include "technological tools and resources such as computers, the Internet (websites, blogs and emails), live broadcasting technologies (radio, television and webcasting), recorded broadcasting technologies (podcasting, audio and video players and storage devices) and telephony (fixed or mobile, satellite, Visio/video-conferencing.)." [41]. Therefore, ideas should be generated considering appropriate ICT tools or resources.

Several techniques can be applied to decide on the most promising idea for the project. First, stakeholder identification and analysis should be conducted to obtain stakeholders' needs of the envisioned solution. The basic stakeholder analysis technique suggested by Bryson [42] was used to identify stakeholders. It helps to identify stakeholders with their interests. The steps are following:

- Brainstorm the list of potential stakeholders
- Prepare a separate flipchart sheet for each stakeholder
- Place a stakeholder's name at the top of each sheet
- Create a narrow column down the right side of each sheet and leave the column blank
- For each stakeholder, in the area to the left of the narrow column, list the criteria the stakeholder would use to judge the organisation's performance (or list what the stakeholder's expectations are of the organisation)
- Decide how well you think the stakeholder thinks the organisation is doing from the stakeholder's point of view. Use coloured dots to indicate a stakeholder judgment of good (green), fair (yellow), or poor (red)
- Identify and record what can be done quickly to satisfy each stakeholder
- Identify and register longer-term issues with individual stakeholders and with stakeholders as a group

The organisation's performance is translated more as the project's solution, and each stakeholder has different expectations of the solution.

Also, observation sessions with a semi-structured interview with the users of the UT waste islands and focus group discussions with students, who are a leading group of UT community members, were conducted to identify their characteristics and needs deeply. Using a semi-structured interview structure, the interview can focus on the main goal of the interview while adjusting or adding questions flexibly based on the interviewee's response [43]. An observation session aimed to investigate the user's waste disposal behaviour at the UT waste islands in front of the toilet in the Waaier building of UT. The focus group discussions were conducted two times, and four students joined in and shared their experiences using the waste islands and ideas.

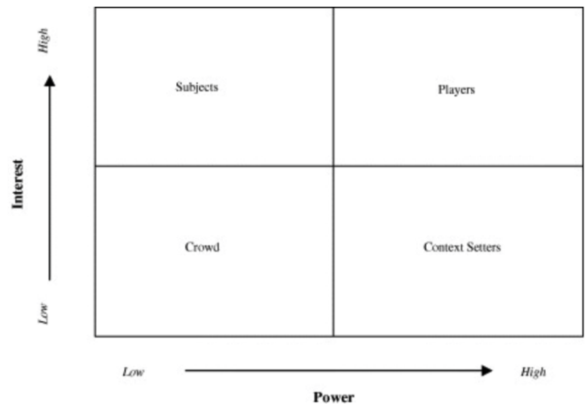


Figure 12. *Power versus interest grid*

After the fundamental stakeholder analysis, observation session, and focus group discussions, the relationship between the project and stakeholders was expressed in the power versus and interest grid (see Figure 12 [42]). Each stakeholder's ability and interest were inspected and determined through the power versus interest grid.

The power versus interest grid is a two-by-two matrix where each dimension describes the stakeholder's interest and the power that affects the issue's future [42]. There are four categories of stakeholder results: players who have high interest and impactful power; subjects who have some interest but less power; context setters who have some influence but more indirect interest; and the crowd with less power or interest [42].

The preliminary requirements were decided based on stakeholder analysis results and background research. Those requirements were ranked with MosCow Method [44]. The MosCow method is a framework for the efficient prioritisation of needs. It has five prioritising levels: '*must'*, '*should'*, '*could'*, and '*won't*' have. Most requirements should have a prioritisation level of '*must'* or *'should'*. These requirements help implement the system based on stakeholders' needs and evaluate the product's functionality [44]. And then, various ideas were generated. During the focus discussion and the observation session, multiple ideas were suggested by users. With those suggestions, different ideas were generated using the mind-mapping technique. And then, each concept was explained with a scenario and evaluated based on preliminary requirements. Three concepts were selected based on the suitability of initial conditions and technical feasibility. The ideas were chosen together with supervisors. After a meeting with the client and based on their feedback, the final concept was chosen.

3.2. Specification

The chosen concept is elaborated more to design the prototype in the specification phase. First, personas [45] were created to develop the prototype for “real” users. The designer can understand users’ needs, experiences, behaviours, and goals by creating fictional characters representing various user types that might use the solution [45]. With the personas, a persona scenario was developed to understand the personas in the problem context [45]. And then, visualisation requirements were listed in two parts: functional requirements and non-functional requirements. They are prioritised using the MosCow method [44]. Functional requirements are what the system should do, and non-functional requirements are how the system should work [46]. With personas and visualisation requirements, a storyline and a storyboard were created. The storyboard helps to simulate the user’s interaction with the prototype [47].

3.3. Realisation

After the product specification is given, the realisation phase follows. It starts with the decomposition of the specification, and the components are realised [40]. Then components are integrated, and the prototype is evaluated [40]. Usually, functional requirements are evaluated in this phase [40]. The chosen design method in this project is the Agile development [48]. A small-scale prototype is developed and evaluated in Agile development, and the cycles are repeated [48]. In this way, the prototype can fit the project's requirements.

3.4. Evaluation

The prototype is evaluated by the client and users in the evaluation phase. The client uses the prototype based on the tasks given and provides feedback by answering the semi-structured interview questions. In this way, the researcher ensures the main goals of the interview are achieved while the questions are flexibly changed based on the interviewee's answer [43]. With the users, user testing is conducted. The user testing method follows Guerrilla testing to approach real and random users and asks for feedback on the prototype easily [49]. The survey was filled out by the user after using the prototype. The researcher makes observation notes to check the user's spontaneous reaction. Non-functional requirements identified from the specification phase are evaluated by the client evaluation and the user testing. It is essential to conduct the testing with the consent of the testing participants. The evaluation process was assessed by the ethical committee of the EEMCS Department of UT to ensure that the evaluation was conducted ethically. All testing sessions were conducted with the consent of the participant.

4. Ideation

The ideation starts with stakeholder identification and analysis. After preliminary requirements elicitation, concepts are generated with mind mapping, and the final concept is decided. The chapter focuses on creating an idea for the ICT-based behavioural intervention to educate UT community members to separate their waste at the UT waste island correctly.

4.1. Stakeholder Needs and Requirements Definition

A stakeholder is "an individual or organisation that has a right, share, claim, or interest, in its possession of characteristics that meet their needs and expectations", such as end-users, end-user organisations, developers, trainers, disposers, or regulatory bodies. [49, 4.1.44]. Stakeholder analysis is taken in the following steps. First, each stakeholder is identified and described as who they are, what they do, and why they are stakeholders. Secondly, each stakeholder's expectation regarding the project will be interpreted as preliminary user requirements (stakeholder's needs). After each stakeholder analysis is finished, their relationship regarding the project will be described with the power versus interest grid. Based on stakeholder analysis, user requirements are identified and combined. Finally, those are prioritised with MosCow method [44].

4.1.1. Stakeholder Identification and Analysis

There are five stakeholders in the project: CFM, the client of the project; UT community members who are actual users of the project's solution; Prezero, the waste management company of UT, the designer; and supervisors. Each stakeholder has different expectations from this project. And it is translated into preliminary user requirements. The steps follow the basic stakeholder analysis technique [42].

4.1.1.1. CFM (Campus Facility Management)

CFM is the UT department that manages the campus facilities. It includes improving sustainability on campus. One of their focuses is improving waste separation. CFM's goal is addressed in the waste plan [11]. The purpose of CFM in this project is to improve waste separation on campus, which is also the project's goal. CFM is the project's client, therefore, an important stakeholder. CFM also helped with the waste analysis for the bin to see the difference in waste management after the envisioned solution was provided. It means CFM has strong power and interest in the project. During the meeting for the project, CFM expressed interest in knowing which waste is still difficult to separate from the system from the UT community so that CFM can develop policies and update the information based on users' feedback. It means CFM is also interested in UT community members. CFM is also strongly connected with Prezero, an essential stakeholder in the waste plan. CFM's expectations are written in the waste plan [11] and the project proposal and were mentioned in the project meeting and concept decision meeting. Those expectations are described and translated into preliminary user requirements in Table 1.

Table 1. *CFM (Campus Facility Management)'s expectations and preliminary user requirements*

Expectation	Preliminary user requirement
The envisioned solution will inform students, staff, and visitors how and why to separate their waste in the appropriate bins (From the project proposal)	Clear information that how and why separate waste properly at the UT island
The envisioned solution will have visual information like more pictures rather than text (From Waste plan 5.2)	Include more visuals like pictures in the solution rather text only
The envisioned solution will inform to UT community members about the desired situation of each waste stream (Residual, PMD, Paper, Organic) (From Waste plan 3.1)	Provide information regarding the desired situation of each waste stream (Residual, PMD, Paper, Organic).
The envisioned solution will inform UT community members about clear and transparent recycling process (From waste plan 3.4.1.)	Provide information regarding the recycling process after waste disposal performed by Prezero
The envisioned solution will have a reporting system to get feedback from users which waste is still difficult to separate. (From project meeting)	Include a reporting system where users can send feedback about their uncertain waste

4.1.1.2. UT Community Members

UT community members are end-users of the envisioned solution. The population is composed of students, employees, researchers, and visitors. UT community is intellectual; therefore, most community members are expected to be interested in sustainability. However, the extent could be various. Their interest in sustainability might not be directly translated into enough interest in recycling at UT. As found in background research 2.3, there is a gap between their interest in sustainability and their actual behaviour. Observing sessions and focus group discussions were conducted to understand UT community members' interests and needs and UT community members' actual behaviour; two observation sessions were performed on the 14th and 20th of October 2021 near the canteen area of the Waaier building at UT. Each observation was conducted between 09:30-and 13:30. The busiest time was between 09:30-10:30 (coffee break) and 12:00-12:30 (lunchtime).

The following points were checked during the sessions: type of waste, speed/hesitance, accuracy, environmental awareness, and knowledge level were inspected by semi-structured interviews.

Twelve subjects were observed during the first observation session, and a semi-structured interview with a cleaning worker was conducted. Most people's decisions were fast, but primarily single-use plastic or plastic packaging seemed to create confusion and delayed waste disposal. A cleaning worker said that residual waste dumping is the biggest problem. Other waste streams like organic or paper were well managed, but residual waste and PMD waste were the most problematic waste streams. Since the waste island observed was near the canteen, most waste was from food packaging. Also, as the bin is near a coffee bar and coffee machine, plastic cups or paper cups were disposed of. Paper cups created confusion as paper cups belong to PMD according to the example waste list provided by CFM, confirmed by Prezero (see Appendix C). However, some people disposed of the paper cups in the paper bin.

Moreover, it was found that the type of waste was mainly related to food packaging. This was also confirmed in the following observation session as well. Twelve subjects were observed during the second observation session, and one cleaning worker was also observed. During this session, five interviews were conducted to examine the people's gap between knowledge and actual behaviour. Questions were asked and adapted depending on the situation (see Appendix D).

During the second observation session, some interviewees confirmed the previous assumption regarding food waste-related waste. Several interviewees mentioned that the materials in the canteen (food packaging, cutlery) create confusion. People were mostly fast to decide, sometimes there was a bit of hesitation, but it was less than 4-5 seconds. One interviewee mentioned that some UT community members are internationals. Every year, new students come, and the new year students are confused with waste streams of the UT waste island, like the meaning of PMD.

Figure 13. *Waste island with a sticker in the library*

Interviewees mentioned the effect of a sticker with a waste separation information sheet attached to a waste island. Some said that there should be a sticker attached to the bin because it would be helpful to know the possible waste of each waste stream. On the other hand, others said that it was not visible enough. During extra informal observation in the library (see Figure 13, [32]), it was found that stickers were not effective enough to separate the waste properly. Regarding behavioural intervention, interviewees mentioned that text and visuals should be mixed with attractive and catch points to get attention.

The requirements from the background research were confirmed by conducting two observation sessions, and various requirements were identified. The UT community is international, and new students are coming every year; the social norms of UT about waste separation are not absorbed by new community members enough. Therefore, this should be considered why recycling is not done correctly. This is because people do not know how to use waste islands properly and are unaware of what UT wants as the desired situation of waste separation. The moral motivation of the UT community members was not confirmed enough. During the interview, asking and getting a truthful answer about whether they care about recycling was challenging. However, even though they said they cared about recycling, they did recycle wrong, confirming the theory that intention and behaviour do not match. Therefore, knowledge regarding clear instructions about recycling is one of the factors carefully considered. Since the decision process is fast, the behavioural intervention should be time-consuming. Rather than only text, adding visuals will increase readability and be less time-consuming to get information. Also, plastic is a confusing waste type; the information regarding plastic disposal should be well-instructed. Mixed packaging or waste also is information that should be considered. Food packaging is the most waste that is generated in the university.

To understand the users' needs deeply, two focus group discussions were conducted on the 18th of November 2021, Thursday, between 12:45 and 13:30, with two participants, and on the 19th of

November 2021, Friday, between 12:45 and 13:30 also, with two participants. During the focus sessions, different perspectives and insights were shared.

All participants mentioned the importance of knowledge of correct waste separation.

One participant mentioned that people do not separate waste properly because they do not know where to put it, and no one told them where waste, like paper coffee cups, should go. Also, the participant mentioned that since the decision is fast, the information should be readable from a distant location, like a big screen. It is related to the steps that users need to take to get accurate information. Those steps should take less effort. Therefore, the development should focus on how the user could use the UT waste island efficiently. It means the project should aim to add value to the UT waste islands. Also, the sticker on some waste bins does not add enough value to separate waste efficiently at the UT waste island.

Opinions about social norms and peer pressure were discussed as well. One participant shared her opinion that people used to do littering but not anymore, as not littering is accepted as a social agreement. Waste separation is the next step; currently, it is in the process of being socially accepted behaviour. If people learn about waste separation at home, they already get used to doing waste separation. Also, UT community characteristic was discussed. Because the UT community is international, they might not know how to use the bin if they come from different countries, as recycling methods vary. For example, PMD could be a new term for some new students.

People could think they are doing waste separation correctly, but if this is not the case, there should be feedback telling them their knowledge is wrong. But this should be done without making them feel guilty or uncomfortable. The willingness to learn and do proper waste separation is difficult to measure. Some mentioned the sticker they get on the container when they separate waste. It is just a smiley face, but it makes them feel good. So positive feedback is essential.

Other aspects were discussed as well. For example, library waste islands tend to be full during exams. And if the bin is full, people throw away their waste in the residual waste as other bins like PMD were already full. Therefore, waste management at the UT should be improved by placing more cleaning personnel or making sure the container is emptied frequently.

During the focus group sessions, different solutions were discussed. Table 2 shows the ideas that were discussed during the sessions.

Table 2. *Ideas discussed during focus group discussions*

No.	Idea
1	A scanner that validates the proper bin
2	VR installation can educate people about the correct recycling method.
3	Kick-in Booklet one page explains how UT expects to use the waste bin and why it is essential to do recycling.
4	Songs that new students can listen to are catchy and attractive. Like it is cool to do recycling.
5	An application that can educate people about the correct recycling method and impact.
6	AR scans and shows which waste should go to which waste streams.
7	Games that educate people about proper recycling methods.
8	Animation or video that explains proper recycling methods.
9	A banner that is in eyesight that explains the proper waste separation.
10	Chatbot saying which waste should go where
11	A map that informs the waste bin location
12	Add personality on waste bin that detects the amount of waste that the container got.
13	Four screens on each bin show the waste in the picture.
14	Add employees' pictures on the bin who clean the container, explaining how much they need to put effort to separate the waste again.
15	Bin gives positive feedback like a smiley when put in the right bin or sound.

By conducting focus group sessions, different aspects of the solution were discussed, which could be used in the ideation phase. Knowledge is indeed essential to ensure people do the proper waste separation. Specifically, proper feedback, even when the user does not check the information, should be constructed so people can think their understanding is correct. The feedback that says their existing knowledge could be wrong should be developed. Other requirements that could be considered, like eyesight, and positive feedback, were discussed. Through the focus discussions, the feedback components of the solution were specified.

In conclusion, observation sessions gave additional insights into people's decision-making processes. Even though there is some hesitation, the duration is short. During the interview, the UT community characteristics were discussed. Since it is an international environment, new students can be confused with the waste separation method on campus. The features of the waste usually disposed of were identified as well. Most of them are plastic cups, paper cups, or food packaging. The effect of the sticker on the waste island was unclear, as the observed waste bin did not have a sticker. People mentioned stickers; however, as seen in Figure 13, stickers' usefulness is unclear. Most interviewees agreed that the behaviour intervention should be a mixture of visuals and text to be more attractive and make it easier to catch the information. Besides, additional requirements were discussed. The information should be in eyesight and readable from a distance to enhance convenience. The Decision-making process should be easy to make so that it is less time-consuming to get the information. Also, the product should provide additional feedback based on the user’s action because people could think what they know is already correct. Therefore, there should be a way to instruct the precise information and make them check the information (e.g., if the user uses the instruction, provide positive feedback. If the user does not use the education at all, still give feedback to let them check their knowledge). UT community members’ expectations and preliminary user requirements are listed in Table 3.

