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Improving Waste Separation on the UT campus.

Educating the UT community about waste separation in a playful manner.

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Abstract

Growing sustainability awareness is driving changes in educational institutions like the University of Twente. Their "Shaping 2030" strategy aims to become a sustainable institution by 2030. Reducing waste on campus is one of the main goals, and the first step is to make sure the university community recycles waste effectively. The aim of this bachelor's thesis is to develop a recycling intervention to educate the UT community about waste separation.

Comprehensive research was done to examine the potential for behavior change and to understand the factors and barriers to recycling behavior. The research identifies various factors influencing pro–environmental behavior, such as demographics, values/beliefs, attitudes, and awareness of consequences. On the other hand, many barriers to pro–environmental behavior were found including a lack of knowledge, encouragement, and time constraints. Additionally, the concept of gamification and the value of including fun elements in the learning process were also explored. In order to positively impact waste separation behavior and educate the users about correct waste separation, an Interactive Arcade–style Installation with a post–apocalyptic theme and two mini–games was created as a potential solution.

The Installation's effectiveness was tested with the UT community. The game successfully promoted waste separation education while engaging players, creating social interaction, and fostering a playful atmosphere. Feedback identified several areas for improvement, including better directions, more educational content, and fixing technical issues. Implementing these recommendations would enhance the game, resulting in a more memorable and captivating experience that educates and promotes recycling habits.

An interactive arcade–style installation can effectively educate and motivate UT community members about waste separation. The installation draws attention, encourages participation, and educates the players on recycling by incorporating play, and interaction. The prototype was well received by the target group, but more work needs to be done before it can be used successfully in a practical environment.

Acknowledgment

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Chapter 1

Introduction

The growing awareness of sustainability is causing change in society, including educational institutions. Climate change has become a topic on national and international agendas. It can be seen in multiple areas of life including schools. The University of Twente has adopted a strategy "Shaping 2030" [1] which describes that it will become a sustainable university by 2030. One of the goals is to reduce waste on campus. The first step in completing this goal is to make sure the community is appropriately recycling its waste. The campus is equipt with waste islands that separate the waste into four streams: residual, PD (plastic, drinks packaging), organic, and paper. According to the waste analysis conducted in January 2020 [1], it was found that about 32% of the debris in the residual stream is genuinely residual waste, 32% is PMD, 18% is organic and another 18% is paper. This proves that actions are needed to increase the perception of recycling such as educating the people on proper disposal techniques, the value of recycling and what happens to the waste when it leaves campus. The University wants to develop technology–based interventions to raise awareness about proper waste separation at the waste islands within the community.

Although the physical solutions are in place, members of the UT should be educated about the recycling process and made aware of the need to recycle. A promising and attractive way of doing it is through play, using interactive media that people are accustomed to. A few challenges may come up in creating a solution to this problem. Firstly, it must fit the target group and location. Students and university staff are busy and might not have time for time–consuming interventions. Secondly, research shows that there are multiple factors that contribute to pro–environmental behavior including education, habits, economic situation, and personal values. This means that the interventions should be designed in such a way as to take the challenges into consideration. And last but not least, interactive media should be used specifically to create a playful but practical learning environment, which needs to be carefully designed to fulfill those requirements.

This leads to the following research question:

How to educate the UT community in a playful manner using Interactive Media?

1.1 Thesis structure

This thesis includes nine chapters and explains the development of the waste separation intervention. The thesis begins with Chapter 1, which is an introductory chapter that also outlines the research questions. Then Chapter 2 conducts a literature review and the state of the art to explore the best approaches to answer the research question. Chapter 3 describes the methodology and techniques used in this project, while Chapter 4 will analyze the stakeholders and their requirements and summarizes the ideation process. Following that, Chapter 5 will focus on the project's specifications and Chapter 6 will cover the project's realization. Chapter 7 will address the evaluation of the high-functioning prototype. Lastly, Chapter 8 will hold the conclusion and discussion regarding the intervention and Chapter 9 will explore the possible improvements for future work.

Chapter 2

Background research

2.1 Waste Separation

2.1.1 Netherlands

Waste that is appropriately sorted is easier to recycle than waste that has not been. According to the Dutch government [2], about 60% of all residential waste is was separated in 2020. The goal is to increase that number to 75% by 2025. Municipalities are getting closer to achieving their objectives. So far, even though waste separation has received such a strong push, the separated waste is frequently contaminated with other waste. Recycling is now more complicated as a result. For the period of 2021 to 2025, the government will concentrate on improving the separation of residual waste. Every residual household waste contains one–third of valuable, recyclable materials that could have been recycled, instead, a large amount is burned in incinerators. They will also try to increase the quality of the waste streams that have been gathered individually (such as plastic and paper).

2.1.2 The University of Twente

As mentioned in Chapter 1 this project focuses on the waste separation on the University of Twente's campus. The UT intends to produce less garbage as part of its goal to reduce its carbon footprint by 15% in 2023. In order to simplify recycling and appropriately dispose of waste that cannot be recycled, the university makes an effort to segregate as much waste as possible [3]. In every building on campus, waste islands (Figure 2.1) are placed where waste can be separated into the four main waste streams:

- PD (plastic bottles, drink cartons, plastic food packaging),
- Paper (paper and cardboard),
- Organic (coffee grounds, food waste, tea bags),
- Residual waste (face masks, aluminum packaging like chip bags and cans, tissues).

Figure 2.1: Waste island.

As mentioned above one of the waste streams is PD (plastic and drink cartons). However, before April 1, 2023, it used to be PMD (plastic, metal, and drink cartons). This means that metal cans should either be returned to a collection point for a deposit or disposed of with the residual waste rather than being put into the PD waste stream. There are also ways of disposing of other waste on campus which include: confidential paper, glass, wood, e–waste, scrap metal, bulky waste, and lab waste.

After trash has been disposed of it is collected by an employee of the cleaning company (Asito), which is then taken and processed by PreZero. The UT's waste is processed in a variety of ways, from energy–recovery incineration to recycling, which can be seen in Figure 2.2. Proper garbage sorting can lower the amount of waste that is unnecessarily burned.

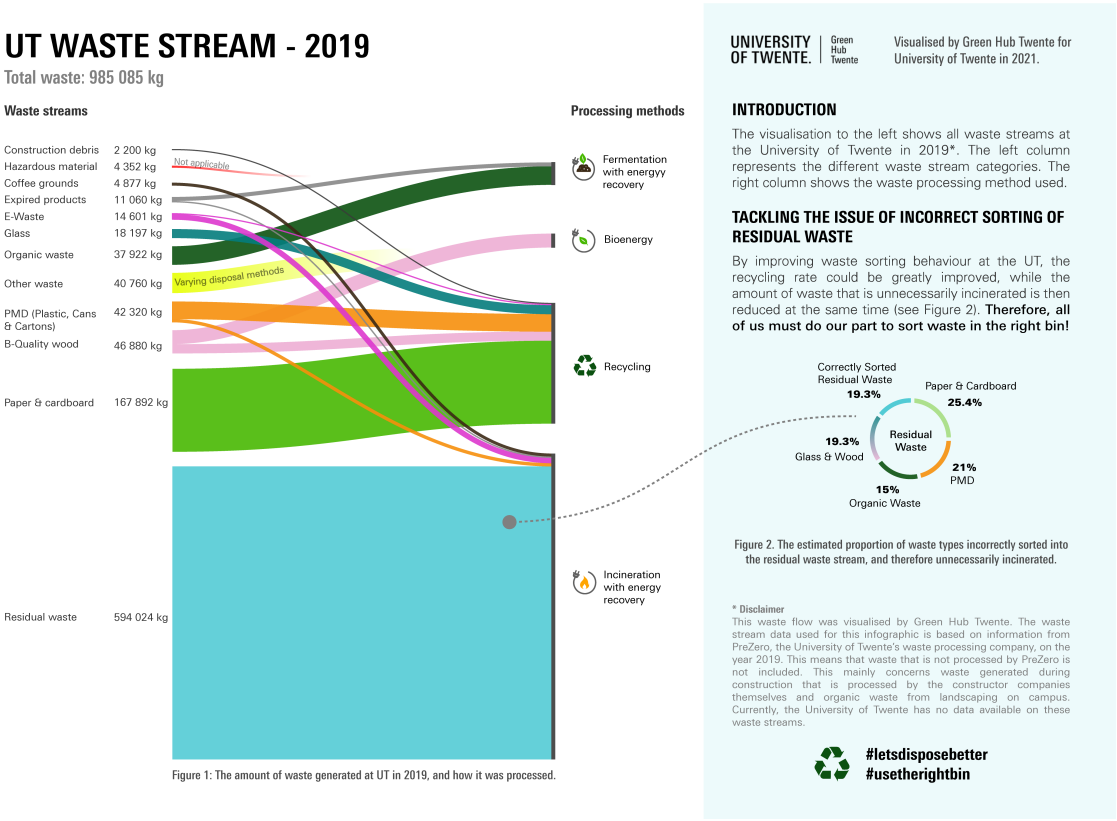

Figure 1: The amount of waste generated at UT in 2019, and how it was processed.

Figure 2.2: A visualization of waste streams at the Univeristy of Twente. Green Hub Twente created this illustration for UT in 2021.

2.1.3 PreZero

PreZero is a German company that specializes in environmental services [4]. The company's primary focus is on gathering, processing, and recycling waste to create raw materials for new products. The business mentions that in addition to the change in the composition of the PD waste stream, there are also changes in the collection and processing of this waste [5]. According to PreZero in 2023 the producer responsibility (UPV) has changed meaning that the producers are responsible for the waste management of their products. This encourages them to produce more consciously with a focus on reuse and recycling. PreZero is in charge of overseeing the entire recycling process as a specialist in the collection, sorting, and processing of PD. The company gives an example of recycling PD (Figure 2.3). PreZero retrieves the plastic packaging, removes any contaminants, and takes it to the sorting facility. Several kinds of plastic packaging are automatically sorted by infrared scanners, magnets, and wind shifters. Each sort of plastic is pressed into a bale and made ready for transportation. Granules are created by a processing company

using sorted plastic. The quality of the grains is examined in a laboratory. For instance, the granules are utilized to create new watering cans, detergent bottles, and soap bottles.

Figure 2.3: The cycle of plastic packaging illustrated by PreZero.

This is important because recycling is better for the environment than incineration. According to the PreZero recycling PD has a negative impact that is at least 40% less than incineration [5]. It was said that the recovery costs for burning one ton of PBD waste were around 1140 euros, while it was 680 euros for recycling.