Table 3. *UT community members' expectations and preliminary user requirements*

Expectation	Preliminary user requirement
The envisioned solution will provide clear instruction about waste separation on the UT campus (From observation sessions and focus group discussions)	Clear information that how and why separate waste properly at the UT island
The envisioned solution will let UT community know about waste separation guideline of UT (From observation sessions)	Provide what UT wants as the desired situation on each waste stream
The envisioned solution will help users to separate mixed waste, food packaging, plastic waste, and residual waste properly (From observation sessions)	Give special attention on giving clear waste separation information regarding mixed waste, food packaging, plastic waste, and residual waste properly
The envisioned solution will provide waste separation instruction with visuals and text. (From observation session and focus group discussion)	Include more visuals like pictures in the solution rather text only
The envisioned solution will be in eyesight (From focus group discussion)	Locate the envisioned solution in eyesight
The envisioned solution will be readable with big text and visuals from a distance (From focus group discussion)	Provide the envisioned solution with big text and visuals so that it can be readable from a distance
The envisioned solution will be easy to understand decision making process of waste separation taking less-time consuming (From focus group discussion)	Provide easily understandable and quick decision-making process of waste separation
The envisioned solution will provide different feedback based on the user's action, even though when the user does not check information (From focus group discussion)	Provide different feedback about waste separation based on the user's action, even though when the user does not check information
The envisioned solution will help the cleaning personnel to empty the waste island bin regularly.	When the waste bin is full, create alert to the cleaning personnel.

4.1.1.3. Prezero

Prezero is a waste management company which has contracted with UT. Currently, waste at UT is collected and emptied by a cleaning company and disposed of in waste stream containers. Then each waste stream container is emptied by Prezero. They are responsible for turning waste into energy or recycling them. The company has delivery conditions for each waste stream[3] to facilitate waste processing. Therefore, they are the primary stakeholders in how the envisioned project solution will help prevent waste separation and help them process waste better. However, this aspect can only be checked in a long-term situation as it takes a while to evaluate the waste separation in total. Prezero is interested in how the envisioned solution will improve waste separation on the UT waste islands. Therefore, they have fewer expectations than other stakeholders. Also, they have less power than other stakeholders as they are neither the end-user nor the client. Table 4 shows Prezero’s expectations and a preliminary user requirement.

Table 4. *Prezero's expectations and preliminary user requirement*

Expectation	Preliminary user requirement
The envisioned solution will improve waste separation on the UT waste islands	Clear information that how and why separate waste properly at the UT island
The envisioned solution will improve the recycling rates of the waste.	

4.1.1.4. Designer

The designer is the person who creates the envisioned solution for the client to solve the problem. The designer conducts the background research with a literature review and state of the art and formulates the requirements that need to be considered during idea generation alongside the stakeholder analysis. Based on the requirements drawn out of the background research the stakeholder analysis, the designer creates various concepts that fulfil the requirements. The designer expects the envisioned solution will satisfy the stakeholders. The designer has high power and interest as the designer is the primary project owner and decides on the final envisioned solution, develops it, and evaluates it. Table 5 shows the expectation and the preliminary user requirement of the designer.

[3] https://prezero.nl/aanlevervoorwaarden (Last visited: 06-05-2022)

Table 5. *Designer's expectation and preliminary user requirement*

Expectation	Preliminary user requirement
The envisioned solution will satisfy the other stakeholders.	Create the envisioned solution that satisfy the other stakeholders.

4.1.1.5. Supervisors

Supervisors are responsible for guiding the designer to finish the project with a stakeholder-satisfying envisioned solution. They evaluate the project result of the designer. They require a tangible prototype that the user can test. Therefore, the expected solution should be tangible to be able to get tested by the end-users. They have high power and interest as they guide the project, and they will evaluate the final envisioned solution. Table 6 shows the expectations and a preliminary user requirement of the supervisors.

Table 6. *Supervisors' expectation and preliminary user requirement*

Expectation	Preliminary user requirement
The envisioned solution will be tangible to be able to get tested by the end-users.	Create the envisioned solution that is tangible and testable by the end-users.

4.1.2. Power versus Interest Grid

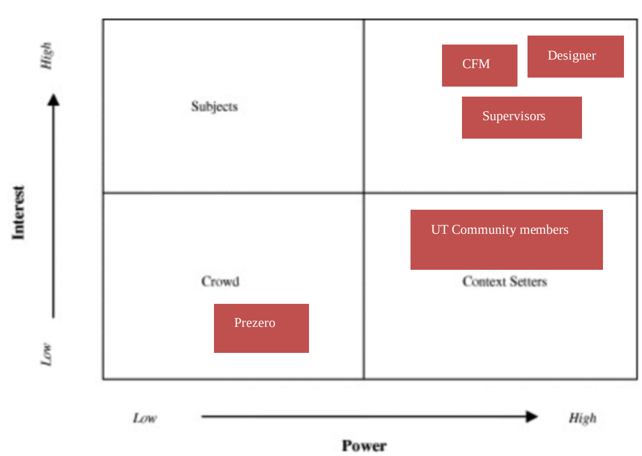


Figure 14. *Power versus interest grid of improving waste separation on Campus project*

Power and interest in the project are various per stakeholder. And those affect the user requirements prioritisation. The power versus interest grid will be used to map the stakeholders in terms of power and interest and see who has the most influence and the highest interest. In this project, CFM, the designer, and the supervisors are stakeholders with both strong power and interest in the project. The designer has the most substantial power in the decision of the final envisioned solution, followed by UT community members, Supervisors, CFM, and Prezero. UT community members are users of the UT waste islands. They have direct power regarding the design of the envisioned solution. However, they are not much interested in the project compared to CFM as they are not the primary client. Prezero has less interest in the project than any other stakeholders as they indirectly influence it.

In summary, in power ranking, first is designer, second is UT community members, third is supervisors, fourth is CFM, and fifth is Prezero. In interest ranking, first is designer, second is CFM, third is supervisors, fourth is UT community members, and fifth is Prezero. Figure 14 shows the power versus interest grid for the project. This power versus interest grid will be referred to during preliminary requirements elicitation to justify the preliminary requirements.

4.1.3. Preliminary Requirements

Throughout the stakeholder analysis, stakeholders' expectations are examined. Their expectations are compared to the requirements that were concluded from background research. And those are prioritised using the MosCow method with a relation of power versus interest grid. Table 7 shows the requirements of the project and their prioritisation.

Table 7. User requirements of the project

No.	User requirements	Sources	Prioritisation
R1	Clear information that how and why separate waste properly at the UT island, with a quick and easily understandable decision-making process of waste separation, and it should be easy to catch with special consideration on the certain waste types (plastic waste, food packaging, residual waste, and mixed waste)	Background research, Stakeholder analysis (CFM, UT community members, Prezero)	Must have
R2	Include visuals like pictures in the solution rather text-only	Stakeholder analysis (CFM, UT community members)	Must have
R3	Locate the envisioned solution at an easily accessible point, like it should be in eyesight, and with big text and visuals so that it can be readable from a distance, in front of the UT waste islands contextually	Background research Stakeholder analysis (UT community members)	Must have
R 4	The solution should provide a clear reason for recycling, for example, what desired situation UT wants on each waste stream	Background research Stakeholder analysis (CFM, UT community members)	Must have
R5	Provide feedback based on the user's action, for example it should still provide feedback whether they check or don't check the solution in positive way.	Background research Stakeholder analysis (UT community members)	Must have

R6	Be non-discriminatory therefore be able to be used by any users regardless of race, colour, sex, or language.	From Background research	Must have
R7	Provide information regarding waste management process (confirmed by Prezero) to emphasise transparent waste management system	Background research Stakeholder analysis (CFM)	Should have
R8	Include reporting system where user can send their uncertain waste	Stakeholder analysis (CFM)	Should have
R9	Be interactive, while considering attracting people (e.g., aesthetic, playfulness)	Background research	Should have

R1 to R6 are considered as 'Must have'. Without those requirements' fulfilment, there is no point in implementing a solution [44]. Also, those requirements are from background research and stakeholders with enough power and interest in the project. Therefore, they must be achieved in the solution. From R7 till R9 are considered as '*Should*' have. Those are essential requirements, but the project can be continued without them. R7 and R8 are 'Should' because they are requirements from background research or CFM that CFM prioritised R1 as the essential requirement, while R7 and R8 are rather additional requirements. Those requirements were used to evaluate each concept.

4.2. Preliminary Concepts

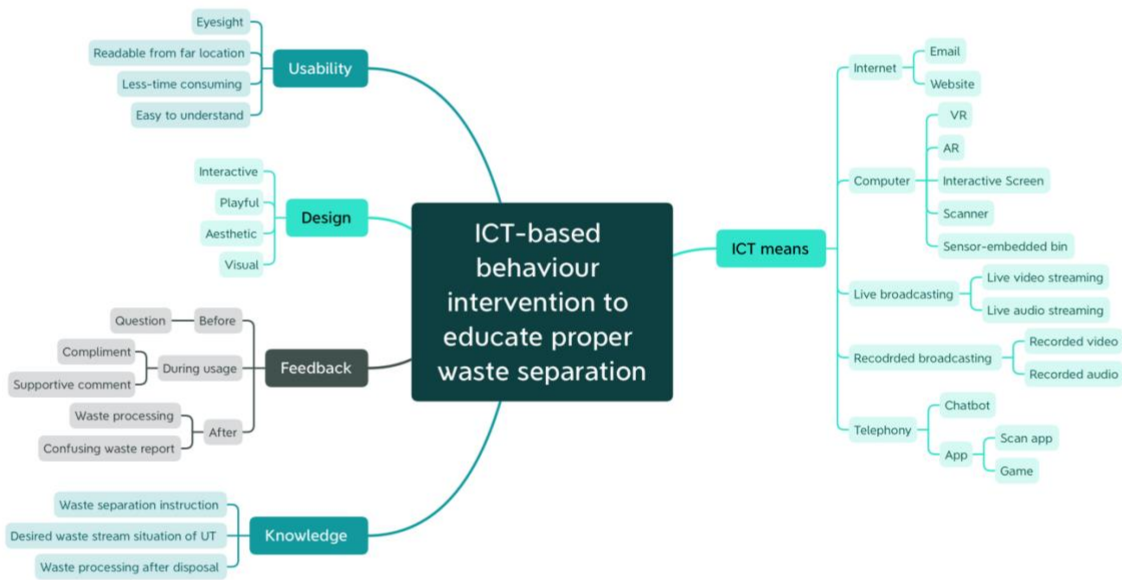


Figure 15. *Mind map to help concept generation*

Various concepts were generated throughout the focus group discussions (see Table 2). They are used as rough ideas and then further brainstormed, utilising the mind mapping technique. Figure 15 shows the mind map to help concept generation.

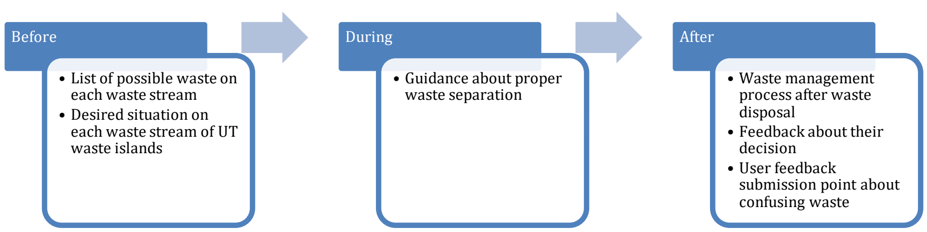


Figure 16. *Behaviour intervention process through knowledge*

Figure 16 shows the behaviour intervention process through knowledge. It was confirmed that three different kinds of knowledge should be provided during the behaviour intervention process. Therefore, all concepts follow this process. As it repeats each idea's explanation, the concept explanation focuses on how the idea interacts with the user. Thus, all ideas fulfil Requirements R1, R4, R5, R6, and R7. In total, five concepts were generated. Each concept is explained with a short scenario of how the user will use the product.

4.2.1. Self-scanner of Waste (C1)

Figure 17. *self-scanner of waste (C1)*

The first concept is a supermarket self-checkout installation (see Figure 17). It has a scanner below that detects plastic-type or recycling symbols. If there is no label, the user can select the pictures shown on the screen. The most confusing waste will be presented as pictures. Therefore, paper and organic waste are not primarily presented on the home screen. When clicking the product, the user can see that one of the waste bins is lit up as to the right bin, and the user can throw away the waste. All requirements are fulfilled in the first concept.

4.2.2. Decision Tree of Waste Separation (C2)

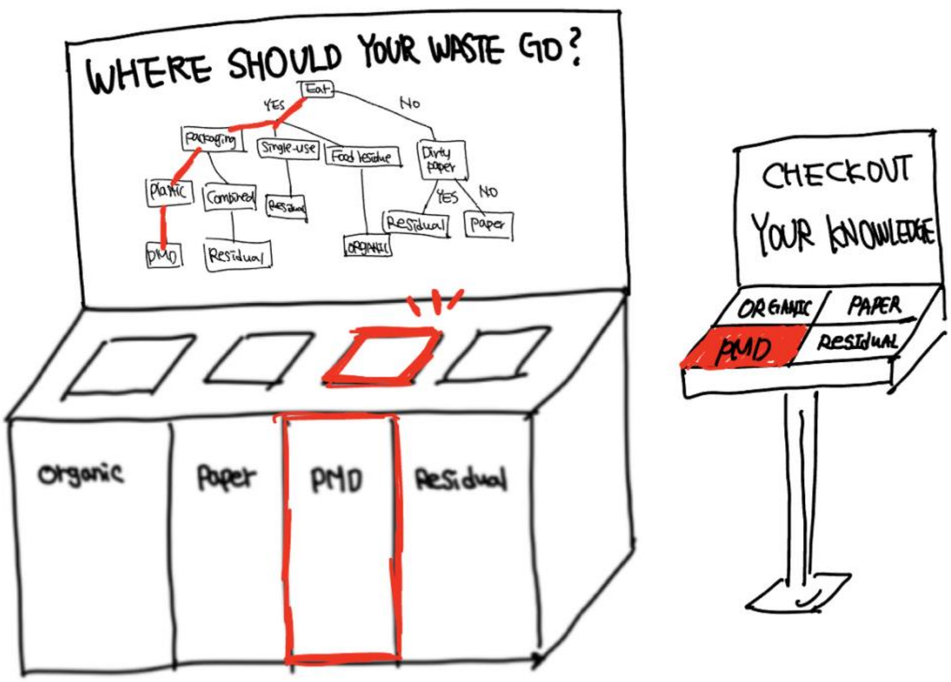


Figure 18. *Decision tree for waste separation (C2)*

The second concept is the decision tree (see Figure 18). When the user clicks the button of each waste stream right next to the bin, the user can see the decision tree branch according to the waste stream. The decision tree shows the possible requirements of a specific waste stream. After checking the potential waste stream, the user disposes of the waste in the bin accordingly. For example, if a user chooses the PMD button, the user will see the decision tree branch that shows the possible waste that belongs to PMD. Whether the user has waste related to eating, it offers a “yes” or “no” situation. After checking the decision tree, the user can dispose of waste in the PMD bin. All requirements are fulfilled except the R2, as there are no visuals like pictures.

4.2.3. Motivate People Each Other (C3)

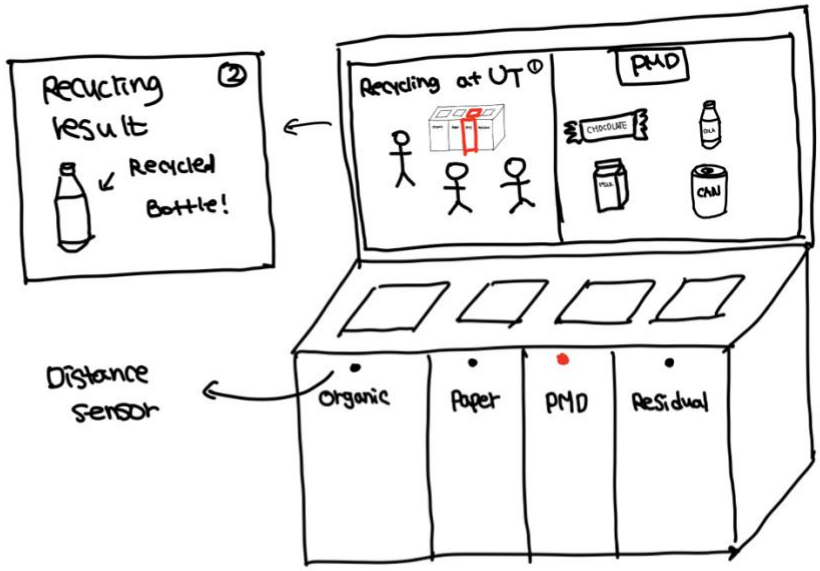


Figure 19. *The screen shows the possible wastes that are thrown away in a particular bin, and the video that people throwing away the correct waste in the bin (C3)*

The third concept is a screen that shows the possible wastes thrown away in a particular bin. A video shows people throwing away the correct waste in the bin when the user is closer to the bin and detected by a distance sensor (see Figure 19). It creates peer pressure by showing people in the UT community that they throw it away correctly. Therefore, social norms are emphasised. Also, people could learn where the waste goes after they throw it away. The concept has constraints of showing all the example waste lists of each waste stream. All requirements are fulfilled in the first concept.

4.2.4. Chatbot guiding Waste Separation (C4)

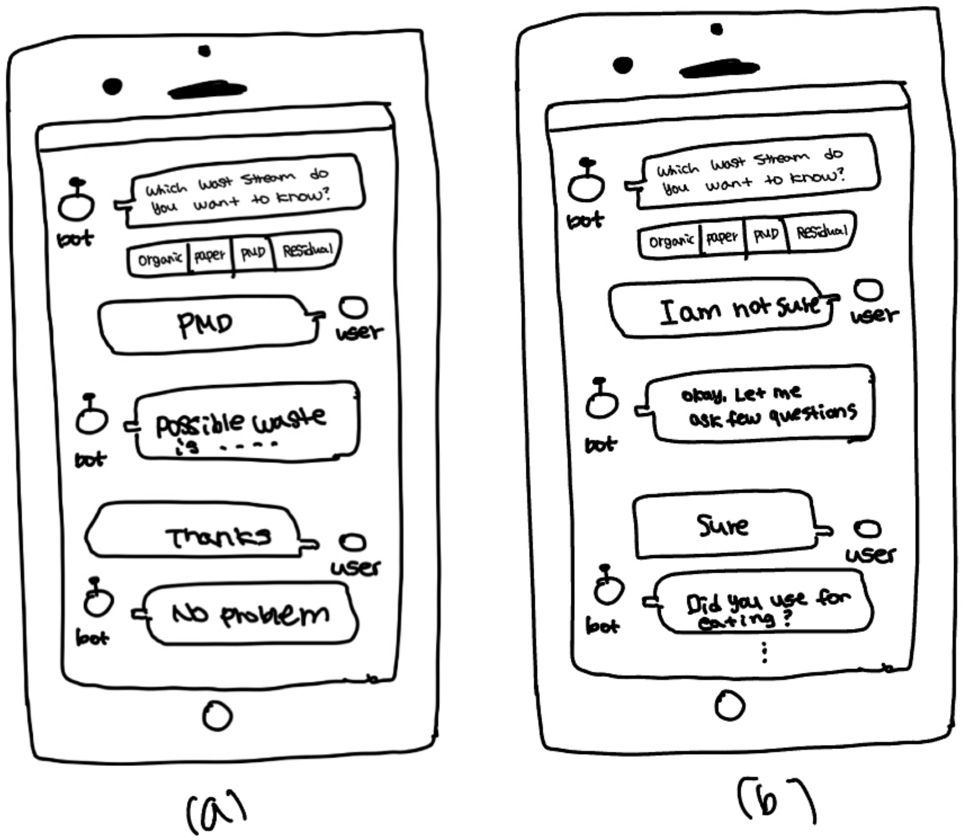


Figure 20. *Chatbot guiding waste separation (C4)*

The fourth concept is a chatbot application that guides waste separation. The user will ask about a possible waste stream that the user wants to know (see Figure 20). The chatbot will guide the waste according to the question shown in Figure 20 (a). When the user is unsure which stream the user needs to choose, the chatbot asks some questions to show the correct waste streams, illustrated in Figure 20 (b). The questions can be formulated based on the decision tree used in C2. All requirements are fulfilled except R3, as it is a mobile application, therefore, the envisioned solution cannot be located next to the waste islands.

4.2.5. AR application that guides possible waste on each waste stream (C5)

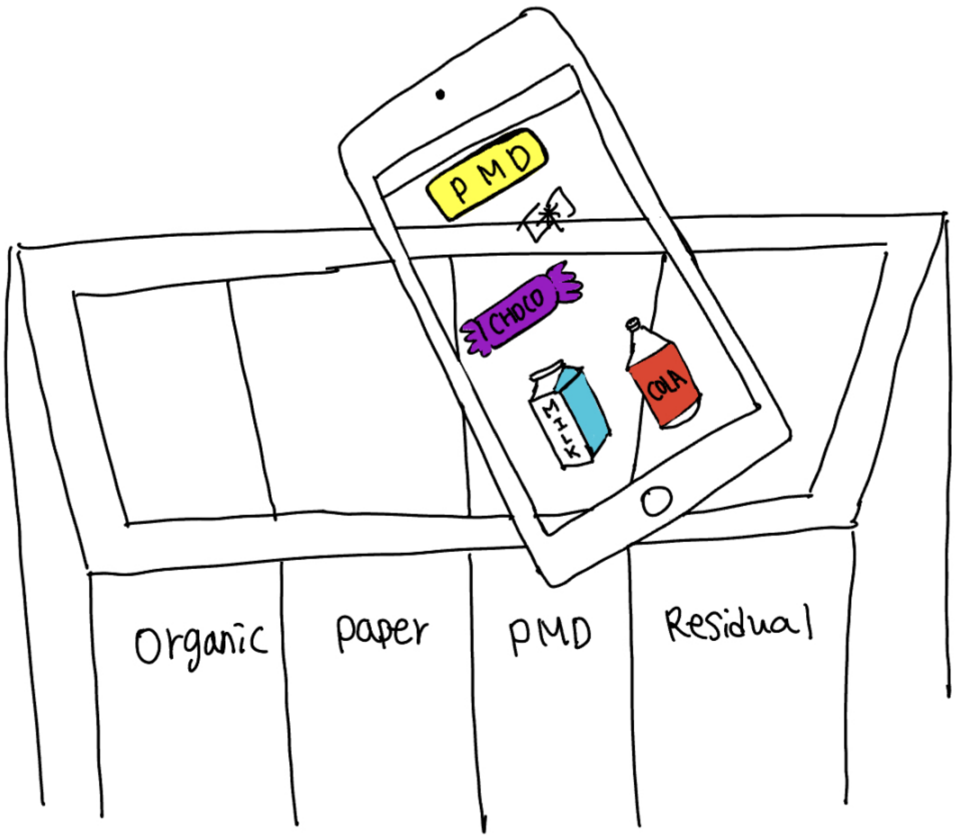


Figure 21. *AR application that guides possible waste on each waste stream (C5)*

The fifth concept is an AR application that guides possible waste on each waste stream. When the user puts the application screen of the smartphone near each waste stream like PMD, the scrollable screen shows potential waste that can be disposed of in the bin with an image. The user can compare its waste to each waste stream guidance. All requirements are fulfilled except R3, as it is a mobile application which makes it difficult to be located next to the waste islands.

4.3. Final Concept Decision

After five concepts were designed, a comparison of ideas was conducted. Advantages and disadvantages are listed, and the fulfilment of preliminary requirements is discussed.

4.3.1. Concept Selection Process

Before selecting the concept, the advantages and disadvantages of the five concepts were compared, and the fulfilment of the preliminary requirements was evaluated.

Table 8 shows the comparison of the concepts.

Table 8. *Advantages and disadvantages of three concepts with preliminary requirements fulfilment*

Concept	Advantages	Disadvantages	Preliminary requirements fulfilment
C1	Time is saved as the automatic scanning is possible.	It is difficult to create a database, and developing the technology is not trivial. Camera detection could create privacy and security issues. People would not learn the correct waste separation themselves as it is automated.	R1, R2, R3, R4, R5, R6, R7, R8, R9
C2	It enables users to learn decision-making process	Time is not saved. People will not check the decision tree.	R1, R3, R4, R5, R6, R7, R8, R9
C3	It creates peer pressure so that people do not neglect the information on the	Time is not saved.	R1, R2, R3, R4, R5, R6, R7, R8, R9

	screen		
C4	It helps to guide users through interactive conversation process	Time is not saved. Additional steps to install application	R1, R2, R4, R5, R6, R7, R8, R9
C5	It is interesting to use, therefore could be attractive to use.	Time is not saved. Additional steps to install application	R1, R2, R4, R5, R6, R7, R8, R9

Figure 22. Chosen concept: decision tree with a selection of waste

As discussed, all concepts meet the requirements R1, R4, R5, R6, and R7. However, C4 and C5 interactions take additional steps to install the application. Also, since CFM plans to develop a serious gaming application [12, 4.1], C1, C2, and C3 are selected to discuss the final concept of the project with the client CFM. The client liked all concepts because all concepts contain educational content. The preferred concepts were C2 and C1. C2 was extensively discussed as a possible concept, as it is easy to understand and embeds logic in the user’s mind. Combinations of C1 and C2 were also discussed. Therefore, users can select the waste shown in C1 and check the decision process to choose the right bin by the decision tree.

The advantages and disadvantages of the five concepts were discussed during the meeting with supervisors. The final concept was decided as concept 2. Because it was the client's most preferred concept, it fulfilled the preliminary requirements. One concern is the time takes to reach a specific waste stream. Therefore, interaction is added by letting the user choose the waste that the user holds. (see Figure 22). If the user selects the 'I am not sure' button on the screen, the user can check the entire decision tree.

4.3.2. Concept Finalisation Process

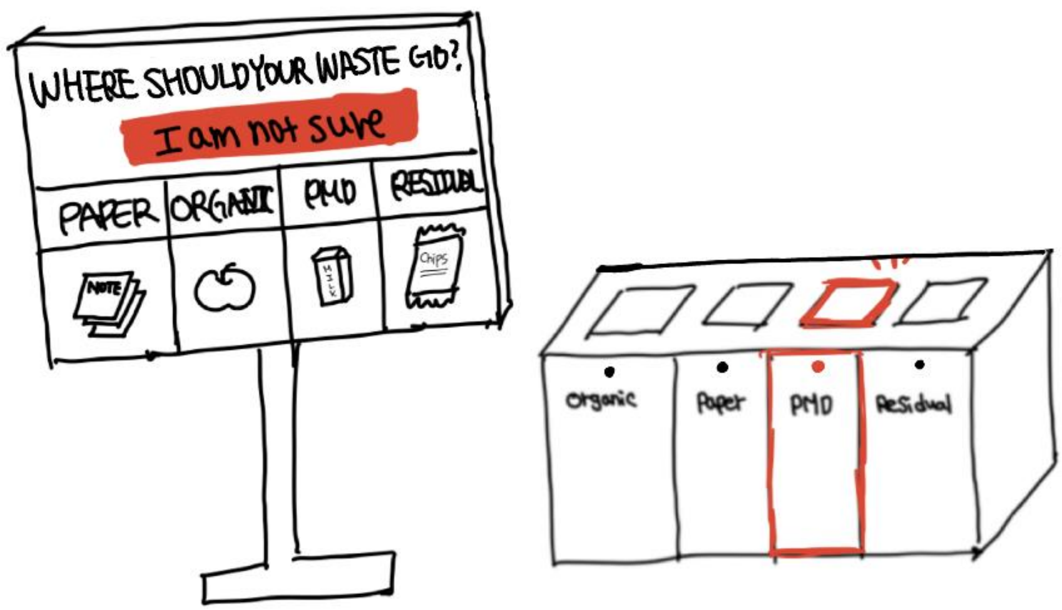


Figure 23. *Finalised concept: Interactive screen that asks questions about waste and guides proper waste separation*

As time is considered one of the most critical constraints, instead of providing the decision tree, asking questions was considered a better solution to reach the information they wanted and needed, like C4 (see Figure 20). The questions should not take too long to get the information, and easy to determine answers. Therefore, behind the questions, there is still a decision tree that should be developed from the engineering side, but users will ask questions to get an answer. It will help the user understand the logic of the decision-making process regarding waste separation. It will save time as the user will get the information based on their situation. The number of questions should be as limited as possible.

Therefore, the final concept is an interactive screen with pictures of possible waste on each stream and the 'I am not sure' button when the user is unsure which waste stream the user should check. Each waste stream has a visual description of the desired situation of each waste stream at the UT waste islands and the consequences if the user disposes of it properly to meet requirement R4. When the user stands in front of each waste stream bin, the sensor attached to the front part of the bin detects the user's presence, and the screen shows information regarding the waste stream. For example, if the user is standing in front of a PMD bin, the screen shows the requirements for waste disposal of PMD (e.g., it should be packaging materials) and the waste process after the disposal. Users can select different buttons on the screen that help to separate the waste properly. First, the user can choose the image presented on the screen. These images should be the most confusing waste from the UT community members. During the observation session, it was found that mixed waste, food packaging, plastic waste, and residual waste are the most confusing waste. Therefore, the main image shown on the home screen should be food packaging waste like plastic bottles, paper cups, or single-use cutleries. Second, users can select different waste streams to see the requirements of the waste. Third, users can choose the "I am not sure" button to get a question to determine which waste belongs to which bin. After the user receives the instruction, the user can dispose of waste in the bin. After disposal, the screen asks, "Are you sure you disposed of it correctly?". It is a valuable question that ensures the user checks the correct information. This question feedback should be constructed carefully so the user does not feel unconformable about the question. The visual description of waste processing will be presented when the user stands in front of the bin.

5. Specification

The final solution was decided during the ideation phase as an interactive screen with a feedback function that detects the user’s waste disposal movement. However, the specification phase is focused on the interactive screen due to the resource constraints (e.g., time) and scoping of the project with a discussion of the supervisors. Therefore, R5 from preliminary requirements is omitted in the solution. The specification starts by creating personas and fictional characters representing different user types of the solution [45]. Next, visual requirements are listed in functional and non-functional requirements with MosCow prioritisation. Based on personas and visual requirements, a storyboard is created to facilitate concrete conceptualisation of the solution.

5.1. Personas

Personas have names, pictures, ages, personality traits, personal backgrounds, goals, and frustrations. Stakeholder analysis identifies the UT community members as students, employees, researchers, and visitors. Since researchers are working in the university, they are employees as well. Also, the community has an international characteristic. Three personas are created. The first persona is a Dutch student who has partial knowledge of recycling. The second persona is an international student who is not used to separating waste. The third persona is an assistant professor who has already sure about the waste separation method. When using Waste Separation Guide Service (WSGS), they described their goals and frustrations with personal characteristics. All personas were created with Figma [51].

5.1.1. Persona 1: Dutch Student

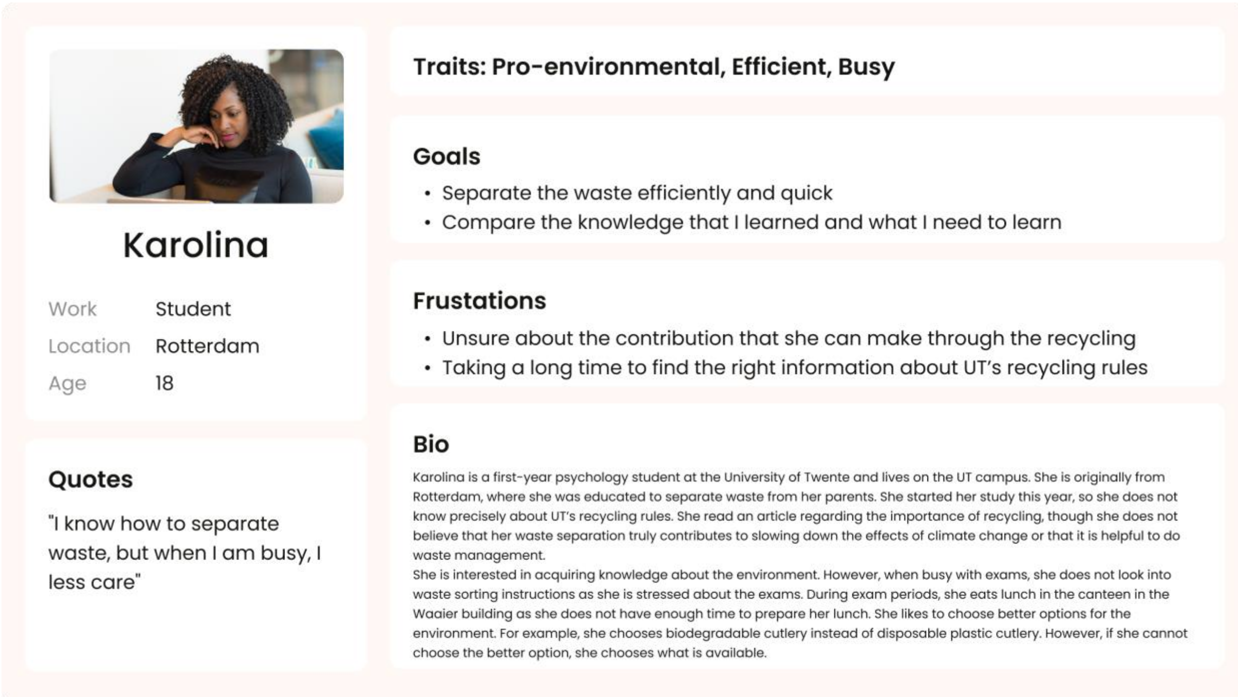


Figure 24. *User persona: Dutch student Karolina*

One of the user types is a Dutch student who already knows about waste separation rules in the Netherlands. They have gotten used to separating waste from their habits at home. However, there is a possibility that the rules that they know are different from UT's recycling rules. Therefore, the user persona is created as Karolina from Rotterdam (see Figure 24). She learned how to separate waste properly from her parents. She is interested in environmental issues. Therefore, she would like to choose eco-friendly options in her daily life. However, she is usually busy because she has multiple assignments and exams. She wants to separate waste properly; however, she does not have enough time to investigate the correct information. Therefore, she needs some service that can give her instructions about proper waste separation according to UT's recycling rules. Also, she is already getting used to recycling, though she is unsure about the impact of recycling. She wants to know more about how her actions influence waste management.