Residual waste is all waste that can no longer be recycled. When something can no longer be separated or recycled PreZero provides a second life for that waste in the form of (sustainable) energy [6]. This creates environmental benefits with energy recovery instead of energy obtained from fossil fuels. The company stated that they annually generate 270,000 MWh of electricity from residual waste, which provides 70,000 Dutch households with energy. PreZero does this by first collecting residual waste from companies and taking it to a transfer location. It is checked that it does not contain a large amount of recyclable material before it is sent to an energy–from–waste plant. The waste is dumped in a waste

bunker where it is distributed over incinerators. Water is heated during combustion, which creates steam that drives a turbine that produces electricity. The remaining residual heat is meanwhile collected. This heat is used to heat residential areas, schools, and greenhouse complexes. The generated electricity goes to companies and households. The released ash is cleaned and used as a building material, for example for foundations.

Figure 2.4: The recycling of residual waste into electricity and foundation material illustrated by PreZero.

Organizations and educational institutions have a lot of paper and cardboard waste like printing paper, notes, and packaging. According to PreZero can recycle paper and cardboard well, with cardboard being recycled up to seven times [7]. Paper and cardboard can become new products. PreZero collects the paper waste and takes it to the sorting facility. The waste is then separated into cardboard, newspapers, folders, and magazines, which are later brought to the paper mill. The material is dissolved, and the pulp is washed and cleaned to be made into new products such as cardboard, paper, and toilet paper.

Figure 2.5: The cycle of paper and cardboard illustrated by PreZero.

2.2 Factors of Pro–Environmental Behavior

2.2.1 Definition of pro–environmental behavior

To understand the values and influences for pro–environmental behavior, as well as to explore possible actions that may drive change in that area, first, a definition must be presented of what is considered pro–environmental behavior. In broad terms, environmental behavior is a behavior with a significant impact on the environment. Although these behaviors may be further separated into intentional, and unintentional [8], this division does not have much impact on this literature review. The classification that is of high importance, however, is that of pro–environmental behavior (more accurately "environment–protective", "environment–preserving", or "environmentally responsible behavior") or "environmentally destructive" (or "unfriendly") behavior. Although the meaning of these terms is quite obvious, labeling behaviors and actions might spark controversy [8]. After establishing the classification for pro–environmental behavior, it is important to what types of behaviors these are.

Understanding the exact behaviors that are relevant to enhancing students' sustainable practices can be helped by categorizing them into three types. Pro–environmental behavior may be classified into "green purchase behaviors", "good citizenship behaviors", and "environmental activist behaviors" as proposed by Lee, et al. [9]. "Green purchase behaviors" are related to the consequences of a particular purchase, "good citizenship behaviors" define non–purchase–related behavior with a direct positive impact on the environment, and "environmental activist behaviors" involve driving political, social and institutional changes to solve environmental issues. Since the question to be answered is about improving waste separation practices of students, the most relevant category is "good citizenship" behavior. According to the discussion above, pro–environmental behavior is any deliberate action or behavior that has a positive influence on the environment, either directly or through motivating others to take action. After determining the definition and classification of pro–environmental behavior it is important to examine the factors that affect such behaviors.

2.2.2 Pro–environmental behavior factors

With a definition of pro–environmental behaviors, the next step is to identify the factors which can influence a person to commit such actions. There are two categories of factors: demographic factors and values/beliefs factors. The first group of these factors can be collectively described as demographic factors. The first such factor is gender: women are considered more emotionally engaged and more empathetic about the environment, believing in change rather than technological solutions [10]. Interestingly, although it might be expected that longer education might lead to more pro–environmental behavior, this correlation does not necessarily hold. There are many identified economic factors but to answer the posed questions they are less relevant, as they concern green purchase behaviors rather than good citizenship behaviors. Surprisingly, there has been a common agreement among researchers, that environmental knowledge has a quite insignificant link to pro–environmental behavior, and many studies reach this conclusion. The factor with one of the highest impacts is the values and beliefs held by the individual. Some frequently mentioned factors in this category identified by previous studies include childhood experiences in nature, experiences of environmental destruction, pro–environmental values held by the family, pro–environmental organizations, role models, and education [11]. There is also strong statistical evidence that highly individualistic societies tend to act more responsibly concerning the environment, and, in those societies, environmental awareness is much more likely to be followed by action [12].

It must be considered that this kind of overview of factors in isolation may not always be reliable. For example, a study of the environmental knowledge and behaviors of university students who are subjected to environmental courses during their education found that contrary to the previously mentioned general belief of the impact gender has on pro–environmental behavior, there was no clear difference among students in respect to that classification [13]. Additionally, the same study proves that the program of a university

student is another factor with statistical evidence of influence on sustainable behavior. In combination with the previously mentioned factors, it may be derived that factors and values influence each other and might have to be considered on a case–by–case basis.

Pro–environmental behavior can be influenced by demographic and value factors. While values and beliefs are consistently recognized as crucial factors, demographics like gender and educational level have inconsistent correlations with pro–environmental behavior. Evidence also points to individualistic societies as having a tendency for being more environmentally conscious and act with greater responsibility.

2.2.3 Barriers to pro–environmental behavior

It is also important to identify factors acting as barriers to pro–environmental behavior since actions influencing such behavior will likely aim at reducing them. According to Blake [14] there are three barriers between environmental concern and action: individuality, responsibility, and practicality. Individuality is defined as a barrier that is within the attitude and temperament of the person. Some people do not prioritize pro–environmental behavior because they are lazy or lack interest [14]. The responsibility barrier is when the individual does not feel responsible for taking environmental action. These are people's perceptions of institutions and responsibility. People do not take action because they believe that they should not take individual responsibility for helping the environment. Some people fail to see how individual efforts will have any impact on the environment. The last barrier is practicality which are the constraints that stop people from taking environmental measures regardless of their intentions. Despite views or intentions, there are still societal or institutional barriers that may prohibit people from taking pro–environmental action. They include a lack of information, encouragement, time, and money. Some people could be physically unable of performing some actions. A case study at Urmia University [15] indicates three barriers to their students participating in domestic waste segregation. The biggest factor was of lack of knowledge about the subject. The second is the university not providing executive and training programs, meaning that the trash segregation was not carried out correctly. The last barrier was the lack of trust in the university, because of the poor performance evaluations of the staff.

Furthermore, people are less motivated to engage in pro–environmental behaviors that involve short–term costs to themselves because of psychological barriers like thinking that the issue is far off in the future and that any personal actions would only be too small to have any significant impact. People who believe they can have little real impact on an issue of this scope may be deterred from making big changes in their lives by this "drop in the bucket" mentality [16]. Another barrier is thinking that environmental issues are in the distant future. According to research on risk perception, people in the United States and Great Britain view climate change as a remote issue with little bearing on them personally [17]. Both these conclusions show that people feel distant from environmental problems which also leads to decreased responsibility for taking sustainable action. In order to remove these barriers to pro–environmental behavior and create a more sustainable future,

it is necessary to recognize these obstacles and take appropriate steps to eliminate them.

2.2.4 Pro–environmental action

Environmental issues are more important than ever, and it is essential to encourage pro–environmental behavior. The most common way of encouraging pro–environmental behavior over the last few decades has been educating and raising awareness, further referred to as EAA methods (education and awareness) [18]. Though these methods are popular, their success rate varies the most as well. The provision of information only had a very little impact even when telling the individual exactly what to do, but multiple improvements show better effects. When information is tailored to the receiving demographic its success rate is higher, raised further by additionally including a public pledge for behavioral change. Contrasting social norms and performance by the means of comparison has also shown success, although if the comparison is not strong enough it may lead to the opposite of the expected result. Other studies have supported a similar claim, showing that the context in which information is provided, or choices are presented (such as the previously mentioned tailoring of information and comparison in EAA methods) has a higher impact due to automatic, unconscious cognitive processes rather than choices made by individuals [19]. This provides valuable information relevant to the research question, and may even provide an answer. Since the purpose of University is education, the ways it can influence pro–environmental behaviors in students may include raising awareness through highly tailored information, pledges for change, and providing the right context of the previously mentioned methods. Although strategies like education and raising awareness have been frequently used to promote pro–environmental behavior, their effectiveness varies. However, presenting choices in the appropriate context and personalizing information to the audience might have a greater impact.

2.3 Theory of planned behavior

In order to predict a person's intention to engage in a behavior at a certain time and location the Theory of Planned Behavior (TPB) was established [20]. The theory was developed to describe all actions that people have the ability to exert self–control. The most important element of TPB is behavioral intent, which is impacted by attitudes toward the likelihood that a behavior will result in the desired outcome and a subjective assessment of the risks and advantages of the outcome. The theory has been used effectively to predict and explain a variety of health behaviors and intents, including substance use, using health services, and smoking. According to the TPB, behavioral success is a function of both ability and motivation. It makes a distinction between the behavioral, normative, and control types of beliefs. According to TPB, there are six constructs that represent a person's actual control over the behavior: attitudes, behavioral intention, subjective norms, social norms, perceived power, and perceived behavior control. Attitudes refer to how a

person views the behavior of interest, whereas behavioral intention relates to the motivational variables that influence a particular behavior. On the contrary, subjective norms concern a person's perception of the opinions of peers and significant others regarding the activity. Social norms, which are seen as normative, are related to the accepted standards of conduct within a community or within a broader cultural setting. A person's perception of behavioral control over elements that may help or hinder the performance of a behavior is influenced by their perception of power. A person's view of how easy or difficult it is to carry out the activity of interest is referred to as perceived behavior control.

The Theory of Planned Behavior can be applied to influence recycling. Park and Ha attempt to combine elements from two theories: TPB and Norm Activation Model [21]. TPB discusses a person's intentional action that results from personal rewards and expectations, whereas NAM focuses on intentional behavior that results from altruistic and moral convictions, namely convictions of what is good and wrong. The goal of the study was to develop a thorough model of a person's desire to recycle. This model suggested four determinants of recycling behavior: attitude, perceives behavioral control, subjective norms, attitude, and personal norms. This study investigated the relationship between TPB and awareness of consequences. The findings showed that awareness of consequences comes before attitudes, subjective norms, and personal norms. People who are aware of the potential repercussions of recycling tend to see the intention to recycle favorably, with a strong sense of social responsibility and personal accountability. This study also provides recommendations to improve how to interact with customers and encourage them to recycle. It is advised that they communicate about recycling's advantages. By doing this, they demonstrate how closely linked the consumers' own action – participating in recycling– and the benefits of their behavior are. The positive consequences of recycling, such as resource conservation, landfill reduction, and energy savings through repurposing, should be included in messages. People should have a higher willingness to recycle by improving their sense of social expectation, moral obligation, and attitude toward recycling.

2.4 Education through play

Educational games and gamification have gained popularity over recent years. Game–like approaches are becoming more common in education. On the one hand, educational games are comprehensive systems created with the intention of instructing their users. Serious game mechanics help translate learning objectives and best practices into gaming by tying design patterns and educational strategies together [22]. Gamification on the other hand employs elements of games in non–game circumstances to spur action [23]. One study compares the effectiveness of learning in an undergraduate course using more traditional approaches (educational games and social networking) and newer ones like gamification [24]. The results indicate that both approaches have a substantial impact on learning performance, but social gamification produced better results in terms of im–

mediacy and for all sorts of assessments. Another study claims that results in favor of gamification over learning without it [25]. There are four factors that contribute to students' enjoyment of gamification, according to Bai and Hew: gamification can encourage enthusiasm, offer performance feedback, satisfy learners' need for recognition, and encourage goal setting. On the other hand, there are two reasons why people don't enjoy gamification: it doesn't add any new benefits, and it might make people feel anxious or jealous.

Lately, play has started to be approached through the development of interactive playgrounds. These are technologically advanced installations that combine the excitement and immersion of video games with the advantages of conventional play [26]. Interactive playgrounds might be as little as a few square meters or as large as public squares, and they can include a broad range of interactive features like toys or camera and projector combinations. By encouraging physical exercise, social contact, or cognitive growth, these installations attempt to give interesting, amusing, and immersive gaming experiences. According to Reidsma, there can be four stages to designing an interactive playground [27]. The first stage is concept generation. This is where the general "story concept" is developed and is later used as a guide for the rest of the design. In the next phase, the playground's interactions are designed along the lines of the story's theme. It focuses on creating individual interactions between its users and the playground. The third step is a systemic variation of the interactions. Each interaction is analyzed along 20 dimensions such as competition, collaboration, and item possession. The last stage is the selection of interactions that will be implemented in the playground.

2.5 Waste Education

According to a study by Christine et al., there are multiple factors to consider when thinking about why certain people recycle [28]. General awareness, understanding, beliefs, and attitudes all contribute to the reason why people segregate waste. However, it is believed that the key factor is information and education about recycling. The study shows that presenting the advantages of recycling should be communicated as one of the main messages. It also demonstrates the necessity to not underestimate people's ignorance of basic recycling practices. For instance, over half of the participants (52%) do not feel educated about local recycling services offered, and 45% do not feel informed on what can and cannot be recycled. Even more (70%) lack knowledge about what happens after the waste is collected. The study also mentions additional three actions: debunking "recycling myths" such as the waste always ends up in the landfills anyway, influencing people to make "green" consumer decisions in favor of recycled products, and enabling individuals to understand the consequences of their individual actions. Park and Ha stated that awareness of consequences increased the intention to recycle indirectly through attitude, subjective norms, and personal norms [21].

2.6 State of the Art

For all students and staff, the waste islands are the main way of throwing out waste on campus [29]. The waste island contains three separate holes dedicated to each waste stream. These waste streams are distinguished by a title, color, and graphic symbol. The organic has a lid to protect from the smell of the decomposing food and PMD has a cup hole that used to be used to gather the coffee cups together. There are two variants of the waste island: one has simple graphics to indicate how to recycle (Figure 2.6) and the other indicates that with text (Figure 2.7).

Figure 2.6: A waste island with simple graphics.

Figure 2.7: A waste island with text explanation.

Last year, an intervention was done by Creative Technology students: Claes and Rhee [30] [31]. The concept of an interactive information board and the waste island with light indicators. The installation incorporates a large interactive touch screen that is positioned above the waste island. The screen serves three purposes. Firstly, when no one is around the screen displays statistical data regarding the quality of waste separation. Second, the screen is activated when a user approached the installation. The screen displayed waste, and the user can select their waste which is then directed to the correct waste stream. Thirdly, the system monitors whether the trash is disposed of accurately or not. The screen thanks the user when it confirms that the trash was separated correctly, otherwise, it dis–plays representative examples of waste for educational purposes. Finally, the selection screen transforms back into an information screen after the user leaves the waste island, updating the information from the most recent waste disposal and providing a small reward to the user.

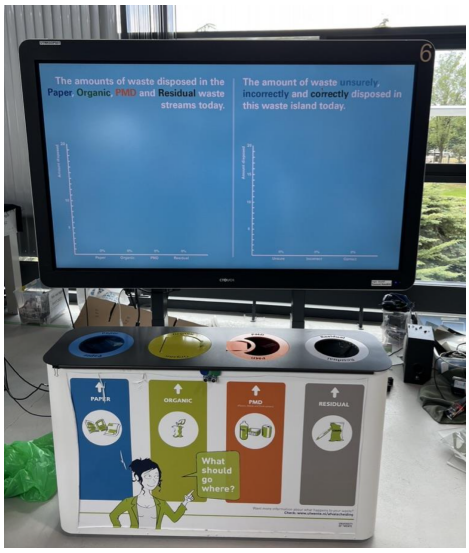

Figure 2.8: The 2022 project's final prototype.

Green Hub Twente is a University of Twente organization that monitors, shapes, realizes, and implements the UT's sustainability policies. Currently, in order to assist people in correct waste segregation, by providing visual information, new posters have been placed above the waste islands in a few selected locations (Figure 2.9) [32].

Figure 2.9: Instagram post from @greenhubtwente showcasing the posters.

The Fun Theory is an initiative of Volkswagen that seeks to change people's behavior by making it fun [33]. Volkswagen Sweden and an advertising firm DDB Stockholm launched Fun Theory in 2009 as a way of increasing sales of environmentally friendly cars

by demonstrating that they were just as fun to drive as conventional cars [23]. They wanted to show that by making something fun to do, human behavior could be improved. They started a competition where individuals could submit their own suggestions for how to use fun theory. The fun theory went viral and encouraged lots of people to think creatively. One of the initiatives was the Bottle Bank Arcade [34] (Figure 2.10), which would make recycling glass bottles more fun. The resembles an arcade game where users can input their glass bottles to earn points. To add to the fun ambiance, the machine also made sounds and lit up. The Bottle Arcade was set up in a public space in Stockholm and gathered many people to try it out.

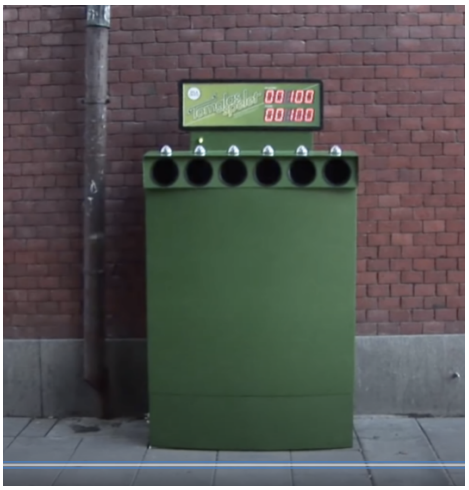

Figure 2.10: The Bottle Bank Arcade

Figure 2.11: The World's Deepest Bin

Another interesting intervention done by Fun Theory is the World's Deepest Bin (Figure 2.11) [35]. The goal of this installation was to make throwing away trash more fun and rewarding. When waste is thrown into the bin, it produces the sound of something dropping very deep. A speaker is concealed within the bin that amplifies the sound. This intervention was done in Stockholm. It is reported that the world's deepest bin gathered more trash than a neighboring standard trashcan, according to Fun Theory. This demonstrated that individuals were more likely to throw out the trash while having fun, instead of littering.

PUCOLJ! (Recycle!) is a board game concept that encourages players to learn the fundamentals of recycling household waste [36]. The environment is the main point of interest for the participants, who are also learning about recycling through play. The game can be played with two to four people and lasts between thirty and sixty minutes. Steps are indicated by one dice, while special actions that might be lucky or unlucky are indicated by the other dice. Once a player has collected a certain amount of tokens, the game is over. The game has a lot of elements to ensure the element of chance and a fast–paced

game. These elements help to maintain focus and help players keep track of their activities during the game. The board is also unique in a way that it can be mixed and matched by the players.

Figure 2.12: PUCOLJ!: A recycling board game.

MonJi is an interactive recycling machine (Figure 2.13) [37]. It has an automated sorting system that divides recyclable trash into categories, such as plastic or aluminum. The installation also contains interactive features such as a mini–game that starts after a user recycles. This interactive machine is a great illustration of a technology–based intervention. Along with its sorting mechanism, the mini–game that begins once a user recycles makes the recycling process more fun.

Figure 2.13: Interactive recycling machine.

2.7 Discussion and Conclusion

In order to achieve its goal of becoming more sustainable, the University of Twente has developed a waste plan where one of the main objectives is to increase recycling rates. The collected waste is gathered by PreZero which sorts and processes the waste to produce materials for new products. Plastic packaging is recycled into new items such as bottles and paper is recycled back into paper. The electricity produced from residual waste is utilized to power homes and businesses. The effectiveness of the waste plan does not only depend on the implementation of waste islands but also on individual pro–environmental behavior.

Demographic considerations and value/belief factors both have an impact on pro–environmental behavior. While attitudes and ideas are constantly regarded as crucial factors, demographic factors like gender and education level show inconsistent connections with pro–environmental behavior. There is also evidence that societies with strong individualism tend to be more responsible and environmentally aware. Individuality, responsibility, and practicality are the three categories of barriers to pro–environmental behavior, where practicality refers to the constraints that prevent people from taking environmental action regardless of their intentions and can include a lack of knowledge, encouragement, time, and money. One way to deal with these barriers and increase pro–environmental behavior is through education and raising awareness.

It is possible to predict a person's intention to engage in a behavior, like recycling, using the Theory of Planned Behavior. The constructs that show a person's control over behavior are attitudes, behavioral intention, subjective norms, social norms, perceived power, and perceived behavior control. According to a study that combined TPB and the Norm Activation Model, the strongest predictor of recycling behavior is awareness of the consequences. Improving attitudes and increasing motivation to recycle can be done by highlighting the benefits of recycling, such as resource preservation and energy savings. Implementing a community–wide recycling program that makes recycling easily accessible and fun is one effective way to raise recycling rates.

In recent years, gamification and the usage of educational games in the classroom have gained popularity. Studies show that both methods have a big impact on learning performance, but gamification performs better across the board in terms of immediacy and assessments. The goal of interactive playgrounds, which include video games with traditional play, is to offer immersive gaming experiences that promote social interaction, physical activity, and cognitive development. Education regarding waste is also crucial because so many people are unaware of the fundamentals of recycling. The intention to recycle can be increased through education and awareness of the advantages of recycling, debunking recycling myths, promoting environmentally friendly consumer choices, and understanding the effects of individual actions.

The interventions mentioned in the State Of The Art demonstrate the different ways that waste separation and recycling can be made more fun, enjoyable, and engaging for people. The use of games, technology, and visual information encourages people to recycle

more and work towards a more sustainable future.

Chapter 3

Methods and Techniques

This chapter describes the methods and techniques used to carry out this project. This chapter will give a general overview of the research strategy and methodology used. The goals of this chapter are to give a comprehensive description of the research process and show how the project was carried out in a systematic way. This allows to ensure the reliability of the research results.