5.1.2. Persona 2: International Student

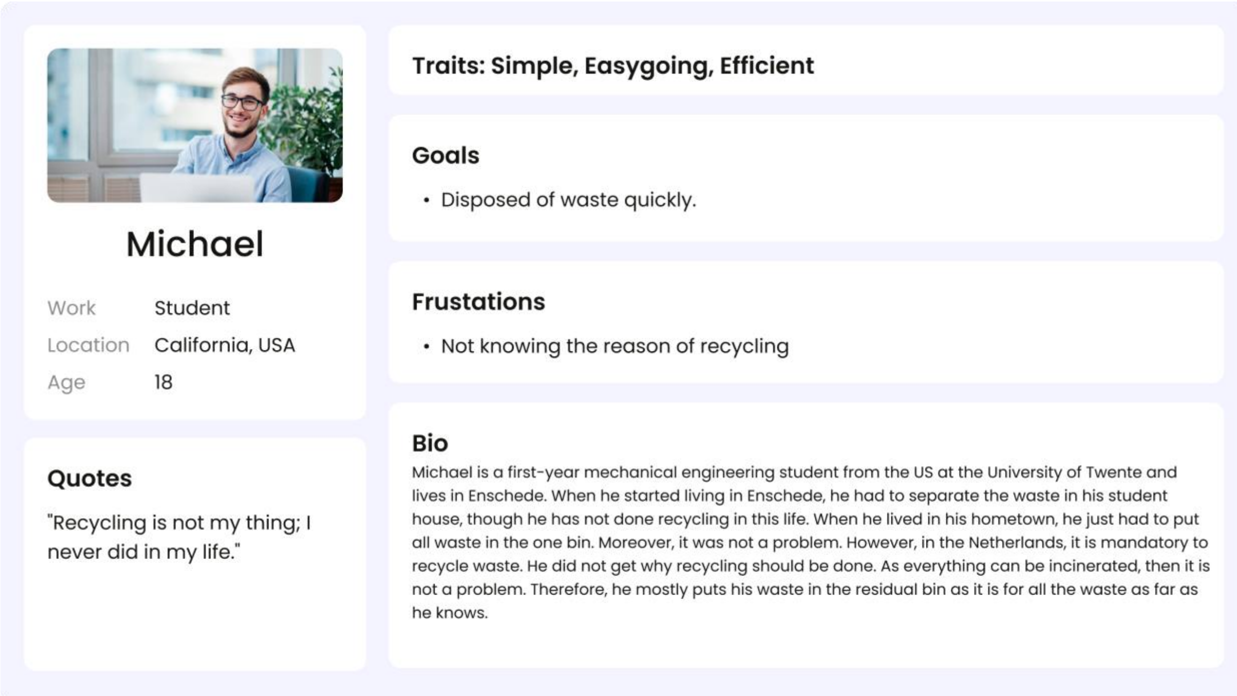


Figure 25. *User persona: International student: Michael*

The second user type is an international student. Most countries have their own recycling rules. Some countries are not recycling. Therefore, Figure 25 shows an international student Michael who is from a city where recycling is not obligated. He is not used to recycling in his life. However, he needs to learn how to do recycling properly as he lives in the Netherlands. He usually disposes of most waste in the residual bin as he believes all waste can be incinerated.

5.1.3. Persona 3: Assistant Professor

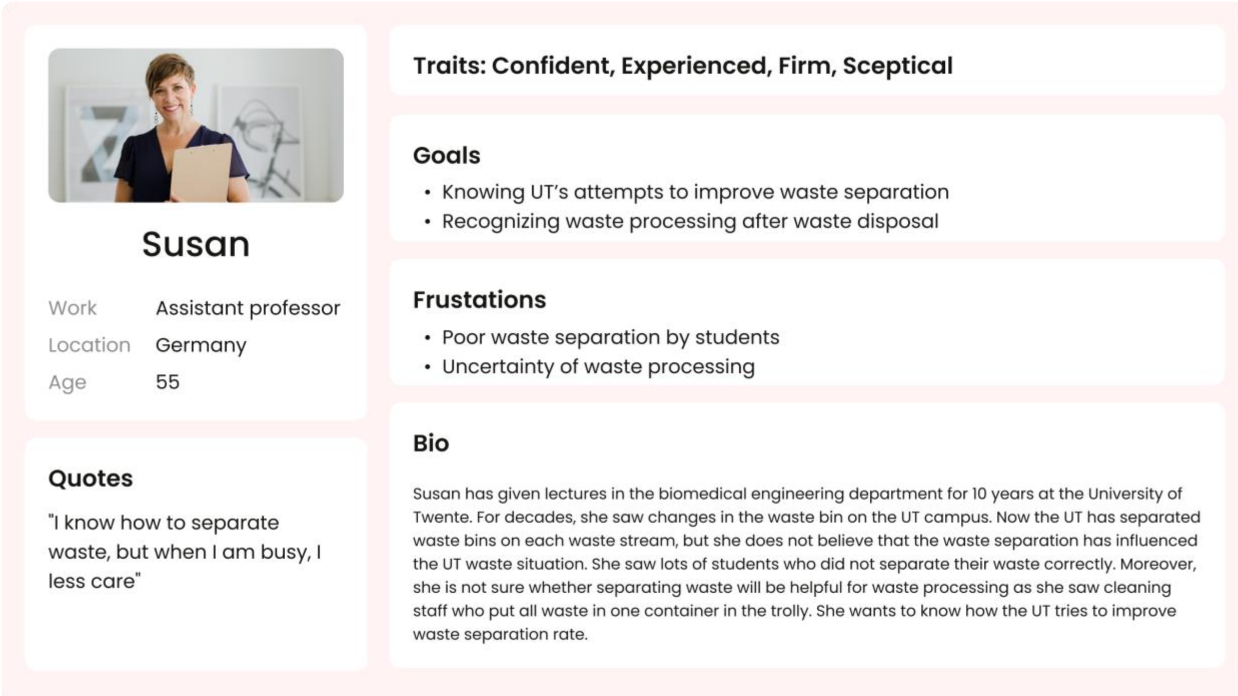


Figure 26. *User persona: Assistant professor*

The third user type is an assistant professor. They are categorised as employees of the UT. Figure 26 shows assistant professor Susan who gave lectures at UT for ten years. She has observed that the campus's policy regarding waste separation has changed. However, she is unsure whether the recycling rate has increased as she observed students who do not correctly separate waste. She would like to know how the UT tried to increase the waste recycling rate and how the waste is processed after disposal.

5.2 Visualisation Requirements

Requirements are necessary to design the solution, so all stakeholders' needs are involved. The visualisation requirements are determined to create WSGS, and those are prioritised using the MosCow method [44]. There are four types of prioritisations: '*must'*, '*should'*, '*could'*, and '*won't'* have. Prioritised requirements will be used to evaluate the solution implemented in the realisation phase. Firstly, functional requirements are listed, and non-functional requirements are listed.

5.2.1 Functional Requirements

Functional requirements explain what the system does, and it specifies product features. Table 9 shows the list of functional requirements. Functional requirements are based on preliminary requirements identified in chapter 4.

Table 9. *Functional requirements of WSGS*

<table>
<tr><th>No</th><th>Requirement</th><th>Priority</th></tr>
<tr><td>FR1</td><td>Select a waste image and find correct waste stream among four waste streams (residual, PMD, organic, and paper) on the touch screen.</td><td>Must</td></tr>
<tr><td>FR2</td><td>Select buttons for one of four different waste streams (residual, PMD, organic, and paper) on the touch screen to see the information describing requirements to be disposed of that waste stream with visualisation.

Residual requirements
The waste contains aluminum materials.
Combined packaging materials.
Dirty papers
Residual waste symbols
PMD requirements
The waste is packaging based
The waste inside should be emptied
The waste should not be hard plastics, if it is not used for packaging, it is hard plastics.
PMD waste symbols
Organic requirements
Food waste
Food waste symbols
Paper requirements</td><td>Must</td></tr>
</table>

	• Clean paper. The paper with a paper clip or staple is fine. • Clean cardboard • Clean magazines • Paper waste symbols	
FR3	See the recycling process after waste disposal with visualisation Residual • Residual waste is incinerated, and it is used to generate electricity and heat. PMD • The PMD waste is sorted to be recycled. Organic • The organic waste will be fermented and composed. Those will be used to generate green gas or electricity. Paper • The papers will be sorted and recycled.	Must
F4	See the desired situation of the UT of each waste stream Residual Desired situation: The amount of waste should be decreased by ¼ of 43kg approximately. PMD Desired situation: No unnecessary plastic usage. Reduce plastic waste. Organic Desired situation: Circular campus (e.g., coffee grounds are collected and recycled).	Must

	Paper Desired situation: More digitization, less paper use.	
FR5	Select a button that says "Click here if you are not sure" on the touch screen (question designed from the decision tree, see Figure 28) and get questions to determine the waste stream of the waste	Must
FR6	See that the screen goes back to start screen after pressing go back to start screen button	Must
FR7	Read the information on the touch screen from eyesight.	Must
FR8	Read the information on the touch screen from a distance	Must
FR9	Send question regarding uncertain waste to CFM	Should

Functional requirements from FR7 to FR9 are requirements derived from preliminary requirements. FR6 is necessary to improve the user's convenience in using WSGS. FR1 to FR5 is related to waste separation knowledge. During the background research, it was found that knowledge is one of the important behavioural intervention determinants. Moreover, it has three different types of knowledge. The first is correcting the method regarding waste separation on the UT campus. The correct information should be confirmed information by CFM and Prezero to provide information to users in the UT context. The second is about the goal of waste separation. The desired situation regarding UT waste separation will be presented. The third piece of information is about the waste management system. Confirming that proper waste separation facilitates the waste management process will motivate users to separate their waste correct—the result of waste separation and information in waste process management on the Prezero website[4]. The data will be gathered through the website, and the knowledge delivery should be designed contextually. FR1and FR2 details were decided after waste stream analysis. FR3 and FR4 are from CFM's waste plan [11]. FR5 is necessary to provide decision logic to the users.

[4] https://prezero.nl/diensten/afvalmanagement (Last visited: 23-05-2022)

5.2.1.1. Waste stream analysis

Functional requirements FR1 and FR2 are related to knowledge regarding waste separation. First, waste analysis was conducted to understand the current waste situation at the Waaier building in cooperation with CFM on the 14th of December 2021 at 15:30 to understand the waste separation situation of UT. During the waste analysis, it was found that the waste that creates the most confusion is paper cups. Also, most waste is related to food packaging, which was already concluded in the preliminary requirements. After then, location analysis was conducted as different locations influence the waste created at the building. Through the waste analysis in the building, it is confirmed that the following waste should be considered as the waste that can be shown as the main image; paper cups, single-use wooden cutleries, bottles, and candy bar wrappers.

After waste analysis, waste stream analysis was conducted. At the University of Twente, PMD, organic, paper, and residual waste are four different waste streams. Each waste stream has an example waste list provided by CFM and confirmed by Prezero (updated 17-06 -2022) (see Appendix D). Also, in the Prezero website[5], the delivery conditions of each waste stream are described. With that information, the requirements of each waste stream will be formulated. First, the example list will be investigated to see what kind of waste belongs to the waste stream. Secondly, requirements will be formulated.

According to the example waste list, permitted waste in the residual stream is the same as the following:

- Face masks
- Aluminium packaging (crisps bags)
- Tea bags
- Pen
- Used tissues
- Pringles cans
- Receipts
- Flowers
- Aluminium foil
- Packaging with multiple materials (e.g., plastic and paper)

Not permitted waste in the residual waste stream is the same as the following:

- Glass

[5] https://prezero.nl/aanlevervoorwaarden (Last visited: 23-05-2022)

- Batteries
- Electronics
- Chemical waste
- Toners and cartridges
- Electronics
- PVC
- Aerosols
- Cleaning cloths
- Smoke detectors
- Bulky waste
- Oils and liquids

Some facts can be concluded from the list. First, dirty papers are not allowed. Secondly, if there is aluminium packaging in the waste, it should be disposed of in the residual waste bin. Thirdly, combined material packaging can go to the residual bin.

Therefore, requirements to be separated in the residual waste stream could be formulated as follows:

- Dirty papers
- The waste contains aluminium materials
- Combined packaging materials

According to the example waste list, permitted waste in the PMD waste stream is the same as the following:

- Plastic bottles
- Cans
- Drink cartons
- Plastic food packaging
- Plastic cosmetics packaging
- Paper coffee cups
- Candy wrappers
- Biobased plastics
- Plastic film (for wrapping food)
- Plastic carrier bags

Not permitted waste in the PMD waste stream is the same as the following:

- Food waste
- Paper and cardboard
- Residual waste
- Styrofoam
- Aluminium packaging (crisps bags)
- Aluminium foil
- Hard plastics
- Not empty packaging
- Packaging > 5 liters
- Aerosols
- Packaging into which another material has been put
- Packaging > A4 size
- Packaging with hazard symbol
- Medication/chewing gum strips

Some facts can be concluded from the list. The waste is mostly packaging based. And the waste should be emptied. It should not be bigger than the A4 size. However, most food packaging is not bigger than A4 size. Therefore, it doesn’t have to be mentioned. The waste should not be hard plastics.

Therefore, requirements be separated in the PMD waste stream could be formulated as follows:

- The waste is packaging based
- The waste inside should be emptied
- The waste should not be hard plastics. If it is not used for packaging, it is hard plastic waste.

According to the example waste list, permitted waste in the organic waste stream is the same as the following:

- Coffee grounds
- Coffee pads
- Food waste
- Fruit and vegetable waste

- Bread
- Soup
- Fish and meat waste
- Dairy products

Not permitted waste in the organic waste stream is the same as the following:

- Packaging
- Paper and cardboard
- Flowers
- Tea bags
- Oil
- Biobased plastic
- Aluminium coffee pods
- Cheese rind
- Shells (oysters etc.)
- Compostable bags
- Garden waste
- Spoiled animal by-products

Some facts can be concluded from the list. Mostly it is food waste that is possible to be disposed of in the organic waste stream.

Therefore, requirements to be separated in the organic waste stream could be formulated as follows:

- Food waste

According to the example waste list, permitted waste in the paper waste stream is the same as the following:

- Paper
- Cardboard
- Magazines
- Printing paper
- Paper with staple or paper clip

Not permitted waste in the paper waste stream is the same as the following:

- Used tissues
- Laminated paper
- Paper cups
- Contaminated paper
- Pizza boxes
- Foil and plastics
- Receipts
- Food residues
- Carbon paper
- Paper packaging with PE coating
- Drink cartons
- Binders

Some facts can be concluded from the list. It should be of clean paper which is not wet or greasy. However, paper with a paper clip or a staple can be disposed of in the paper waste stream. Clean cardboard or magazines are also disposed of in the paper waste stream.

Therefore, requirements to be separated in the paper waste stream could be formulated as follows:

- Clean paper and paper with a paper clip or staple are fine.
- Clean cardboard
- Clean magazines

Figure 27. *Weggooiwijzer symbols*

Additionally, waste logo analysis was conducted to facilitate a more straightforward and quick understanding of waste. In the Netherlands, symbols called "Weggooiwijzer[6]" guide which part should go to which waste bin (see Figure 27). If users check the symbol, then it will be easier to separate the waste. In the solution, a question regarding containing the symbols will be asked to categorise the waste efficiently.

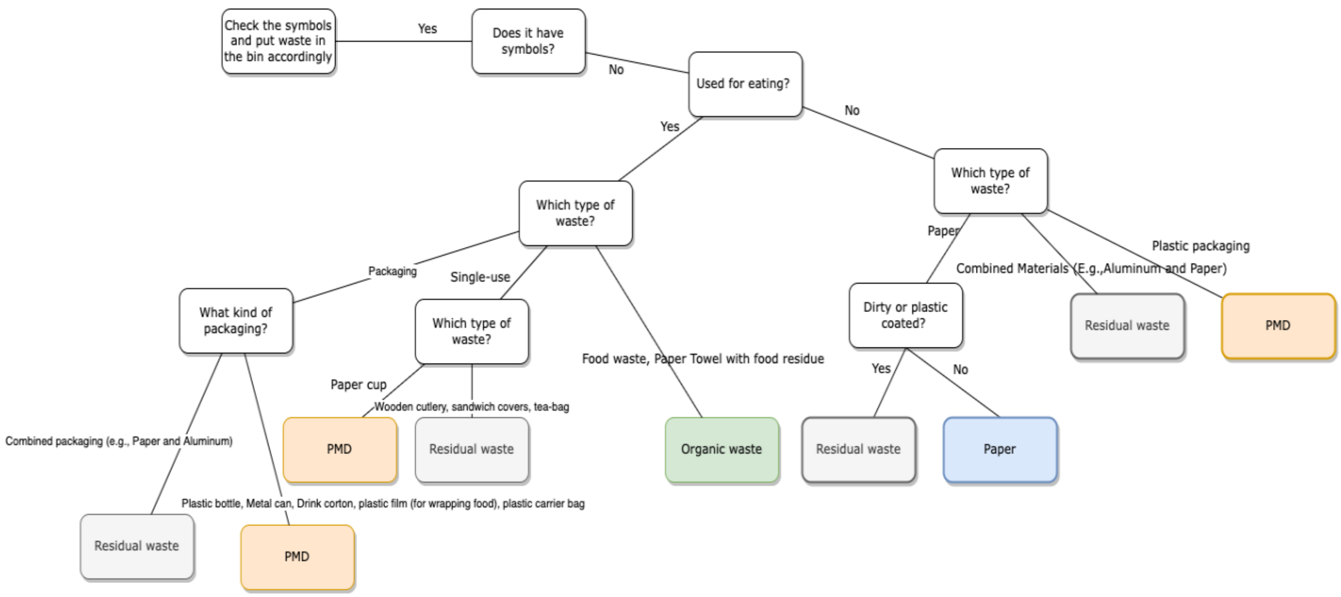


Figure 28. Decision tree for waste separation guiding questions

Based on requirements, a decision tree is designed to formulate questions (see Figure 28). That decision tree is used to develop questions when the user is unsure about the waste stream.

5.2.2 Non-functional Requirements

Non-functional requirements are related to how the system should function.

Table 10 shows non-functional requirements based on background research and stakeholder analysis.

[6] https://kidv.nl/weggooiwijzer (Last visited 23-05-2022)

Table 10. Non-functional requirements of WSGS

No	Requirement	Priority
NFR1	The information provided on the touch screen is accurate based on reliable source which is confirmed by Prezero (reliability)	Must
NFR 2	Time to get the information to separate the waste correctly is within 4-5 seconds (response time)	Must
NFR 3	Feedback regarding uncertain waste by user is collected anonymously and not collecting user's personal data (privacy and security)	Must
NFR 4	The functionality is easy and accessible to users (usability)	Must
NFR 5	The functionality is non-discriminatory therefore be able to be used by any users regardless of race, colour, sex, or language	Must
NFR 6	The number of questions does not exceed more than 5 when the user selects "I am not sure" button.	Should
NFR 7	The design of the user interface is appeal to the user aesthetically.	Should
NFR 8	The user interface is interactive.	Should

5.3. Storyboard

The storyboard helps the designer to conceptualise the product easier. Persona 1 Karolina is the main character who interacts with WSGS. The storyline supports the storyboard. The entire storyboard is presented in Appendix E.

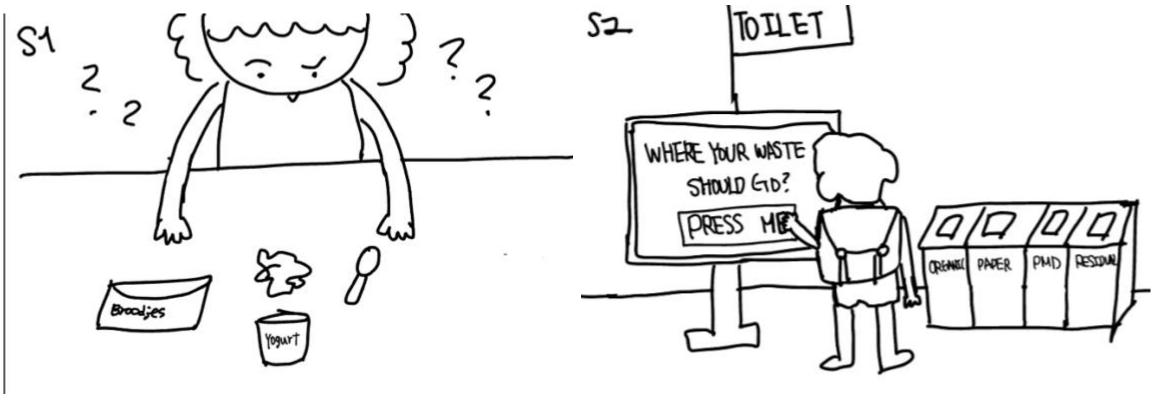


Figure 29. *(From left) Scene 1: waste created at lunch, Scene 2: Select the 'press me' button on the screen*

The first scene is about waste created at lunch (see Figure 29 S1). At lunchtime, Karolina goes to the canteen to grab a quick lunch. Today, she chose vanilla yoghurt and Frikandelbroodje and ate them during the lunch break. After finishing lunch, she had a bunch of waste from the lunch. She had plastic packaging from the yogurt, greasy paper from the Frikandelbroodje cover, a wooden spoon, and tissue papers used to clean the food scraps from the table.

The second scene selects the ‘press me’ button on the screen (see Figure 29 S2). She goes to a waste island near the toilet to throw away her waste. At about 10m, she sees a big screen next to the waste island that she did not see previously. She looks at the text on the screen with the button ‘Press me’. She is interested in the screen and presses the button.

Figure 30. *(From Left) Scene 3: select wooden cutlery in the residual waste section, Scene 4: requirements of the residual waste stream and the recycling process after waste disposal, Scene 5: dispose of waste in the residual waste bin*

The third scene describes Karolina selecting wooden cutlery in the residual waste section (see Figure 30 S3). After clicking the button “Press me”, she sees the main screen. It displays each waste stream with the main waste images and desired situation of each waste stream. Also, there is a ‘Click if you are not sure’ button. She finds the wooden cutlery in the image list from the residual waste section, and she chooses that.

The fourth scene shows a residual waste information display (see Figure 30 S4). The screen indicates that it should belong to the residual waste as a wooden spoon, and it displays requirements of the residual waste stream and information that waste will be incinerated and converted to heating energy. It also mentions that proper recycling helps improve waste processing. After knowing that she had made the right decision for waste disposal, she felt good that she had helped to improve the recycling process after waste disposal. Also, she found that her paper waste should go to the residual waste. She puts the Frikandelbroodje cover and wooden spoon in the residual waste bin (see Figure 30 S5).

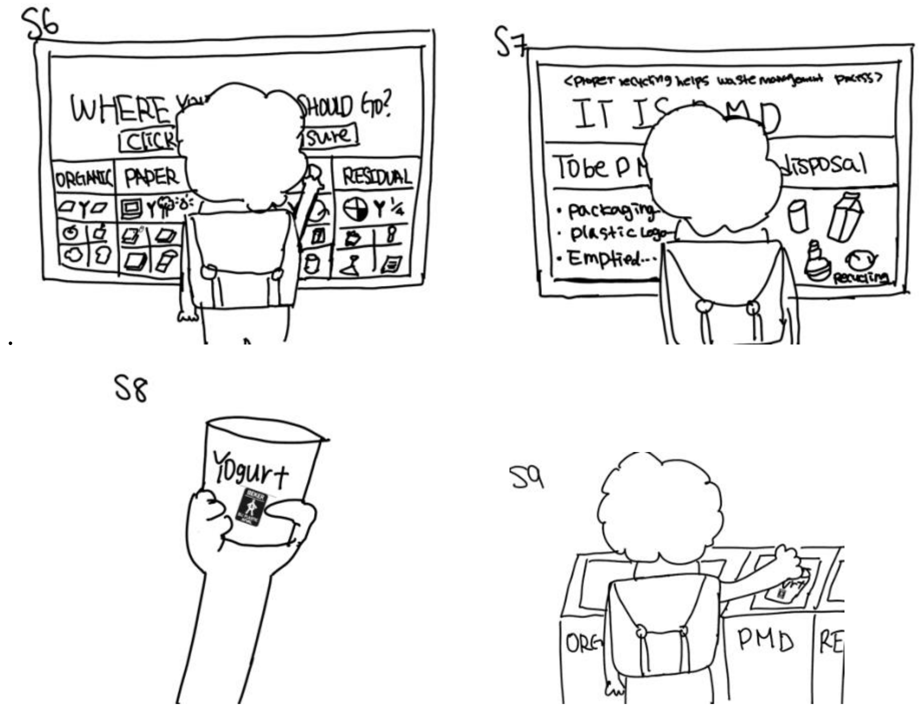


Figure 31. *Scene 6: select the PMD waste stream in the PMD waste section, Scene 7: display information regarding PMD waste, S8: find symbol in the yogurt pack, S9: dispose of the yogurt pack in the PMD bin*

After that, she also checked whether vanilla yoghurt packaging was in the image list but could not find it in the image list (see Figure 31 S6). She thinks it should be in PMD as it is made of plastic and plastic packaging. To confirm the decision, she clicks the PMD button above the desired situation of the PMD waste stream visual description. It displays requirements to be PMD waste stream and information that waste will be recycled into other plastics. It also mentions that less plastic usage helps to reduce unnecessary plastic waste (see Figure 31 S7). She finds the symbol in the yoghurt pack that can go into plastic packaging (see Figure 31 S8). Therefore, she put the yogurt packaging into the PMD waste bin (See Figure 31 S9).

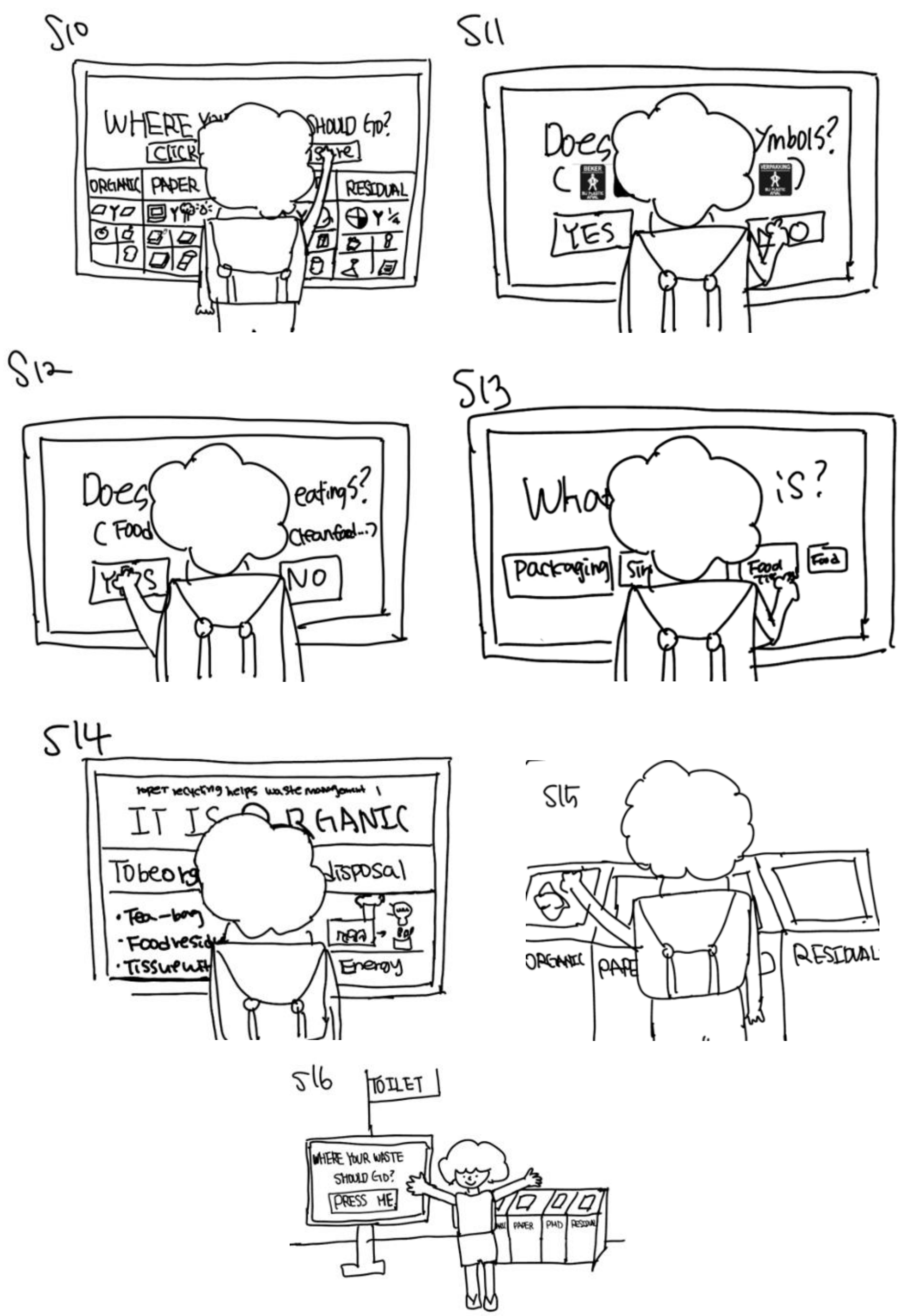


Figure 32. *Scene 10: select the "Click if you are not sure" button. Scene 11: First question: does it have symbols? Scene 12: Second question: Is it related to eating food? Scene 13: Third question: Which type of waste is it? Scene 14: display information regarding organic waste, Scene 15: dispose of the waste in the organic waste bin, Scene 16: finish waste disposal with support of WSGS*

She has the tissue that she used to clean food, and she thinks it could belong to the residual waste, but at the same time, she is not sure about it. She finds that the button says, "Click if you are not sure".

She clicks the button to check where the tissue should go (see Figure 32 S10). She looks at the first question of whether her waste has symbols on the waste. She chooses “no” as it does not have one (see Figure 32 S11). She looks at the second question of whether her waste is related to food (see Figure 32 S12). She chooses “yes” as it is used to clean the food. Next, she gets another question that asks which type of waste it is. There are four types of waste presented: Packaging, single-use waste for food (cutlery, paper cup, food container), tissue with food scraps, and food (including teabag). She chooses tissue with food scraps (see Figure 32 S13). And then, she sees that the last answer says that tissue with food scrap belongs to organic with requirements to be organic waste stream and information that waste will be composted and recycled (see Figure 32 S14). After that, she puts her waste in the organic bin (see Figure 32 S15).

After finishing waste disposal with the support of WSGS, she is happy about her proper waste disposal (see Figure 32 S16).

5.4. Visual Components

Visual components to design the prototype are preliminarily decided before entering the actual prototyping phase. Not all details were decided to ensure the design's flexibility during the prototype. However, the font and colour palette were decided beforehand to facilitate the start of the design.

Figure 33. *Colour palette of the prototype*

The user interface design of the prototype is focused on playfulness and a round shape to look like a game interface. The colour palette[7] refers to the current waste islands and the vivid colours are chosen to be visible from a distance (see Figure 33). The font of the design is selected as Baloo Bhaina[8], which is round shaped font.

[7] https://coolors.co/palette/ef476f-ffd166-06d6a0-118ab2-073b4c (Last visited 13-10-2022)
[8] https://www.freebestfonts.com/baloo-bhaina-font (Last visited 13-10-2022)

6. Realisation

In this realisation phase, the prototype development process is discussed. The prototype is developed based on the functional and non-functional requirements obtained in the specification phase. First, the tools that are used in the realisation phase are described. Then, the prototype is elaborated. Finally, the prototype is evaluated with functional requirements listed in the specification phase, and future improvements are suggested.

6.1. Tools

Figma [49] is the program to build a web or app prototype or wireframe of the website. It was used to design the interactive screen prototype. With Figma, the entire user interface and interaction were designed as well. C-touch [52] is a smart touch screen used as a screen or computer. It was used to improve the interaction experience of the prototype.

6.2. Prototype

The prototype of WSGS is a form of an interactive screen. Three elements should be considered in the design of an interactive screen: user interface, information, and interaction. Firstly, the working process is elaborated. Secondly, user interface design is presented with information design, and interaction design is explained.

6.2.1. Working Process

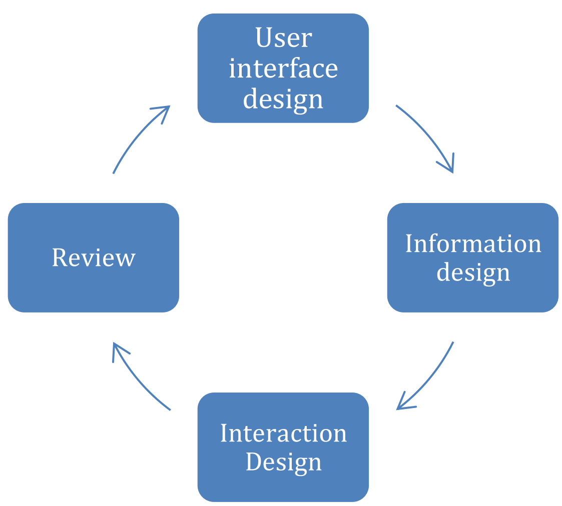


Figure 34. *design cycle of the prototype*

There was a design cycle during the working process (see Figure 34). First, the entire user interface was designed, and information was filled in according to the layout. These often happened simultaneously. And then, an interaction was added to the prototype depending on the needs for the navigation of information. The cycle was repeated three times after reviewing the intermediate designs following the Agile development manner [48]. There were improvements after each cycle.

Figure 35. *Initial main screen design*

During the first cycle, it was found that the initial main screen design provides too much information to users, as shown in Figure 35. The initial main screen shows four images of waste on each waste stream and the desired situation of each waste stream. Also, the “Click if you are not sure” button was located above the waste bins. Due to information overload, the user cannot focus on the information that the user needs. Therefore, the main selection screen design focused on reducing the amount of information and simplifying the user's choice. The information screen regarding the waste stream had the same feedback: too much information was provided, so the design was simplified. When testing with C-touch, the screen design didn’t fit on the entire screen. It was challenging to focus on the screen as most interaction was happening in front of the user. The primary screen size was adjusted to the centre, minimising the user’s eye movement. There was feedback about the design in general. There was some suggestion that the button design could be more straightforward as the 3D effect of the button is an outdated design. Therefore, the design has been changed to a more straightforward style. And the “Click if you are not sure” button was changed to the “I am not sure” button for easy reading.

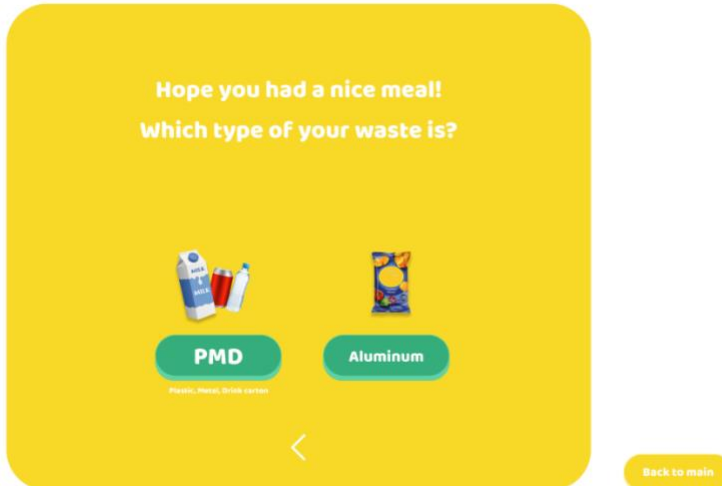


Figure 36. *Initial question screen design*

During the second cycle, supervisors had feedback that the categorisation of the waste when the user selects the “I am not sure” button was not detailed enough. As shown in Figure 36, when the user selects food packaging in the first question, the second question provides only two choices, and it does not reflect most waste kinds in the context of waste generated on campus. The supervisors provided feedback that there could be more images, and the pictures of waste should represent the waste generated in the canteen at the Waaier building of UT. After receiving the feedback, another waste analysis in the canteen was conducted. All places near the canteen area were visited, and possible waste pictures were taken. And then, they were used to entail the categorisation of waste. Also, supervisors said that waste symbols mentioned in Figure 27 are creating more confusion as not all waste contains symbols, and they are not entirely aligned with the waste separation policy of UT. Therefore, the use of the waste symbols to distinguish waste streams was omitted, and the questions and requirements were reformulated.