3.1 Design Method

This project follows the Creative Technology Design Process developed by Mader and Eggnik [38]. Figure 3.1 shows the four main phases of the Creative Technology Design Process: Ideation, Specification, Realization, and Evaluation. This model mixes divergence and convergence in a cycle to broaden the design space to encourage creativity and then constrains it to work toward a solution. It underlines the value of design checkpoints that allow for feedback and more detailed planning. The process considers the various paths taken by a design project as well as how technology and user experience interact. The method is adaptable and goes through each stage more than once to revise and improve a product's design and prototype. It combines research, user feedback, and prototyping to provide a working prototype that satisfies stakeholder and user needs. To guarantee the validity of this project, this methodology provides a thorough and organized approach to the design process.

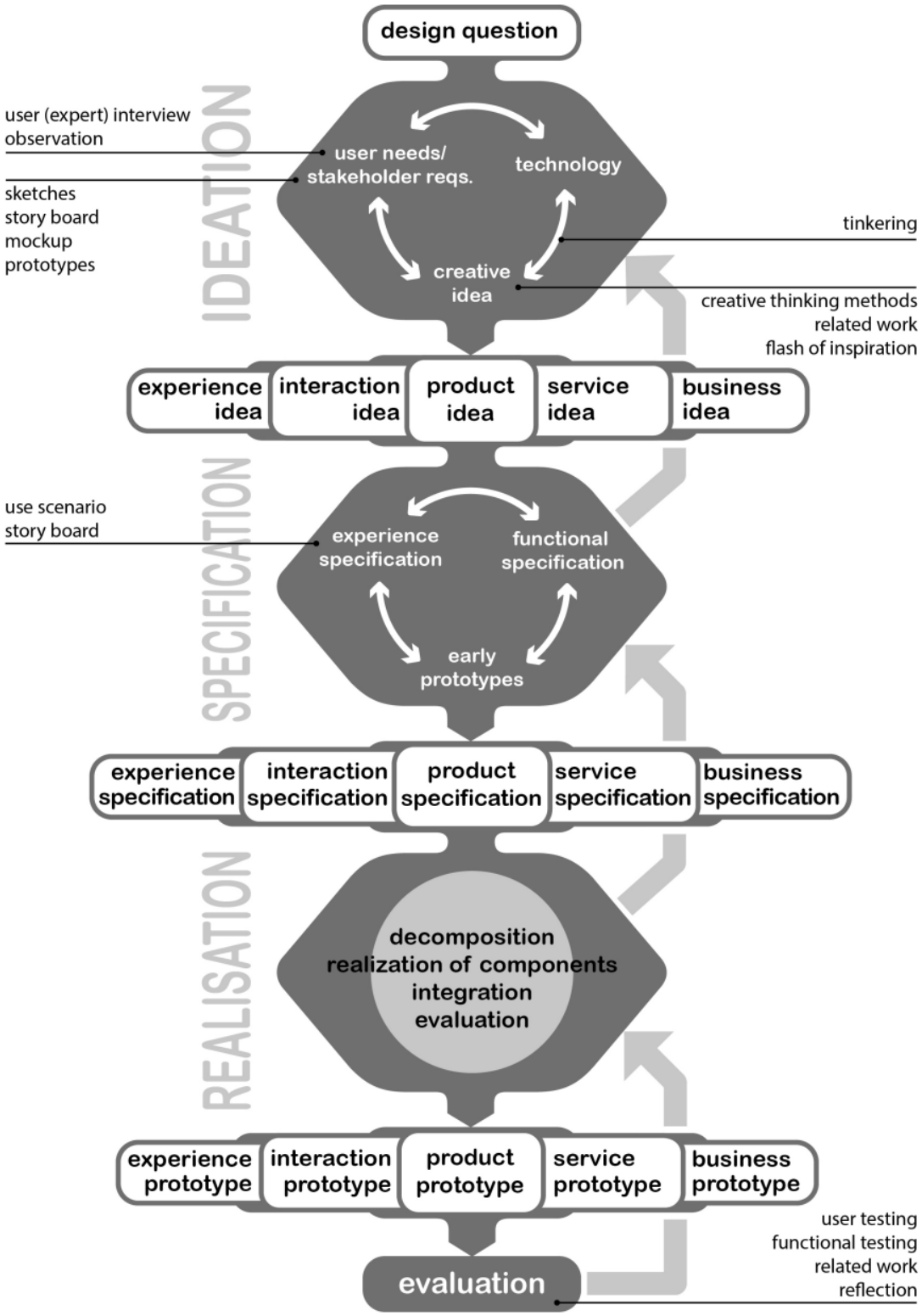

Figure 3.1: A Creative Technology Design Process

3.2 Ideation

3.2.1 Stakeholder Identification and Analysis

Identification of stakeholders involves identifying parties who can affect the project or who will directly be impacted by its results. An analysis of the stakeholders is done in order to determine the key stakeholders. An overview of all the stakeholders in the research and development process is presented by the Power–Interest Grid [39]. This technique is used to classify stakeholders into four groups according to their influence, power, and level of interest in the project. Four quadrants make up the matrix, each of which represents a different approach that should be taken toward the stakeholders. The "Monitor" quadrant has stakeholders with little influence and low interest in the project. The "Keep informed" quadrant includes stakeholders that have limited influence but have a big interest in the project. The "Keep satisfied" quadrant has stakeholders who have a lot of influence but low interest in the project. Lastly, the "Manage closely" quadrant includes stakeholders who have both high power and high interest. Figure 3.2 shows the empty matrix. The stakeholder's level of interest is represented by the horizontal axis, while the stakeholder's impact is represented by the vertical axis. The Power–Interest evaluation will allow to better comprehend the different stakeholders in this project and assess how important stakeholders will affect the design process.

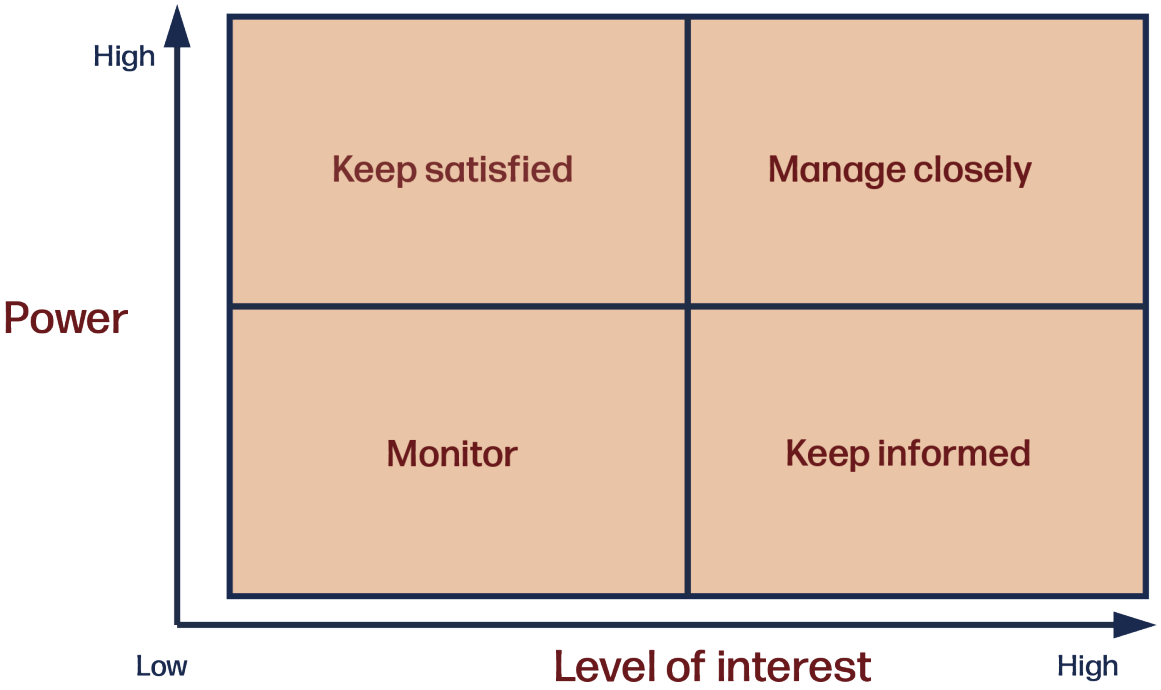

Figure 3.2: Power–Interest Grid

3.2.2 Requirements Elicitation and Prioritization

The next step is to establish each stakeholder's needs after identifying them and using the Power–Interest Grid to analyze their engagement.

Eliciting requirements for this project was done by obtaining data from various stakeholders to understand their needs, expectations, and preferences in relation to recycling processes and initiatives. First, the key stakeholders were determined. The next step was gathering information from these stakeholders through interviews. Another way of eliciting requirements was through background research and state–of–the–art.

Prioritization is essential in order to achieve the best possible solution, even though all requirements are important. This project used the MoSCoW method in order to prioritize requirements [40]. This approach categorizes and ranks the requirements allowing for better management and ensuring that the most important requirements are handled first. MoSCow divides the requirements into four different categories: Must have, Should have, Could have, and Won't have. Each of these groups indicates a different level of importance. "Must–have" requirements are crucial, and the project will fail if they are not included. These are the basic requirements that must be met in order for the project to be regarded as successful. The "Should–have" requirements are significant but not urgent. Although it would be unfortunate, the project can nonetheless proceed without them. If time and resources allow, the "Could–have" requirements would be preferred to be included but not required. The importance is lower, and their absence does not have as great of an effect on the project's success. The least important requirements are the "Won't–have" requirements and they are eliminated or given another chance to be added later. These requirements are purposefully left out in order to manage the project's expectations or define its scope.

3.2.3 Concept Ideation

In order to transform the research question, stakeholder requirements, and background research into an interactive product multiple brainstorming sessions were done. Brainstorming is a creative thinking method used to generate ideas and solutions to problems or questions. The researchers tried to come up with as many ideas as they could during these sessions, regardless of how feasible or useful they were. Then, these concepts were discussed and analyzed to find the most promising concepts. In order to organize these ideas a brainstorming technique called mind–mapping was used [41]. Mind maps offer a non–linear diagram that includes all the thoughts brought up in a brainstorming session. To make a mind map, an overall topic or issue is placed in the middle and then all coming thoughts are branched out from it.

3.3 Specification

3.3.1 Storyline

The written storyline serves as a script or blueprint that guides the entire development process, making it an important part of the realization phase. It gives a clear narrative direction and makes sure that the game's design, gameplay mechanics, visual assets, and audio components all support the intended story. Additionally, it acts as a reference point for control of quality, ensuring that the final product aligns with the intended vision.

3.3.2 Storyboard

For a game to be realized, a storyboard is essential as it offers a visual roadmap that specifies the gameplay and story components in sequential order. It helps to comprehend and organize the game's structure. The storyboard also acts as a communication tool. By anticipating potential problems and challenges, the storyboard makes time and resource management possible.