During the third cycle, user interface design and interaction were finalised.

6.2.2. User Interface Design

There are three types of screens. The first is the primary selection screen in which a user can choose four types of waste stream buttons and the “I am not sure” button. The second is an information screen which presents requirements to be a particular waste stream, the recycling process after waste disposal, and UT’s goals regarding the waste stream. The third is a question screen that asks several questions when the user selects an “I am not sure” button. The information screen designs the user sees at the end of the question are a variation of the existing information screen. Each screen is elaborated in order.

Figure 37. *Main selection screen design*

Figure 37 shows the main selection screen when a user first sees the screen. There are five buttons that the user can select. Those are four different waste stream buttons (Residual, PMD, Organic, Paper) and the “I am not sure” button. The user can choose one of four waste stream buttons to see information regarding that specific waste stream or select “I am not sure” to get questions to choose the correct waste stream of the waste. The waste stream button leads to the information screen explaining the specific waste stream requirements to be disposed of and shows the recycling process after waste disposal in the waste stream and UT’s goals for the waste stream.

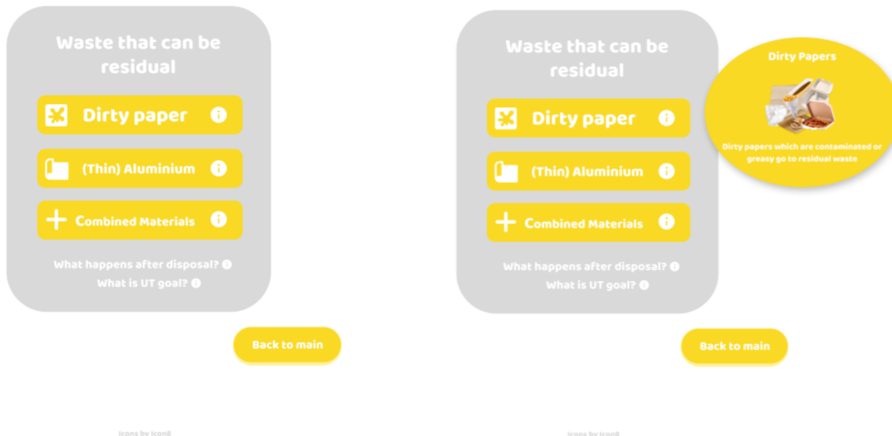


Figure 38. *(Left) Waste stream requirements of the residual waste stream, (Right) bubble describing the requirement detail.*

Figure 38 shows the waste stream requirements of the residual waste stream and detail. There are three requirements on each waste stream to facilitate easy reading by a user and put an icon left to the text for the user to remember the requirement easily with the visual element. When the user clicks the text box, the bubble pops up and shows the example images of waste that fit the requirements. For example, one of the possible wastes that can be disposed of in the residual waste stream is dirty paper. And dirty paper examples are used paper towels, pizza boxes, and paper food wrappers or containers. In Figure 38 (right), the bubble shows the example waste images of the dirty papers and a short description of the dirty paper. Therefore, the user can check the detail if the user wants.

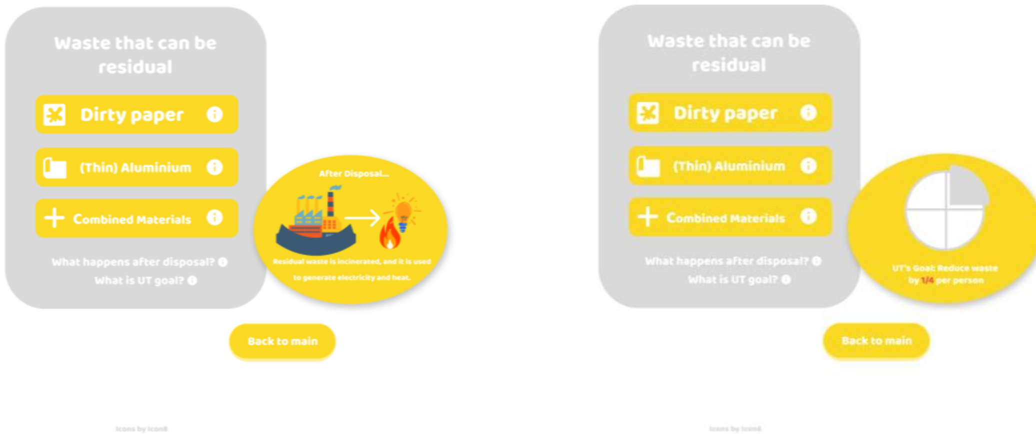


Figure 39. *(Left) After the waste management process of the residual waste stream, (right) UT's goal regarding the residual waste stream*

The user can also check the waste management process after waste disposal of each waste stream and UT’s goal regarding each waste stream. In Figure 39, the left image shows the waste management process of the residual waste stream. When the user clicks the text “What happens after disposal?”, an explanation bubble appears, showing how the residual waste is used after the user separates it properly. The right image of Figure 39 shows UT’s goal regarding the residual waste stream: to reduce residual waste by 1/4.

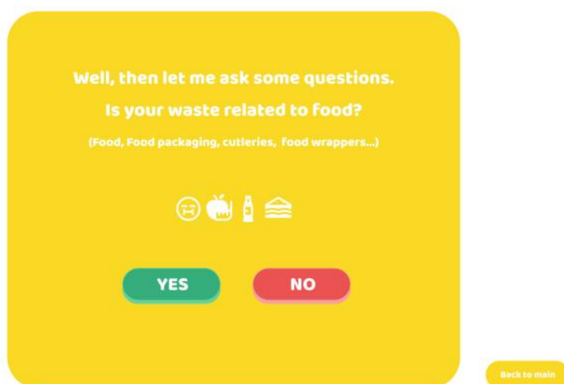


Figure 40. *"I am not sure" button first question: "Is your waste related to food?"*

When the user selects the “I am not sure” button on the main screen, as shown in Figure 37, the user sees the first question, which asks whether the waste the user holds is related to food. Examples of waste include food, packaging, cutleries, and food wrappers. To ease an explanation of the user interaction flow, in this explanation, a waste example is can. The following screen explanation is based on the can waste. Since the waste is a can, the user selects the 'YES' button in Figure 40.

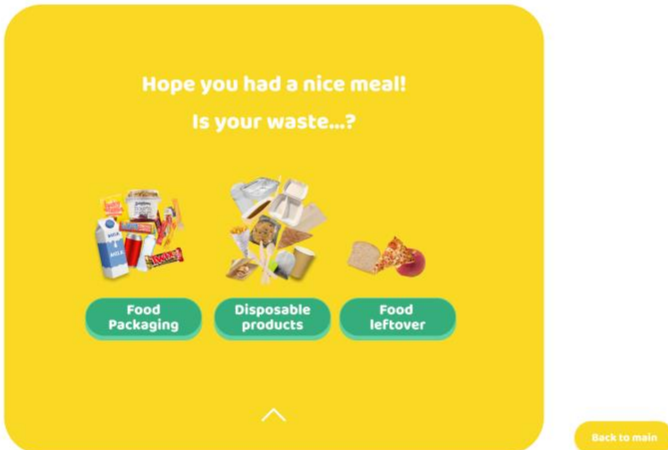


Figure 41. *"I am not sure" button second question: "Is your waste...? Food packaging, disposable products, or food leftover*

After the user selects the "YES" button in the previous screen, the user sees the next screen, which provides three options to choose as shown in Figure 41. Waste that is related to food can be categorised as food packaging, disposable products, and food leftover. Since the can belongs to food packaging, the user can select the "Food packaging" button.

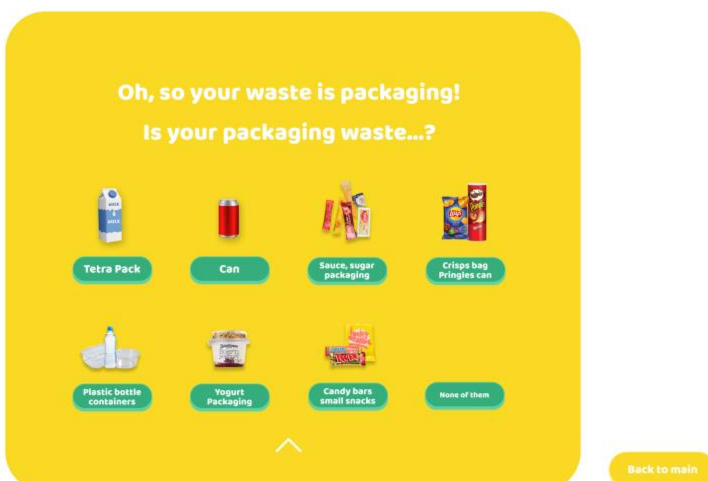


Figure 42. *"I am not sure" button third question: Is your packaging waste...? Tetra pack, can, sauce, sugar packaging, chips bag, pringles can, plastic bottle, containers, yoghurt packaging, candy bard, small snacks, or none of them.*

After the user chooses the “Food packaging” button, the user sees the third question, which asks about the type of waste. Food packaging waste is categorised into eight classes. The user can choose the “Can” button in Figure 42.

(a) (b) (c)

Figure 43. *The final screen of "I am not sure button": (a) PMD Waste stream; (b) recycling process of PMD waste stream; (c) UT's goal regarding PMD waste stream*

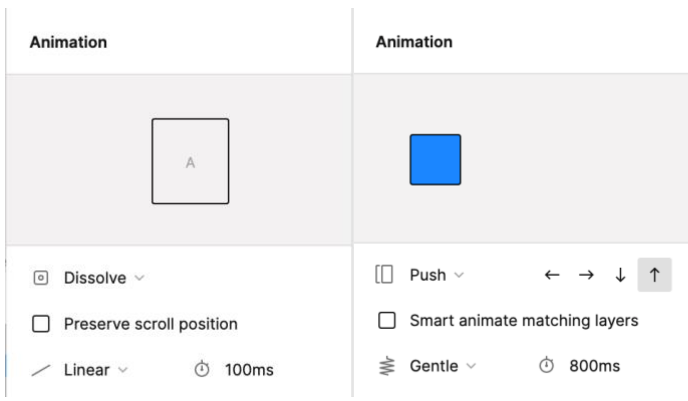
Since the can is PMD, the result screen shows the PMD waste stream with a visual description and detailed explanation, as shown in (a) of Figure 43. In (a), there are two texts which are “What happens after disposal?” and “What is UT goal?”. The user can click the text and see the detailed explanation in (b) and (c) of Figure 43.

Figure 44. *Result screen in case the user selects "None of them".*

The user can select the "None of them" button if they cannot find the type of waste the user holds. Then, the screen shows the residual waste stream requirements as the waste which cannot be categorised could go to the residual waste stream, as shown in Figure 44. By listing the requirements of the residual waste stream, the user can ensure that the waste goes to the proper waste stream. Also, suppose the user wants to report the uncertain waste. In that case, the user can send an email to the CFM sustainability management department so that the department can answer the question that the user sends.

6.2.3. User Interaction Design

The user interaction of WSGS is designed with the Figma prototype function. By connecting buttons, the user can use WSGS interactively. There is 62 frames total, and each frame is connected to another structure by button action. The user interaction design overview of WSGS is in Appendix F.



(a) (b)

Figure 45. *Animation of the user interaction of WSGS*

Figure 45 shows the animation effects used for the user interaction of WSGS. The (a) shows the dissolve animation effect setup used in the text, like requirements, after waste disposal or UT's goal regarding the waste stream. After the user clicks the text, the explanation bubble pops up with the dissolve animation effect. The (b) shows the push-down animation effect that is used in the button animation effect of the other buttons like the "YES" or "NO" button, selecting a type of the waste and main screen buttons.

6.3. Evaluating Prototype based on Functional Requirements

After the prototype was created, it was evaluated with the functional requirements in chapter 5. FR2 was adjusted after receiving feedback about using waste symbols for waste separation from supervisors, as the symbols did not align with UT waste separation rules. Table 11 shows the fulfilment of the functional requirements. The table shows that most functional requirements were achieved except the FR1. During the design cycle, the FR1 was not required to fulfil because adding images to the main screen created more distraction, which could increase the possibility of creating confusion of selecting buttons. Therefore, the FR1 was dropped from the functional requirements. Instead, the image visuals were placed on the top of the waste bin so the user could see the waste and click the waste stream if the user found the waste there. Instead of selecting each image to determine the correct waste stream, click the waste stream was included.

Table 11. *Functional requirements fulfilment*

No	**Requirement**	**Priority**	**Requirement Fulfilment**
FR1	Select a waste image and find correct waste stream among four waste streams (residual, PMD, organic, and paper) on the touch screen.	Must	(Dropped)
FR2	Select buttons for one of four different waste streams (residual, PMD, organic, and paper) on the touch screen to see the information describing requirements to be disposed of that waste stream with visualisation. Residual requirements • The waste contains aluminum materials. • Combined packaging materials. • Dirty papers PMD requirements • The waste is packaging based • The waste inside should be emptied • The waste should not be hard plastics, if it is not used for packaging, it is hard plastics. Organic requirements • Food waste	Must	YES

	Paper requirements • Clean paper Paper with paper clip or staple are fine. • Clean cardboard • Clean magazines		
FR3	See waste management process after disposal with visualisation Residual • Residual waste is incinerated, and it is used to generate electricity and heat. PMD • The PMD waste is sorted to be recycled. Organic • The organic waste will be fermented and composed. Those will be used to generate green gas or electricity. Paper • The papers will be sorted and recycled.	Must	YES
F4	See the desired situation of the UT of each waste stream Residual Desired situation: The amount of waste should be decreased by ¼ of 43kg approximately. PMD Desired situation: No unnecessary plastic usage. Reduce plastic waste. Organic Desired situation: Circular campus (e.g. coffee grounds are collected and recycled).	Must	YES

	Paper Desired situation: More digitization, less paper use.		
FR5	Select a button that says “Click here if you are not sure” on the touch screen (question designed from the decision tree, see Figure 28) and get questions to determine the waste stream of the waste	Must	YES
FR6	See that the screen goes back to start screen after time-delay or pressing go back to start screen button	Must	YES
FR7	Read the information on the touch screen from eyesight.	Must	YES
FR8	Read the information on the touch screen from a distance	Must	YES
FR9	Send question regarding uncertain waste to CFM	Should	YES

6.3.1. Suggested Changes to the Prototype

A few suggestions regarding the prototype could be fulfilled in the next prototyping phase. First, the button interaction effect could be more dynamic. When the user touches the button, the button could have a vibration effect so that the user feels like touching an actual physical button. This one could not be achieved due to technical constraints like using c-touch. Secondly, the button colour can change when the user hovers over it. These details could be performed after confirming the prototype design as a detailed part. Lastly, back to the previous screen button could be implemented on each page.

7. Evaluation

In the evaluation phase, the prototype was tested with two main stakeholders: the client CFM and UT community members. With CFM, a semi-structured interview was conducted along with task-based testing. With UT community members, user testing was conducted along with a survey and observation session. The evaluation set-up is described in each section, and evaluation results are presented within general, content, and usability feedback. Based on both evaluation sessions, non-functional requirements are evaluated. Lastly, remarks are discussed.

7.1. Client evaluation

Before conducting the user testing, the prototype was evaluated by the client. The meeting has two aims: information confirmation and client satisfaction evaluation. The prototype was tested by CFM throughout the session and evaluated according to non-functional requirements.

7.1.1. Evaluation Set up

The meeting was conducted for around 1 hour in room PLAY at the DesignLab of UT on the 4th of July in 2022 between 13:30-14:30. The information on the prototype was checked with the client to ensure the information regarding waste separation provided by WSGS is correct. Also, the client tried using the prototype to dispose of different types of waste. Then, the client could understand how the prototype would interact with an actual user. Meanwhile, observation notes were made by the researcher. After the information confirmation and the testing were finished, a semi-structured interview was conducted (see Appendix G). The prototype was evaluated in three types: general feedback, content feedback, and usability feedback. In general feedback, general satisfaction of the client and suggestions were asked. In content feedback, information reliability was checked. In usability feedback, the usability of WSGS was asked. The questions of the semi-structured interview were designed with consideration of non-functional requirements.

7.1.2. Evaluation Results

In general, the client was satisfied with the prototype regarding the design and interaction. Moreover, some information regarding the waste separation had to be corrected. Therefore, the final revision of the prototype regarding waste separation rules was made based on the information on the website updated on the 8th of July 2022 [53]. When the client tried to find the right waste stream for paper cups, yogurt packaging, and teabag, the details of the waste separation rules were mentioned and corrected. Regarding the usability of the prototype, the client was satisfied in general. Additionally, the improvement of the back buttons was mentioned, and it was left as suggested changes to the prototype due to the technical constraints of Figma.