3.3.3 Persona's

Creating relevant personas that are able to act as representative users is crucial before designing and specifying the entire interaction [42]. This will be accomplished by identifying the personality traits and demographics that matter when interacting with the intervention.

3.3.4 Interaction scenarios

An interaction scenario is a description of how a user interacts with a system or product in a particular context [43]. It explains the steps a user takes to complete a certain job or objective while utilizing the product. A number of scenarios will be developed in order to construct a scenario analysis for the use of the product [44]. To create such scenarios three questions need to be answered:

- For who is the product?
- What is the goal of the product?
- In what situation is the product used?

By combining all components, the researchers create a comprehensive set of use cases for which the product should perform optimally. The whole set of scenarios offers information about the wants and needs of the users.

3.3.5 Functional and non–functional requirements

The stakeholder requirements obtained during the ideation phase will be transformed into visualization requirements. They will be divided into functional and non–functional requirements [45]. A functional requirement defines what a product has to do in order to be useful to its user. It outlines the crucial features and operations required for the product to satisfy the needs of its intended purpose. On the other hand, non–functional requirements are qualities and features that a product must have in order for its owner and user to find it suitable. These requirements define important elements including performance, aesthetics, usability, and security. In some instances, fulfilling these non–functional requirements is essential to the product's success as a whole. Non–functional requirements are often more challenging to measure but are just as crucial to the success of the final product. These criteria will be then categorized using the MoSCoW technique which was described in section 3.2.2.

3.4 Realisation

Once the specification has been completed the prototype will be developed. The visualization requirements will guide the development process. The first emphasis will be on satisfying the requirements marked as "Must". The "Should" requirements will also be addressed once the "Must" have been met. This whole process will be done in collaboration with a fellow researcher. Individual parts will be tested to function properly and then put together to make the finished prototype.

3.5 Evaluation

Once the prototype is completed it will be evaluated. The evaluation aims to determine the effectiveness and influence of the intervention. First, a functional requirements test will be performed by the researcher to determine if the functional requirements have been met.

In order to evaluate the results and identify areas for improvement, this phase involves gathering information from user testing. First, the participants will go through the whole interaction with the installation. Second, the users will answer a questionnaire followed by an interview. The purpose of user testing is to evaluate the prototype's effectiveness, usability, and user experience.

A questionnaire is a structured data collection technique used in evaluations and user testing to gather feedback from participants about their experiences and satisfaction with a product [46]. For this evaluation, the survey will collect quantitative insights using Likert scale questions [47]. The survey data identifies the prototype's strengths and weaknesses.

In order to get detailed qualitative data from participants about their interactions with the prototype, a structured interview will be conducted [48]. For consistency throughout

all interviews, the interviewer will use a predetermined set of questions in a specific order. It allows for better comparison of responses, making the analysis easier. The consistent format makes sure that every crucial component of the user experience is covered. This data will be essential for determining problems experienced by users, and making recommendations for improving the design.

To guarantee that the participant's rights, privacy, and ethical considerations are respected, it is important to obtain voluntary and informed consent. The participants will be given detailed information about the goal, process, potential risks, rewards, and confidentiality measures related to their involvement before any data is collected. Before choosing to take part in the evaluation they will have to chance to clarify any uncertainties. Participants will be made aware that participation is entirely voluntary and are free to revoke their consent at any moment with no repercussions. The participants will also be made aware that their information will be kept in an anonymous manner.

Chapter 4

Ideation

In this chapter, the stakeholders will be identified and analyzed. To understand the needs and preferences of the key stakeholders, such as the UT community, clients and supervisors must be evaluated. The requirements of these stakeholders will be then described and analyzed. This information is then used as a starting point for brainstorming that will produce many concepts, which will be described. A decision will be reached at the end, and the final concept will be presented.

4.1 Stakeholder Needs and Requirements Definition

The stakeholder needs and requirements definition is important for a number of reasons. Firstly, it helps make sure the final product matches the needs and expectations of the stakeholders. Secondly, it enables collaboration and communication between the researchers and the stakeholders. This reduces misunderstandings and raises the possibility of the project's success. Thirdly, this provides a basis for prioritization and decision-making in the ideation and specification phase.

4.1.1 Stakeholder Identification

Stakeholder identification describes the individuals, groups, and communities that have an interest, involvement, or influence in this project. This involves finding all relevant stakeholders who could have an impact on the project's success. This establishes the basis for understanding the needs and expectations of the stakeholders.

UT–CFM: The UT Campus Facility & Management is a crucial stakeholder in this project. They are the client of this project and have an interest in the outcome. They have a role in providing resources such as information and analytics.

UT Community Members: The UT Community Members are a very important stakeholder in this project. They are directly affected by the project's outcome. As the primary users of the intervention, their input and satisfaction are crucial for the success

of this project. The university community includes students, faculty, staff, administrators, and visitors. Their participation and involvement are essential to the success of this project. Therefore, they have a direct influence on the design process. The project's design and implementation phases should take into account their requirements, preferences, and feedback. They will also be a crucial part of the realization and evaluation phase of the project.

Supervisors: The supervisors of this project have a direct interest in the success of this project. They are responsible for overseeing the project and making sure that it meets the set goals and deadlines.

Developers: The developers are responsible for the implementation of this project, making sure that it complies with the requirements. They are also in charge of the planning and design of the intervention. The success of the project is in the developer's best interest.

Waste Company – PreZero: The waste company is responsible for collecting and managing the waste collected at the University. The University has to adhere to the collection rules they imply meaning this project has to adhere to them as well.

4.1.2 Stakeholder Analysis

A Power–Interest matrix is shown in Figure 4.1 to help with understanding the stakeholders' relationships, determining their influence over the project, and determining their degrees of interest. To do the stakeholder analysis a Power–Interest Grid was used which was described in Chapter 3.

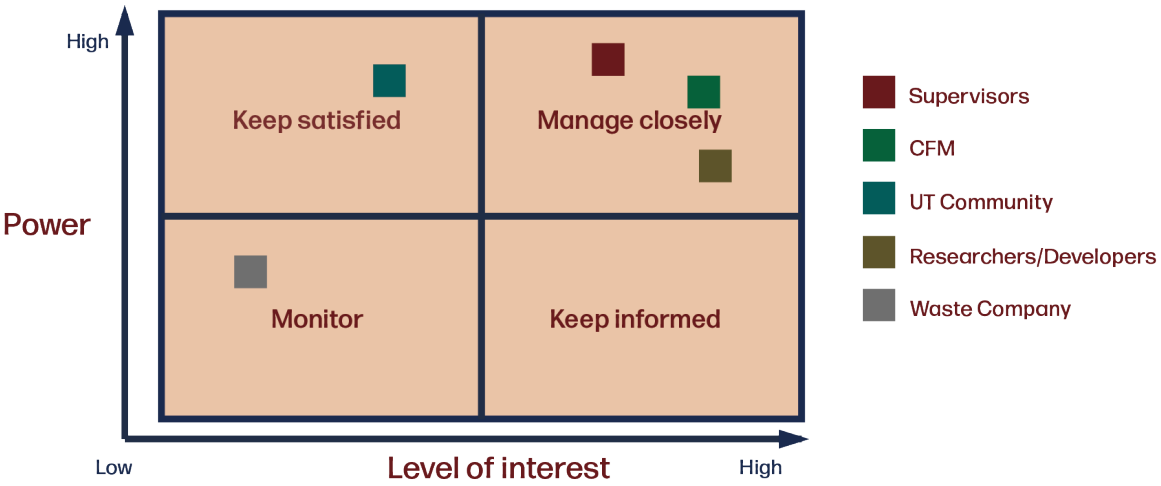

Figure 4.1: Power–Interest Grid with stakeholders of the project.

In the High Power–High Interest category, we have three stakeholders: Supervisors, UT–CFM and Developers. These are the stakeholders that have the greatest influence on

the project's success and are also decision–makers.

In the High Power–Low Interest category, we have one stakeholder: the UT community. The users of the intervention have a great say in how it will be designed.

In the Low Power–Low Interest category, we have one stakeholder: the Waste Company. This is the stakeholder we should monitor, as a change in their policies can influence our project.

4.1.3 Stakeholder requirements

Following the identification and analysis of stakeholders' level of involvement in the project, Table 4.1 lists the stakeholder requirements.

Stakeholder requirements		
Requirement	**Priority**	**Stakeholder**
The installation must educate on waste separation rules.	Must	UT–CFM, Supervisors, PreZero
The installation should invoke social interaction.	Should	Supervisors, Developers, UT Community
The installation game can be replayable.	Could	Supervisors, Developers
Interacting with the installation must be entertaining.	Must	UT Community, Supervisors
Interactions with the installation should be intuitive.	Should	UT Community
The installation could educate on general sustainable behavior.	Could	Developers
A full intended user experience with the installation should take no longer than 5 minutes.	Must	Supervisors, UT Community
The installation game could be played individually as well as cooperatively.	Could	UT Community, Developers
The interaction with the installation should be memorable.	Could	UT Community, Developers

Table 4.1: Stakeholder requirements.

4.2 Concept generation

4.2.1 Ideation

During the ideation phase, multiple brainstorming sessions were held. These sessions took into account information from both background research and stakeholder requirements. Figure 4.2 shows a mind map that represents the results of a brainstorming session. The mind map shows potential ways to solve the research questions.

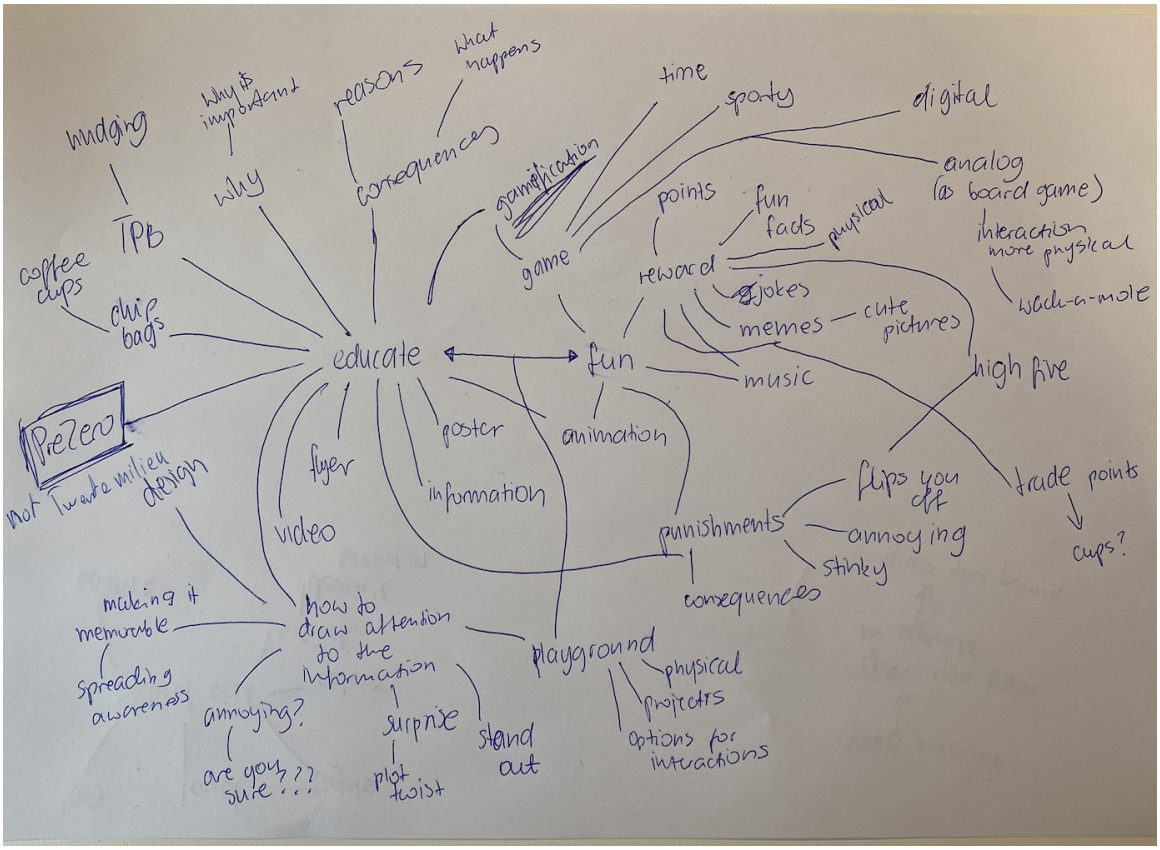

Figure 4.2: Ideation mind map.

4.3 Preliminary concepts

4.3.1 Arcade machine

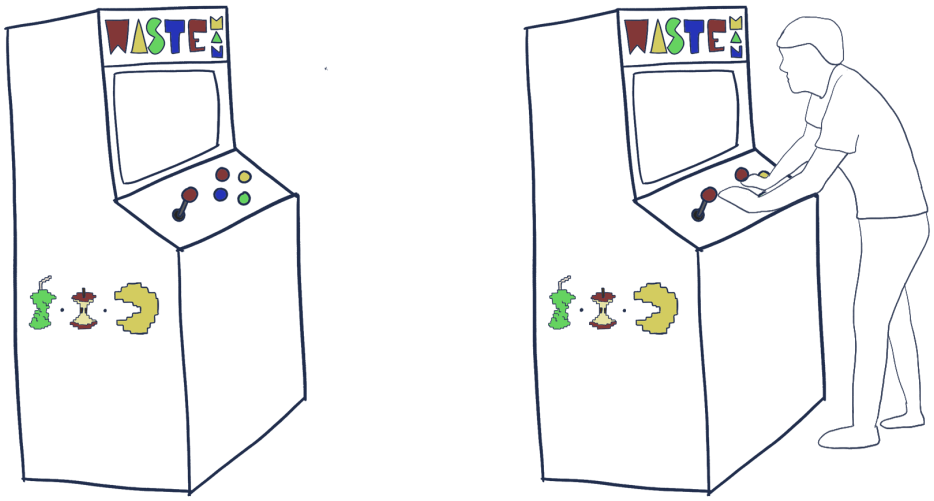

Figure 4.3: Concept 1: Arcade Machine

The arcade machine was intended to be a fun and educational way to encourage waste separation. The machine has a retro appearance, complete with flashing lights and waste–themed artwork in the style of the 80s and 90s. It has at least two classic games, such as Pac–Man or Gold Miner, with a waste separation twist, and it keeps track of high scores. The games themselves would also use pixel art to fit the arcade theme. The scenario shows a person approaching the machine, playing the game, and learning about waste separation while they are playing. They can better segregate trash using the knowledge they have gained and encourage their friends to play the game as well. In addition, the arcade machine could be activated by "paying" with an empty coffee cup or bottle.

4.3.2 Game machine pillar

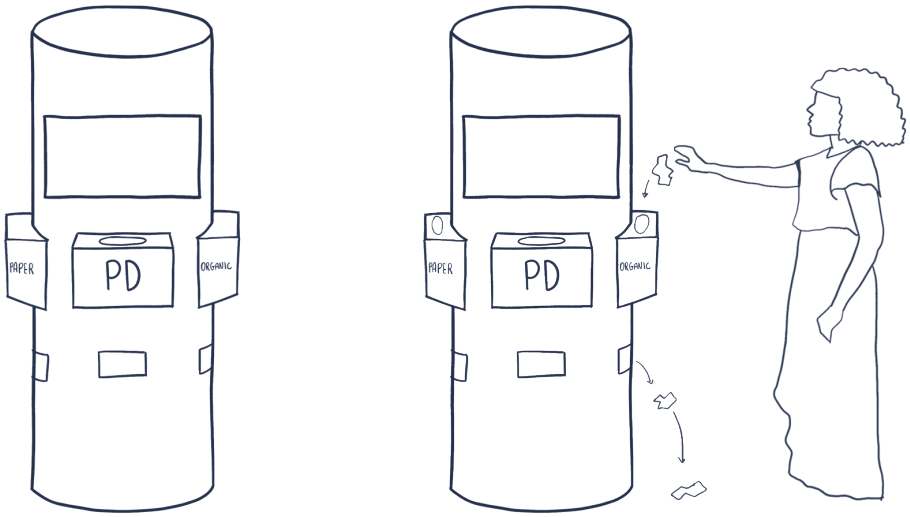

Figure 4.4: Concept 2: Game machine pillar

The game machine pillar is a standalone installation with bins on all four sides. It features flashing LED lights that indicate the game element, with 3D–printed items representing trash. Its features include speakers for music and sound, the ability to shoot out tagged trash, and the ability to check the trash using RFID. In the scenario, a user approached the installation, launches the game, and receives a quick introduction. Then, the music begins, and the lights surrounding the bins begin to flash. When all things have been separated from the rubbish, the timer is stopped, and the users' points are counted.

4.3.3 Reaction game

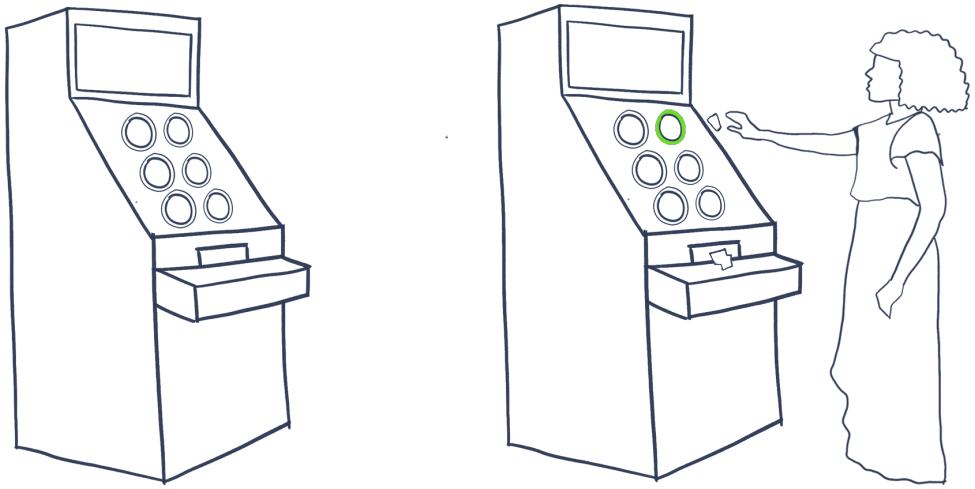

Figure 4.5: Concept 3: Reaction game

The reaction game is a physical arcade–style machine with four/six holes and a dispensing hole that resembles a skeeball, arcade basketball, or whack–a–mole machine. It replicates waste using 3D–printed objects. The trash is checked using RFID. There are also speakers for sound and music. A player approaches the machine, starts the game, and is given a briefing. The trash is dispensed when the music begins. The user must then try to insert the object into the hole that corresponds to the proper waste stream. Points are asses based on the amount of time the object has been separated correctly. No points are given if the item is separated incorrectly. The game ends after a certain amount of time, and the points are shown. By switching the color of the lights around the holes, the holes switch the waste streams they stand for.

4.3.4 Story game

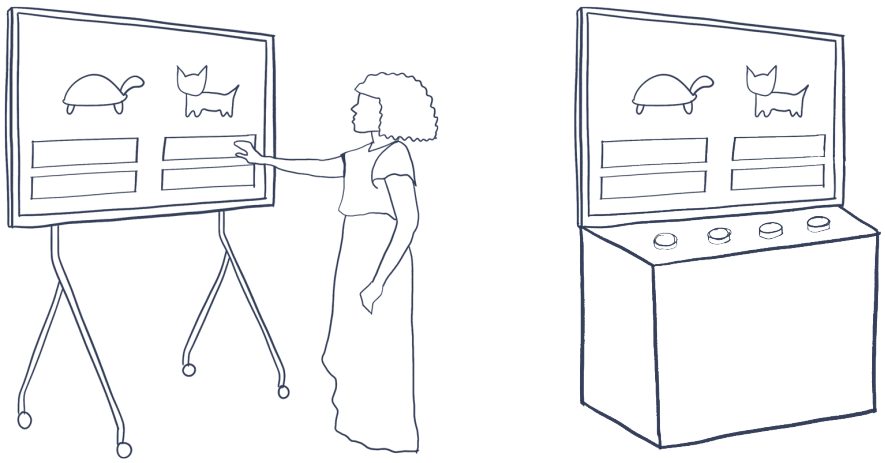

Figure 4.6: Concept 4: Story game.

The story game is an installation with an interactive story game in it. The interactive screen is designed to have an idle animation to draw users' attention. Users can engage with the game by pressing buttons, using a touch screen, or other eccentric input that can influence the animation. In the scenario, the user approaches the screen, taps it with their finger, and decides what the protagonist will do following a scene. The user's decisions affect how the game end, and because of that, there are multiple potential endings to the game. This also makes the game replayable multiple times. The user learns about waste separation and what happens to the waste through the story.