7.2. User Testing with the UT Community Members

After the stakeholder meeting with CFM, the waste separation rules were adjusted in the prototype. Then, the user testing was conducted in one of the buildings at the UT. The user testing participants were UT community members who were the prototype users. The testing participants were selected randomly but ensured that the participants had their waste need to be separated. Therefore, the researcher approached people coming to the waste islands to separate the waste and asked them to participate in the testing. In this way, the selected group of testing is random but relevant. During the user testing, UT community members tried out the prototype and gave an evaluation by answering some survey questions.

7.1.1. Evaluation Set up

First, user testing was designed to test and evaluate the prototype. Originally, the user testing was supposed to happen in the Waaier building with C-touch. However, it was not possible due to the unavailability of the C-touch in the building. Therefore, the Technohal building was selected as the alternative location. The building still has relevance with the prototype because the waste separation rules of the UT are still valid in the building.

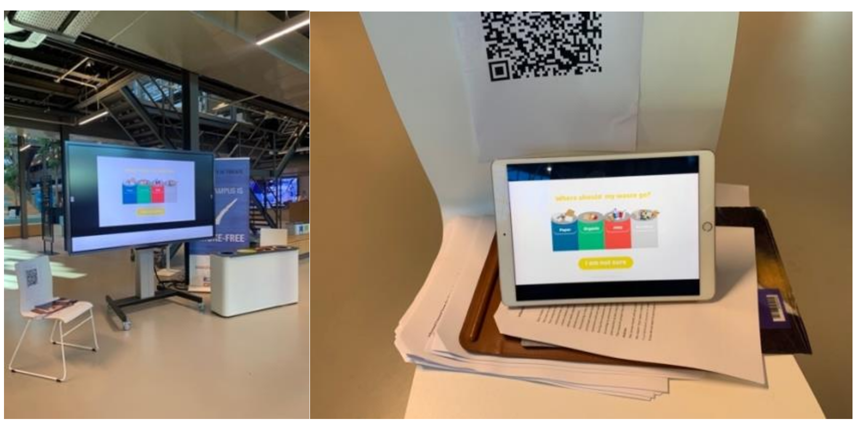


Figure 46. *(Left)User testing setup in Technohal, (Right) Tablet(iPad) for user testing*

The testing was conducted in one of the waste islands near the cafeteria in the Technohal building from 10:00-14:30 on the 6th of September 2022. The initial plan was to use a touch screen provided by the Technohal building for user testing (see Figure 46 [54] left). However, due to the lagging of the touch screen with an unstable internet connection, which slowed down interaction, a tablet (iPad) was used (see Figure 46 [54] right). Although there were some technical difficulties, the users could still try out the prototype and give feedback about the prototype.

During the user testing, participants could separate the waste they were holding. They got separate task waste with the help of WSGS. Approximately 5 minutes were spent for each participant, including answering the survey questions. The survey evaluated the non-functional requirements and the user's satisfaction with the prototype. Survey questions can be found in Appendix H. Also, an observation session was simultaneously conducted to assess the user's interaction with the prototype (see Appendix I). The testing was conducted by the participants who signed in the consent form. The EEMCS ethics committee assessed and approved the consent form (see Appendix J).

7.1.2. Evaluation Results

In this phase, 16 participants joined in the user testing. Eight participants are Dutch students, six are international students, and two are visitors who are not from the University of Twente. Unfortunately, it was not possible to do the testing for employees. A possible reason could be that the Technohal building is mainly used by students rather than employees.

Firstly, the users provided feedback on the contents of the WSGS. The user's waste disposal was checked to determine whether it was correct after using WSGS. Appendix K shows the waste disposal results after the use of WSGS. All columns' answers are from the testing participants, except the last right column, which the author adds. After the use of the WSGS, 14 out of 16 waste disposals are evaluated as correct separation. One incorrect disposal was made as food leftover was disposed of in the PMD waste stream. The Gum package was disposed of in the PMD bin. 10 people used the waste stream button to select the correct waste stream of the waste. 6 people used the "I am not sure" button to select the correct waste stream of the waste.

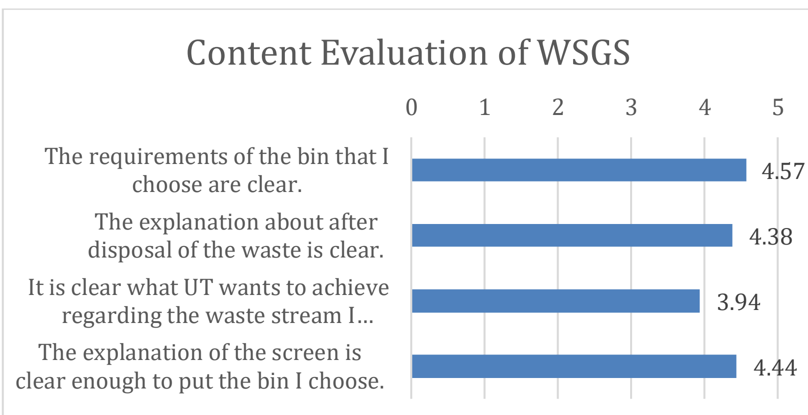


Figure 47. *Content evaluation of WSGS*

Figure 47 shows the content evaluation of WSGS. On average, user testing participants showed high satisfaction with the information provided by the prototype. The satisfactions regarding the explanation about the after-disposal of the waste and the UT's goals regarding waste disposal are relatively lower than other information like waste requirements. Besides, one participant left a comment about the uncertainty of the waste stream for gum waste.

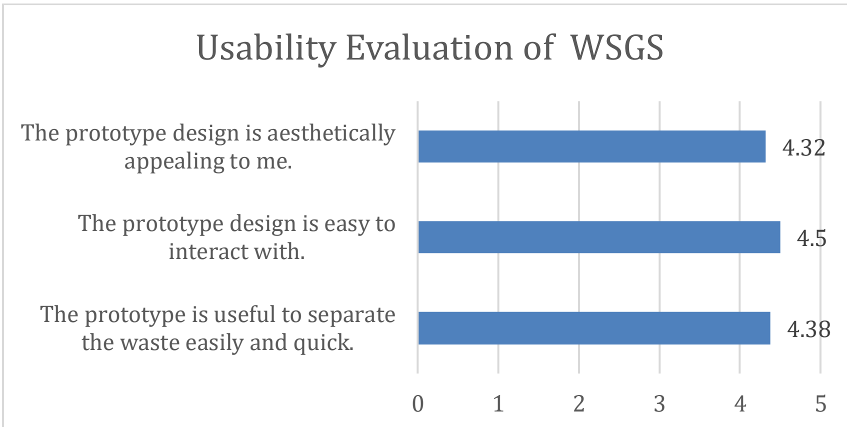


Figure 48. *Usability evaluation of WSGS*

Figure 48 shows the usability evaluation of WSGS. The interaction was evaluated as the highest satisfied feature regarding usability, efficiency was the next, and aesthetics was the last. Besides, there are some comments and suggestions by participants. Two participants mentioned the end of the interaction. One participant noted the end pop-up with the waste bin that should be disposed of. Another participant commented that it would be nice to have an "I am done" button that indicates the interaction has ended. Meanwhile, one participant commented: "It was easy to check, and I like the short description to read rather than too long sentences".

7.3. Evaluation based on Non-functional Requirements

Non-functional requirements were evaluated after the stakeholder meeting and the user testing. Table 12 shows the fulfilment of the non-functional requirements.

Table 12. *Non-functional requirements fulfilment*

No	Requirement	Priority	Requirements met?
NFR1	The information provided on the touch screen is accurate based on reliable source which is confirmed by Prezero (reliability)	Must	YES
NFR 2	The time to get the information to separate the waste correctly is within 4-5 seconds (response time)	Must	NO
NFR 3	Feedback regarding uncertain waste by user is collected anonymously and not collecting user's personal data (privacy and security)	Must	YES
NFR 4	The functionality is easy and accessible to users (usability)	Must	YES
NFR 5	The functionality is non-discriminatory therefore be able to be used by any users regardless of race, colour, sex, or language	Must	YES
NFR 6	The number of questions does not exceed more than 5 when the user selects the "I am not sure" button.	Should	YES
NFR 7	The design of the user interface is appeal to the user aesthetically.	Should	YES
NFR 8	The user interface is interactive.	Should	YES

Most of the requirements were fulfilled, although NFR2 could not be achieved. During the user testing, it was observed that the interaction time between the prototype and the user took longer than 4-5 seconds. In general, it took longer than 1 minute. When the user first tried out the prototype, the user spent some time exploring what features or information were in the prototype. Therefore NFR 2 could not be fulfilled.

7.4. Evaluation Conclusion

The prototype was evaluated in terms of contents and usability by Client evaluation and user testing. During client evaluation, the prototype was tested by the client, and information on waste separation was corrected additionally. During the user testing, the user separated waste after exploring WSGS, and 14 out of 16 participants separated waste correctly. The contents of the prototype were clear to most participants, and the usability of the prototype was evaluated positively by most participants. Most non-functional requirements were achieved except NFR2, as most participants spent time exploring the prototype for more than 1 minute.

8. Discussion

In the discussion section, findings from the results are interpreted. The limitations of the evaluation results are mentioned, and recommendations are presented for further research and prototype improvement.

8.1. Discussion

The evaluation results indicate that most users separated the waste correctly after using the prototype and left with a positive user experience. It means the prototype could help users learn about proper waste separation at UT. The characteristics of the prototype could explain these results.

First is contextual communication. From the background research, it was found that the communication of the information should be contextual. WSGS focuses on delivering information to the user about the waste that the user holds. The waste example list was changed into the requirements and questions in WSGS. This way, the user can focus on the information that the user needs rather than checking the whole list. The user can learn why waste should be in a specific waste stream, remember the requirements and adapt them to select the waste stream with other waste next time. Additional information like the waste management process after waste disposal and UT's goal regarding the waste stream functioned as giving the user motivation and obligation to separate the waste indirectly.

The second is interactivity. As the background research shows, automatic waste sorting did not contribute to long-term learning about waste separation. Instead, interaction and playfulness were emphasised. It does not provide information to a user in a one-directional way, but it gives options to think about possible answers by offering questions. In this way, the user can learn information about adequate waste separation in a more straightforward manner. WSGS achieved meaningful interaction by letting the user choose the option that the user is interested in. A visual explanation is also a key to remembering the information quickly. The WSGS displays information not only in text but also in visuals like pictures or illustrations. Hence, the user can easily distinguish waste.

The last is easy access. The stakeholder analysis and background research findings show that people tend to check the information when it is provided in front of the waste islands. Since WSGS is next to the bin, the user can skip the additional step to search for the information on the internet but can check it directly in front of the UT waste islands.

Hence, it could be concluded that the following points should be considered: contextual information delivery, meaningful interaction, and easy access when designing the solution to educate the UT community members to learn about proper waste separation on campus easily.

8.2. Limitations

Although the solution was designed to educate the UT community members about proper waste separation on campus, the research has some limitations.

Firstly, the research did not include the UT community members group who might not be interested in using the prototype. Evaluation results were based on testing participants willing to try out the prototype. Therefore, the research could not answer whether the solution would be effective for people who are not interested in using the prototype.

Secondly, the evaluation results represent group results who tried the prototype for the first time. For education, repeated information exposure to learning about waste separation should be continuous. For now, it is only found that people who first tried it found that prototype interesting. However, it is unknown whether the prototype will be used by the people who have already tried it.

Thirdly, the evaluation focused on the prototype's usability in the educational aspect. With the results, it is difficult to answer whether the UT community members' prototype usage directly influences proper waste separation to increase the proper waste separation rate.

Lastly, the evaluation sample size was 16; therefore, it is challenging to represent the whole UT community members.

8.3. Recommendations

There are some recommendations if the research is continued.

First, it could be further researched how to engage the UT community members to use the prototype when they are less interested in learning about proper waste separation or engage them to use it multiple times to learn new information. The engagement could be improved by adding a feedback feature in the prototype, for example.

Secondly, further study is needed to investigate the relationship between the education of the UT community members about proper waste separation and the increased proper waste separation rate on campus. These could be done by long-term study with close contact with Prezero. They can help to evaluate the waste separation rate on the campus. If possible, an interview with them can be conducted to check the waste separation situation after using WSGS. For example, the waste separation rate can be checked if the paper cups are appropriately separated into the correct waste stream.

Lastly, Multiple testing in different areas will be necessary to evaluate the long-term waste separation improvement. It will be also easier to reach out to broader UT community members, such as employees.

8.4. Prototype Improvement

Some prototype improvement points could be mentioned for further research.

Firstly, the feedback feature of the prototype can be added and tested. The feedback feature will also enable the user who does not check the waste separation information on WSGS.

Secondly, the waste separation information of the prototype should be checked and updated continuously. CFM should update the information regularly based on feedback from the user. Then the questions and requirements should be updated as well.

9. Conclusion

From the request by CFM, the reason for the problem of poor waste separation was analysed, and the reason was found that the waste separation information was not contextually delivered to the user of the UT waste islands. Therefore, the research question was set as follows: How to educate UT community members to separate the waste properly in the UT waste islands? To answer the research question, sub-research questions were formulated. Based on the sub-research questions, factors for pro-environmental behaviour focusing on recycling behaviour, behaviour intervention determinants techniques, and state of the art were investigated.

The background research found that people tend to separate the waste properly when they are morally motivated or obligated to recycle it and know about the proper waste separation. During the background research, three assumptions about the poor waste separation behaviour of the UT community have been made:

1. People do not know the correct waste separation method.
2. People do not care about proper waste separation
3. People do not trust the waste management system

To tackle these assumptions, Waste Separation Guide Service (WSGS) was designed to deliver reliable and contextual waste separation methods for the user's waste. The user can also check the UT's goals for the waste stream, which implies the importance of proper waste separation on the UT campus and the waste management process after the waste disposal. The sources are from the waste plan by CFM and CFM's example waste list, which strengthens the reliability of the information. The behaviour intervention should be easy to reach, provide positive feedback, and communicate the information to people contextually and with playfulness, interaction, and aesthetics. Stakeholder analysis also strengthens the importance of more accessible and contextual information delivery with visual description.

These findings were used to formulate the preliminary requirements of the prototype ideation.

With the requirements of the background research and stakeholder analysis, WSGS was designed as an ICT-based behaviour intervention to provide waste separation-related information interactively and contextually by guiding the users about proper and reliable waste separation methods. Also, it motivates them to do appropriate waste separation by providing information about the waste management process after waste disposal and UT's desired situation of each waste stream. WSGS was designed to be next to the UT waste islands. The main screen has buttons for four different waste streams (paper, organic, PMD, residual) and the "I am not sure" button. The waste stream button directs to the requirements of the waste stream. Users can check the further explanation of the requirements, the waste management process after disposal of the waste, and the UT's goal regarding the waste stream. When the user is unsure which waste stream should be chosen for the waste that the user holds, the user can select the "I am not sure" button. Then, the user gets the questions to guide the user to the correct waste stream of the waste that the user holds.

After the prototype was developed, an evaluation was conducted to check whether the prototype helps to educate UT community members to do proper waste separation in UT waste islands. During the client evaluation, CFM confirmed the reliability of the information. The design of the WSGS fulfilled the satisfaction of the CFM as well. During the user testing, 14 out of 16 testing participants separated waste correctly according to the guidance of the WSGS. Also, they left with positive experiences with the use of the prototype.

From the evaluation results, it could be concluded that the testing participants found that the prototype is an easy and quick way to learn about proper waste separation in the UT waste islands. After using the prototype, they learned what waste should be in a specific waste stream, why it should be in a specific waste stream, and how the waste is managed after disposal of the waste. Furthermore, the information was provided contextually, with meaningful interaction and easy access. The conclusion could be that contextual information delivery, meaningful interaction, and easy access are essential in designing the solution to educate about proper waste separation.

The research focused on education about waste separation to UT community members. People interested in using the prototype during the evaluation had a positive experience. However, people who were not interested in or did not care about proper waste separation were not engaged in the evaluation. Therefore, it is an open question of how to engage the people who do not care about waste separation or are not interested in using the prototype. Secondly, the evaluation focused on validating the prototype's usability, which means the evaluation results could not answer the effect of improving waste separation on campus. In addition, evaluation results were from the people who first tried the prototype. Lastly, the sample size of the evaluation was 16, which means the research results cannot be generalised to the entire UT community.

Thus, future research could investigate how to engage the UT community members who are less interested in learning about proper waste separation and repeated engagement in learning. Furthermore, a long-term analysis could be conducted to investigate the general proper waste separation increase on campus by testing the prototype with different locations and engaging more UT community members to use the prototype. It is necessary to be exposed to information repeatedly to be educated. The feedback feature could be developed for prototype improvement to engage more UT community members who are not interested in using the prototype. The waste separation information should be updated regularly.

In conclusion, the research question "how to educate UT community members to separate waste properly in the UT waste islands?" could be answered in the following way: the solution should be informative and easy to learn about waste separation to educate UT community members to separate waste properly. In this way, the client CFM could benefit from using the solution to educate UT community members to separate waste properly in the UT waste islands.

Appendices

Appendix A: Questions for determining proper BCT

No.	Question
1	Is it applicable for recycling behaviour?
2	Is it a knowledge delivery behaviour intervention technique? If so, what kind of knowledge is delivered by this technique?
3	Is it considering pro-recycling behaviour factors?
4	Is it communication-based technique? If so, does communication happen contextually?
5	Can it be translated to ICT based solution techniques?
6	Is the behaviour technique contextual?
7	Does it affect one of the factors of pro-recycling behaviour? (Moral motivation, Moral obligation, knowledge)
8	Could it be used to implement ICT-based behavioural interventions?