4.3.5 Board game table

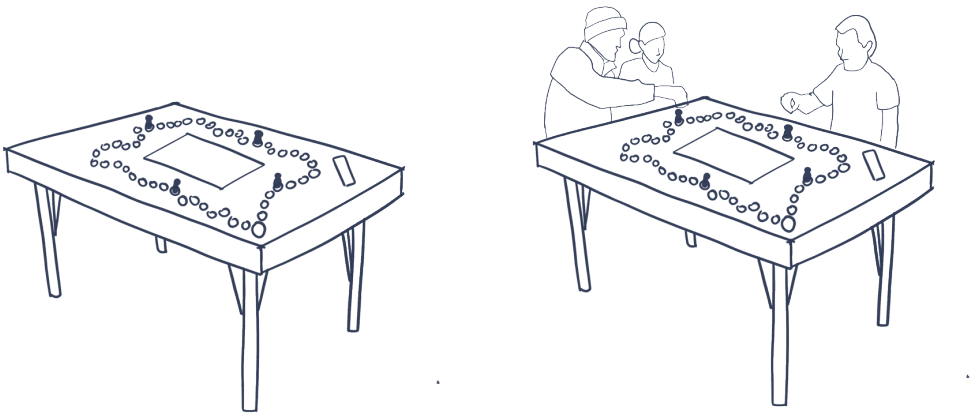

Figure 4.7: Concept 5: Board game table.

The board game table is an installation that features a table with an integrated board game in it that would be playable with multiple people. It has a screen in the center that shows game elements through lights, sounds, and music and is approachable from all sides. The game characters and objects are 3D–printed and there are physical interactions connected to the table game. While the screen shows animations on what to do or give players information, the table uses light detection to keep track of the movement of the pawns on the board. Users engage with the game by touching the screen. Users select their characters (pawns) to move around the board as the game begins with music playing in the background. They must do particular tasks in order to advance in the game. The objective of the game is for the players to complete the journey faster than their opponents.

4.4 Preliminary concept

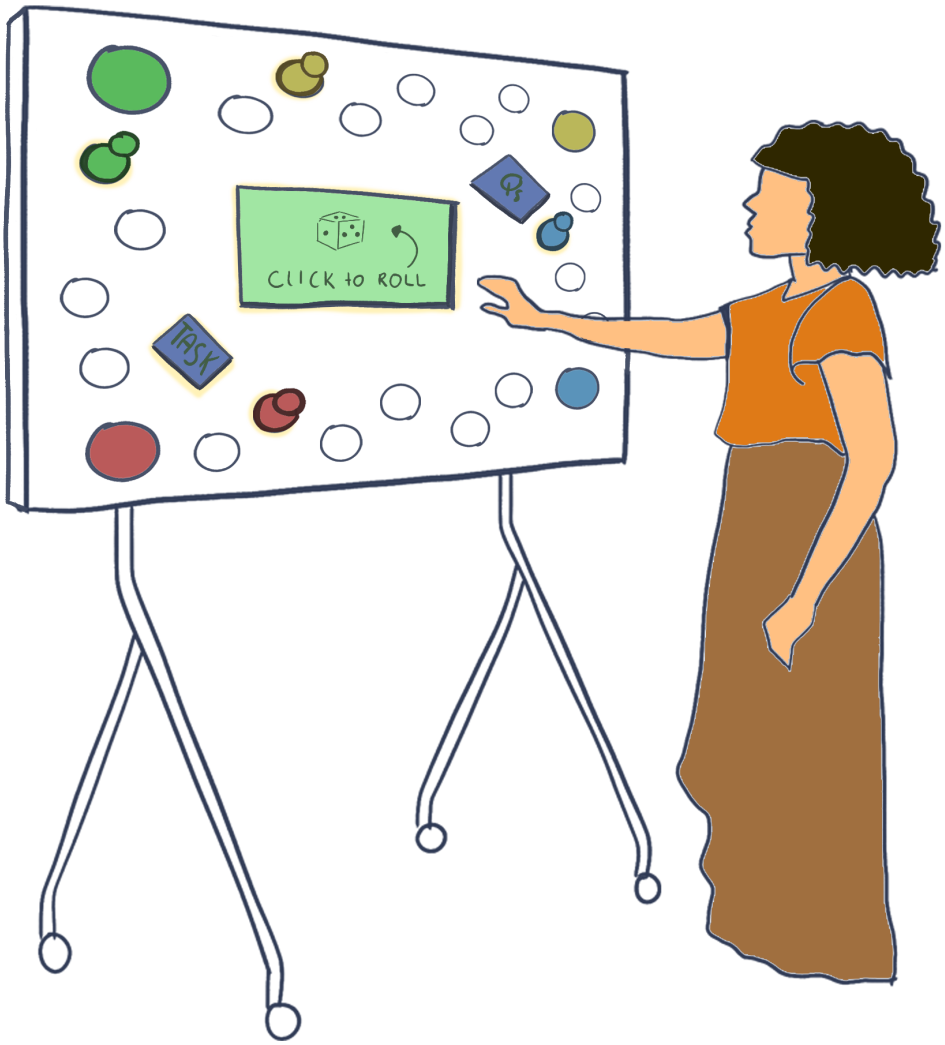

Figure 4.8: Preliminary chosen concept.

The chosen idea is a vertical board game with a retro and colorful design. Multiple players can play cooperatively or compete with one another using the game's features. The lay–out of the game will be vertical, and the main objective is to demonstrate how fun waste separation can be. The user must set the pawns in the starting position, hit the play on the

screen and one player rolls the virtual dice to being the game. Players learn about waste separation and what happens to the waste when it is collected from the game's narrative. The game could include twists to keep the players interested, such as snarky comments, cynical narration, and unexpected choices or outcomes that have an impact on the game's course. The game will have a 5–minute time limit and be made to be entertaining as well as educational.

4.4.1 Ideas for the board game

Escape the curse of the Wasteland (Temple)

Time: 5 minutes Players: 2–4 Gameplay: Inspired by "Escape the curse of the Temple" [49]. Start in the middle of the temple (trash), by earning points you are able to exit the temple (garbage pile) and the maze within. Points are trash items assigned to the individual members of the team which they find by exploring. In order to explore more parts of the maze they need to do certain tasks/puzzles. After all members find their items and come together at the end of the maze they're able to open it and finish.

- The goal of the game is to escape a cursed Wasteland by finding the exit before time runs out.
- To set up the game, each player chooses a character (waste stream) and takes a set of colored dice. The board is placed in the center of the table and the wasteland tiles are arranged around it. The trash tiles are placed on the board, and the soundtrack is started.
- Players then roll their dice to determine their starting position on the board. Once the game begins, players must move around the Wasteland, collecting trash and activating the trash to unlock doors and find the exit.
- The game is played in real–time, with all players rolling their dice simultaneously and shouting out instructions to each other. Players must work together to overcome obstacles and avoid being trapped by the wasteland's curse. They must get all of their assigned trash and then come together to open the exit.
- In addition to rolling dice to move and activate gems, players must also roll a special black die to progress through the Wasteland. If a player rolls a curse symbol on the black die, they must immediately return to the starting tile and roll the black die again before they can continue.

Exploding Trash (Exploding Kittens Inspired)

Time: 5 minutes Players: 2–4 Gameplay: Inspired by "Exploding Kittens" [50].

- The goal of the game is to be the last player standing while avoiding getting blown up by an exploding trash card.
- At the beginning of the game, each player is dealt a hand of cards. The deck is made up of various cards, such as (normal) Trash cards, Defuse cards, and various action cards. This is also when a player draws which waste stream they are.
- On a player's turn, they draw one card from the deck and play as many cards as they like, using them to try to manipulate the game in their favor or to baffle their opponents. For example, they can use a Nope card to cancel out someone else's action, or a See the Future card to peek at the top few cards of the deck. Their goal is to have as little of the other trash (from other waste streams) as possible when the Exploding Trash card is drawn.
- If a player draws an Exploding Trash card, they are immediately out of the game (and have to count how much of their waste and "other" waste they have) unless they have a Defuse card. A Defuse card can be played to "defuse" the explosion and move it to the bottom of the deck, giving the player a chance to stay in the game (this card can be a task or just simply a card that says "you have defused the explosion by separating the metal from PD)
- The game continues until all but one player has been eliminated. That player is the winner!

RPG Game

Time: 5 minutes Players: 1–2 Gameplay:

- You're a piece of trash (in the game) and you and your other waste friends go through the journey of waste separation/recycling. You know where you're supposed to end up but not the process you're gonna go through. Using pre–zero's waste separation techniques, the trash gets more and more separated and you and your friends to overcome the issues of incorrectly separated trash. This could include polluted trash, trash with leftover food in it, or items that have been wrongfully put in residual.

Another option:

- Players take on the roles of adventurers tasked with saving a kingdom that has been plagued by pollution and waste. To do so, they must explore different areas of the kingdom, fight monsters, and collect recyclable materials to turn them into useful items.
- The players are tasked with collecting a variety of recyclable materials from different areas of the kingdom, such as plastic, glass, and metal. They must bring these materials to a recycling center to turn them into useful items that will help the kingdom become more sustainable and reduce pollution.

- In each area, players must find and collect recyclable materials. Once players have collected enough materials, they can bring them to a recycling center to create useful items.
- Players can also encounter NPCs who can give them quests or provide useful information. For example, an NPC might ask the players to collect a certain amount of recyclable materials in exchange for a valuable item.

Another option:

- Players take on the roles of survivors in a post-apocalyptic world where the earth has been ravaged by pollution and waste. To survive, they must explore different areas of the wasteland, fight off dangerous scavengers, and scavenge for recyclable materials to take them to the LAB and fix the world.

Into board game:

- The board is divided into different areas of the wasteland, such as abandoned buildings, scrapyards, and junkyards. Each player chooses a survivor character with a unique set of skills and abilities and places their pawn on the starting space. Players also receive a set of resource cards, which represent the recyclable materials they scavenge.
- The main quest is to collect a variety of recyclable materials from different areas of the wasteland and bring them to a LAB to turn them into useful items. Players must collect a certain amount of each type of material to complete the quest and win the game.
- On their turn, players roll dice to determine how many spaces they can move on the board. They can move in any direction and must avoid dangerous scavengers who will attack them if they land in the same space.
- When a player lands on a space with recyclable materials, they draw a resource card. The card shows the type and amount of material they have found.
- Players can also draw encounter cards, which represent other survivors they meet in the wasteland. These cards provide opportunities for players to trade resources or complete side quests for valuable rewards or get information about what happened to the world.