Appendix B: BCT evaluation

Group	BCT name	Determinants	Behaviour interventions	Application idea
1.Goals and planning	1.7. Review outcome goal(s)	Knowledge Moral motivation	Communication	People can review the status of waste management
2.Feedback and monitoring	2.1. Monitoring of behaviour by others without feedback	Knowledge	Communication	Observation session (Part of behaviour change strategy)
	2.7. Feedback on outcomes of behaviour	Knowledge, (as it provides feedback) Moral motivation (it could motivate or demotivate people) Moral obligation (people compare each other)	Communication Charges	Give feedback how much recycling was improved by their recycling
4.Shaping Knowledge	4.1. Instruction on how to perform a behaviour	Knowledge	Communication	Give correct instruction how to do recycling
5.Natural consequences	5.2. Salience of consequences	Knowledge (possible consequences) Moral motivation (knowing environmental impact)	Communication	Teach the possible consequences of recycling

	5.3. Information about social and environmental consequences	Knowledge Moral obligation	Communication	Let them know how UT community put importance on recycling
7.Associations	7.1. Prompts/ cues	Knowledge	Communication	Put sticker on the bin to remind to do recycling
9.Comparison of outcomes	9.1. Credible source	Knowledge	Communication	Use reliable source for waste disposal instruction (e.g., confirmed by government, scientific-based source)
10.Reward and threat	10.4. Social reward & 10. 5 Social incentive	Moral motivation	Communication	Give positive feedback about recycling behaviour
12.Antecedents	12.1. Restructuring the physical environment	Moral obligation	Convenience	More accessible recycling point
	12.2. Restructuring the social environment	Moral obligation	Convenience	Let people do recycling together

13.Identity	13.1. Identification of self as role model	Moral motivation Moral obligation	Communication Charges	Let people who do recycling identify themselves be a good role-model for new UT community members (e.g., new students) and guide them.
14.Scheduled consequences	14.5. Rewarding completion	Knowledge Moral motivation	Communication Charges	Gives Co2 emission reduction estimation
	14.6. Situation-specific reward	Moral motivation	Charges	After finishing recycling, giving positive feedback or coupon
15.Self-belief	15.1. Verbal persuasion about capability	Moral motivation	Communication	Tell people that they are good at recycling, and they contribute to the environment and society
16. Convert learning	16.3. Vicarious consequences	Moral motivation	Communication Charges	Cleaning staff or waste management give compliment to the people who recycle waste

Appendix C: Example Waste List regarding four waste streams, provided by CFM, confirmed by Prezero (updated 17-06-2022)

Waste stream	**Permitted waste**	**Not permitted waste**	**Location**
Paper and cardboard	Paper Cardboard Magazines Printing paper Paper with staple or paper clip	Used tissues Laminated paper Paper cups Contaminated paper Pizza boxes Foil and plastics Receipts Food residues Carbon paper Paper packaging with PE coating Drink cartons Binders	
Organic	Coffee grounds Coffee pads Food waste Fruit and vegetable waste Bread Soup Fish and meat waste Dairy products Paper towel with food residue	Packaging Paper and cardboard Flowers Tea bags Oil Biobased plastic Aluminum coffee pods Cheese rind Shells (oysters etc.) Compostable bags Garden waste Spoiled animal by-products	
PMD	Plastic bottles Cans	Food waste Paper and cardboard	

	Drink cartons Plastic food packaging Plastic cosmetics packaging Paper coffee cups Candy wrappers Biobased plastics Plastic film (for wrapping food) Plastic carrier bags	Residual waste Styrofoam Aluminum packaging (crisps bags) Aluminum foil Hard plastics Not empty packaging Packaging > 5 liters Aerosols Packaging into which other material has been put Packaging > A4 size Packaging with hazard symbol Medication/chewing gum strips	
Residual	Face masks Aluminum packaging (crisps bags) Tea bags Pen Used tissues Pringles cans Receipts Flowers Aluminum foil Packaging with multiple materials (e.g., plastic and paper)	Glass Batteries Electronics Chemical waste Toners and cartridges Electronics PVC Aerosols Cleaning cloths Smoke detectors Bulky waste Oils and liquids Styrofoam	

Appendix D: Observation session interview questions

1. Which waste do you have?
    a. Which one is most confusing?
2. How aware of the waste separation problem (32% only residual waste)?

3. What is the most challenging thing when separating waste / What is the most confusing waste?

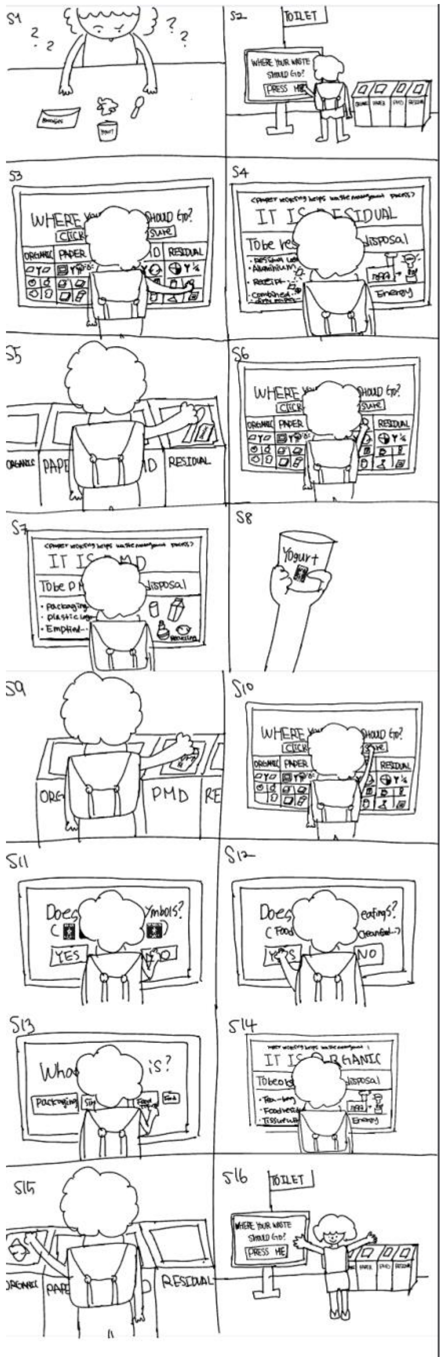
4. What can help you to do better waste separation?

    a. Does sticker work?

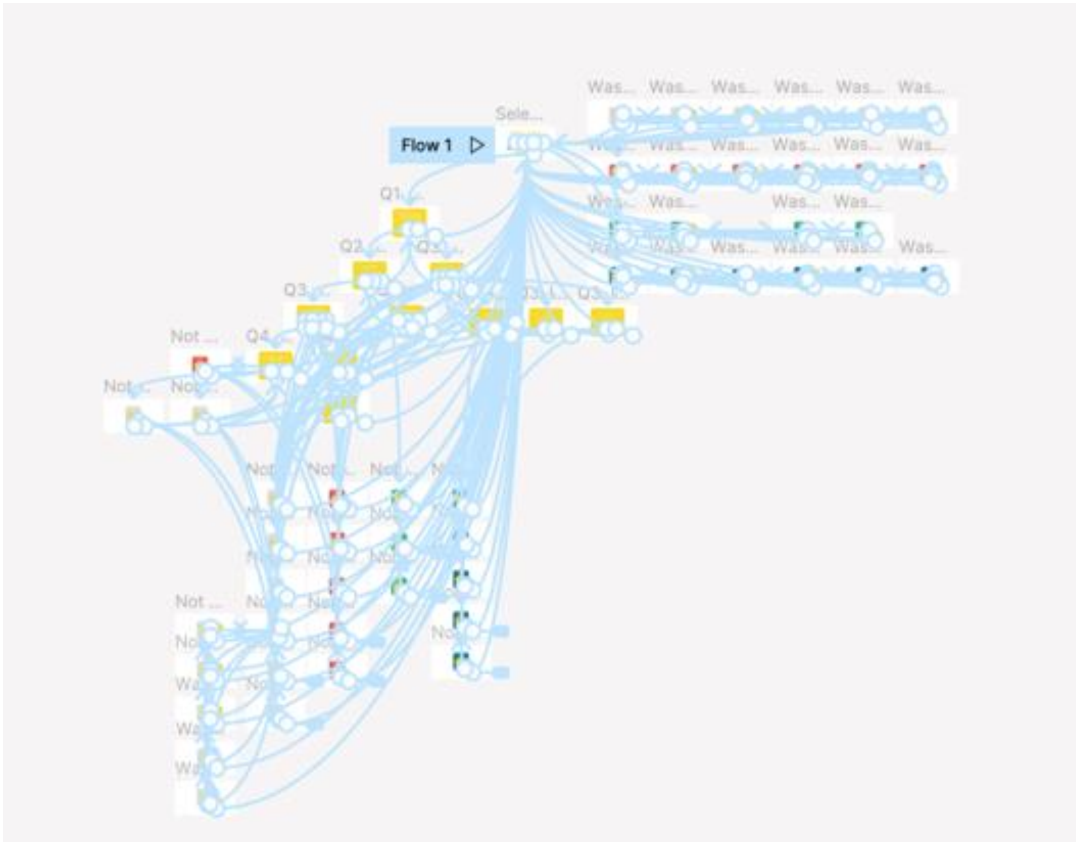
    a. App?

    b. What else?

Appendix E: Storyboard of WSGS



Appendix F: User Interaction Design overview of WSGS



Appendix G: Semi-structured interview questions for CFM meeting

Introduction

The Waste separation guide screen is designed to educate UT community members on separating waste properly on the UT waste island. With this interview, I would like to ask about your opinion about the prototype, satisfaction, and suggestions. For now, you can interact with the prototype and see what you can do and what you can see. After then, you will receive three scenarios with different waste types. And you can try to separate waste according to the explanation on the screen. While you interact with the screen, I will make some notes regarding your interaction.

Waste separation Scenario

Task 1. Paper cup

Task 2. Yogurt Packaging

Task 3. Tea bag

Content Feedback

Q. It the information provided by the screen clear and correct according to the CFM and Prezero agreed waste separation rules?

Usability Feedback

Q. How do you think about the UI design of the screen?

Q. How do you think about the Interaction with the screen?

General Feedback

Q. As a client, what do you think about the prototype? To what extent are you satisfied with the prototype?

Q. What do you want to suggest about the prototype?

Appendix H: Survey questions for the UT community members

Dear reader,

We would like to inform you about the research you have participated in.

This research focuses on **improving how people separate waste**. It is important since research has indicated that improving waste separation is one essential strategy to slow down climate change and create a better ecosystem. To attain this goal, this research focuses on how to give information about waste separation in UT waste islands to educate people to separate waste in the UT waste islands properly.

Participating in the research means you are asked to separate your waste with the support of the prototype (waste separation guide screen) and fill in a **survey** consisting of a few multiple-choice questions and one open-ended question, which should take no longer than 3 minutes to fill in. During the evaluation session, the researcher will conduct the **observation and make written notes** according to the note templates previously made. During observation, your waste separation behaviour and reaction to the interaction of the waste separation guide screen will be observed.

The research project has been reviewed by the Ethics Committee Information and Computer Science.

The survey results will be used for the research, and no personal data will be used or mentioned for the report. Your name is asked if you want your results removed, in which case you can send an email to h.yun@student.utwente.nl with the name you used to fill in the survey.

If you do not want to participate in the research, you can reject the participation.

If you have any complaints about this research, please direct them to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, P.O. Box 217,

7500 AE Enschede (N.L.), email: ethicscommittee-cis@utwente.nl).

Section 1 Agreement and general information.

Q1.I have read the introduction and I agreed on it.

[ ] Yes

Q2. Which categories are you in?

[ ] Dutch Student

[ ] International Student

[ ] Dutch Employees

[ ] International Employees

[ ] Visitors (not from University of Twente)

Section 2 Information about waste you separated

In this section, you will answer regarding the waste you separated with the support of the Waste Separation Guide Screen (WSGS). Please answer about only one waste that you have separated.

Q. What waste did you separate?

[ ]

Q. If you choose none of them, could you fill in here what did you separate?

Q. If you choose none of them, did you send your uncertain waste picture through email address sustainability@utwente.nl? (Only answer if you answer to question 4).

Q. Which bin did you separate the waste?

[ ] Paper

[ ] Organic

[ ] PMD

[ ] Residual

Q. Which button did you use to get the information?

[ ] Waste stream (Residual, Paper, PMD, Organic)

[ ] I am not sure

Section 3 Evaluation of information provided by WSGS (Content Feedback)

In this section, you will answer about your satisfaction regarding information provided by WSGS.

Q. The requirements of the bin that I choose are clear. (From 1 to 5**)**

Q. The explanation after disposal of the waste is clear. (From 1 to 5**)**

Q. It is clear what UT wants to achieve regarding the waste stream I choose. (From 1 to 5**)**

Q. The explanation of the screen is clear enough to put the bin I choose. (From 1 to 5**)**

Section 4 Evaluation of usability of WSGS (Usability Feedback)

In this section, you will answer about your satisfaction regarding using WSGS.

Q. The prototype is useful to separate the waste easily and quick. (From 1 to 5**)**

Q. The prototype design is easy to interact with (From 1 to 5)

Q. The prototype design is aesthetically appealing to me (From 1 to 5)

Section 5 Final Evaluation Feedback

In this section, you can make suggestions or comments regarding WSGS.

Q. Any suggestions or comments? (General Feedback)

Appendix I: Observation Session Note Structure

Observation Session Notes

Date:

**User personal information will not be recorded during the observation session.*

**Participants will be distinguished by numbering.*

Participant [   ]

1. Proper separation of the correct waste stream
    a. Yes
    b. No

2. Choose the bin
    a. Confidence
    b. A bit of confusion
    c. A lot of confusion

3. Interaction time with the screen till the waste disposal
    a. Time:
4. User expression after using a screen
    a. Satisfied
    b. A bit satisfied
    c. A bit disappointed
    d. Disappointed

Appendix J: Informed Consent Form

Informed Consent Form for User testing regarding Waste Separation Guide Screen

Dear reader,

We want to inform you about the research you have participated in.

This research focuses on **improving how people separate waste**. It is important since research has indicated that improving waste separation is one essential strategy to slow down climate change and create a better ecosystem. To attain this goal, this research focuses on how to give information about waste separation in UT waste islands to educate people to separate waste in the UT waste islands properly.

Participating in the research means you are asked to separate your waste with the support of the prototype (waste separation guide screen) and fill in a **survey** consisting of a few multiple-choice questions and one open-ended question, which should take no longer than 3 minutes to fill in. During the evaluation session, the researcher will conduct the **observation and make written notes** according to previously made note templates. During observation, your waste separation behaviour and reaction to the interaction of the waste separation guide screen will be observed.

The research project has been reviewed by the **Ethics Committee Information and Computer Science.**

The survey results will be used for the research, and no personal data will be used or mentioned for the report. Your name is asked if you want your results removed, in which case, you can email h.yun@student.utwente.nl with the name you used to fill in the survey.

If you do not want to participate in the research, you can reject the participation.

Consent Form for User testing regarding Waste Separation Guide Screen

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 [20/06/2022], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	□	□
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions 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 observation recorded by written notes and online survey filled by the participant.	□	□
I understand that personal information collected about me that can identify me, such as my role within the UT community (Whether you are student or employee), will not be shared beyond the study team.	□	□

Signatures

______________________ ______________________ ________

Name of participant 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 Signature Date

Study contact details for further information:

Researcher: Hyeji Yun (h.yun@student.utwente.nl)

Supervisors: Kasia Zalewska (k.zalewska-kurek@utwente.nl)

Richard Bults(r.g.a.bults@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 K. Waste disposal results after the use of WSGS

What waste did you separate	If you choose none of them, could you fill in here what did you separate?	Which bin did you separate the waste?	Which button did you use to get the information?	Correct waste stream?
Paper coffee Cup or Plastic Cup		PMD	Waste stream (Residual, Paper, PMD, Organic)	Yes
None of them	sticker on banana peel	Residual	I am not sure	Yes
None of them	Nail veil	Residual	Waste stream (Residual, Paper, PMD, Organic)	Yes
Cardboard		Paper	Waste stream (Residual, Paper, PMD, Organic)	Yes
Paper napkin with food residue		Residual	I am not sure	Yes
Receipt		Residual	I am not sure	Yes
None of them	Gum package	PMD	Waste stream (Residual, Paper, PMD, Organic)	No
Food leftover		PMD	I am not sure	No
Candy bars or small snacks		PMD	I am not sure	Yes
Paper coffee Cup or Plastic Cup		PMD	Waste stream (Residual, Paper, PMD, Organic)	Yes
Plastic bottle or containers		PMD	Waste stream (Residual, Paper, PMD, Organic)	Yes

Plastic bottle or containers		PMD	Waste stream (Residual, Paper, PMD, Organic)	Yes
Paper wrappers or containers		Residual	I am not sure	Yes
Paper coffee Cup or Plastic Cup		PMD	Waste stream (Residual, Paper, PMD, Organic)	Yes
Plastic wrapper, film		PMD	Waste stream (Residual, Paper, PMD, Organic)	Yes
Paper coffee Cup or Plastic Cup		PMD	Waste stream (Residual, Paper, PMD, Organic)	Yes

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