4.5 The second iteration of the preliminary concept

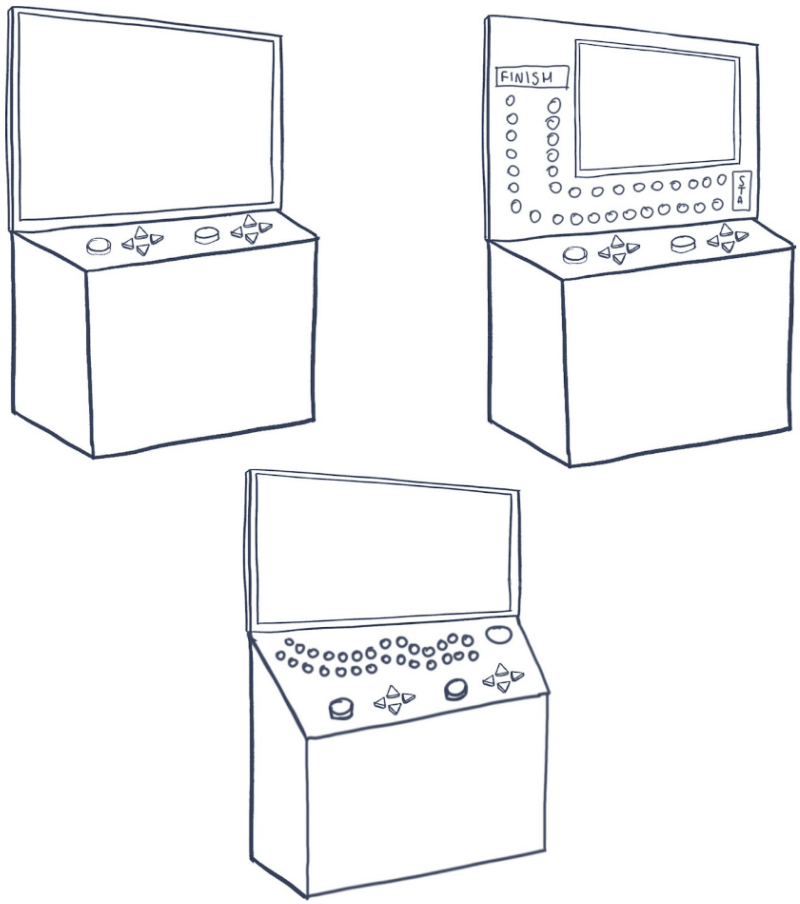

Figure 4.9: The second iteration of the preliminary concept

The second iteration of the preliminary concept would be an arcade–like installation, "Trash Party", which would offer an exciting and educational gaming experience for two players within a 5–minute timeframe. This concept was inspired by MarioParty [51]. The main goal would be to beat your friend to the finish line. To move closer to the finish– players play minigames. Winning minigames grants you more moves closer to the finish (ex. 4) and the loser moves less (ex. Doesn't move or just 1 move). The minigames are trash themed and aim to teach the players about recycling. The minigames are around 30–45 seconds long.

Potential story: A recycling wizard stops you while you're recycling improperly and shows you the future if you continue on this path (trashy wasteland or whatever). You then

start a quest in order to stop waste stream pollution (together with your fellow player(s)). In this quest, you're presented with separation tasks in order to combat the pollution. By scoring enough points throughout the minigames you're able to fight pollution and win the game (beat your friends)

4.6 Final concept

The final concept underwent three iterations and was created by combining several concept ideas. It was decided to combine concepts 1,4,5, and 6 to create the best interactive and educational solution to the waste separation problem. This iteration also took the sustainability of the materials into account as well as other factors such as the size of the monitor. The sketch of the final iteration can be seen in Figure 4.10. The prototype would utilize a CTouch touchscreen [52] with a wood panel attached to the screen stand. For the implementation, I would be responsible for the game's plot, presentation, and game design, while Hans Nielen would be in charge of the physical appearance, inputs, and communication between the inputs and outputs.

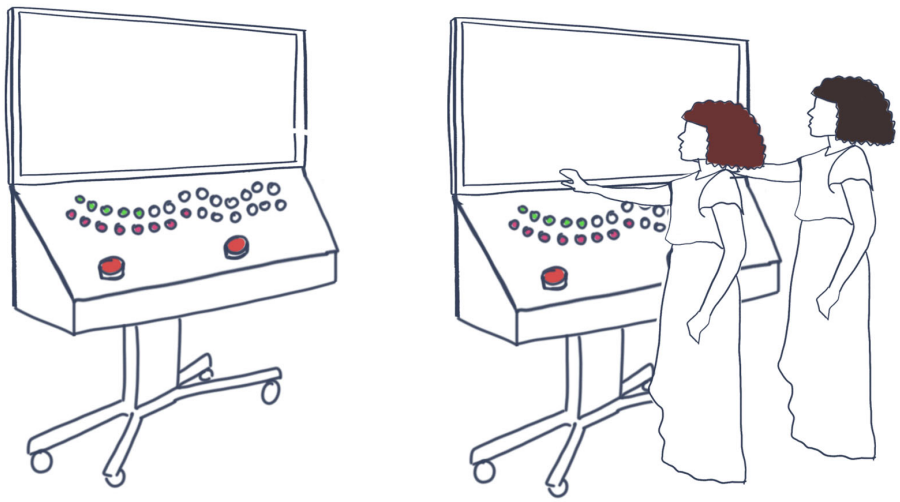

Figure 4.10: Final concept.

The final concept is an arcade-style installation that facilitates a hybrid board game. The chosen concept combines digital mini-games with the storytelling of board games.

The design consists of a touchscreen, an interactive board game, and controllers. The screen is used to present the visuals, story, and game, with the tough screen element used in a mini–game. The interactive board under the screen represents the score and where the user is in the story's journey. Lastly, the physical controllers are used to interact with the game on the screen and to play the mini–games. The installation is meant to be interacted by two users and the game time will be no longer than 5 minutes. First, the installation is idle and displays an inviting "poster" to encourage people to interact with it. When a user comes close to the installation, a sensor will pick it up and change the idle screen to the "home" screen of the game, which incites the users to start the game by pressing the start button. The next step the users take is indicating how many players they will be by either pressing one or two buttons and then confirming it with the start button. The game is then explained to the users and the story begins. After that the first mini–game appears, the rules are quickly explained and the users play the game. When the game is finished the scores are shown which are visualized by LEDs in the board game. The user then needs to move their pawns to the correct spot on the board. In between the games scenes from the story are shown. The users play mini–games until one player reaches the end of the board. The goal of the game is to beat your friend to the finish line. To move closer to the finish– players play mini–games. Winning a mini–game grants you more moves closer to the finish (ex. 4) and the loser moves less (ex. Doesn't move or just 1 move). The mini–games are trash themed and aim to teach the players about recycling. The mini–games are around 30–45 seconds long. As mentioned before the whole game is tied with a story. The story is meant to have a recycling theme but also make the users more invested in the installation. The mini–games are also recycled–themed. They are meant to educate users about waste separation in a fun way.

Chapter 5

Specification

During the specification phase, the chosen concept is further developed by gathering specific needs from stakeholders. The designer can add more details to the design, improving its functionality and appeal to the user by recognizing both functional and non-functional requirements. Furthermore, these specifications help in preparing for the realization phase, during which the prototype will be made.

5.1 Specifying the game design

The game design is an integral part of making the intervention successful. Educating the users can be done through the story and game mechanics. It is important to think through these components to properly get the point across to the users.

5.1.1 Mini-games

The mini-games are essential for educating the users about recycling by providing a fun and exciting learning experience. Users can actively participate and learn through direct involvement thanks to the practical approach these games offer. Users are able to gain a greater grasp of recycling principles within the mini-games. That is why choosing the mini-games was an important, yet hard choice.

Mini-game 1 - Memory game

The first game chosen to be included in the design was a memory-based game. First, the user would have to memorize in which waste stream the waste item is. After a couple of seconds, the trash would get mixed up in the middle of the screen, after which the user would have to put it back into its correct waste bin. The user would get points based on which items they put back correctly. This idea was inspired by Messy Memory from Mario Party [53].

A memory game is a good tool for learning recycling principles due to its cognitive benefits and fit with recycling concepts. Players are required to use active recall. The game promotes the players' memory skills, focus, and pattern recognition– all of which are crucial for understanding recycling. Additionally, a memory game provides a fun and enjoyable learning experience, making it an effective educational tool. Users may find this mini–game a useful and entertaining instructional tool since it provides a practical and interesting way to learn recycling principles.

Mini–game 2 – Trash miner

The mini–game called "Trash Miner", which was influenced by Gold Miner [54], offers an interesting way to teach about waste separation. In this game, players assume the role of miners trying to fish out non–recyclable waste items from the recyclable ones. Players use a claw to pick up objects similar to Gold Miner, but instead of gold, they aim for and take non–recyclables from the collection. By playing Trash Miner, users actively participate in waste separation, reinforcing the knowledge of recyclable and non–recyclable materials. The goal of the game is to separate the non–recyclables from the reusable waste by having players make quick decisions and planned actions. Their understanding of waste separation is improved by this practical experience.

Trash Miner offers entertaining and immersive gaming, making the learning process enjoyable and memorable. Players gain the ability to recognize and distinguish between residual and recyclable waste through repeated practice, enabling them to make wiser decisions in real–life recycling. This game offers an engaging platform for users to learn about waste separation by incorporating the mechanics and concept of Gold Miner. It effectively mixes fun, nostalgia, and learning, resulting in an engaging experience.

5.1.2 The story

The story of the game is essential for creating a link between the mini–games and the game's overall aesthetic. The story offers a narrative structure that connects the mini–games, giving players a seamless and interesting experience. As players go through the stages of the game, it enables a sense of progress and continuity. The narrative gives players a reason to keep playing.

The story also establishes the overall mood and concept of the game affecting the mini–game decisions, aesthetic decisions, and visual style. The connection between the mini–games and the overall aesthetic is essential for maintaining player engagement and immersion. Additionally, a strong story and artistic decisions can evoke feelings and provide gamers with a memorable experience. This emotional connection can enhance the player's investment in the game and strengthen the impact of the educational messages in the game.

Along with establishing a connection between the mini–games and the overall aesthetic, the story itself can serve as an important educational aspect of the game. The

educational concepts about waste separation can be conveyed through the story segments between the mini–games. Players can learn about the consequences of improper waste separation through these cutscenes. By incorporating educational material into the narrative players can understand the consequences of not recycling and build a sense of responsibility for environmental protection. These segments can promote environmental consciousness and encourage players to consider the consequences of their actions, fostering a sense of empathy and responsibility towards the environment.

The connection between the mini–games, the overall visuals, and the educational components are all important factors in creating an engaging game. Choosing the correct story for the game can be difficult, but it also is very significant. Selecting an appropriate story requires careful consideration of various factors. The narrative should be in line with the intended audience, appealing to their motives and interests. Furthermore, it must be interesting and appealing to draw the players in. Moreover, the selected story must successfully incorporate the learning objectives of waste separation. In order to ensure that the users have an enjoyable experience, as well as receive useful information, it should find a balance between being educational and engaging. The story should also motivate the users to actively participate in the game's goals by providing a sense of progress, purpose, and accomplishment throughout the gameplay. Additionally, a good plot makes it easier for the players to connect with the educational elements of the game, which increases the likelihood that they will remember it and apply what they learn in real life.

Several interesting story concepts that could correspond with the recycling theme were developed in the brainstorming process. One idea takes players into a world of magic and fairytales where they would be set out on a mission by a Wizard to bring nature back into balance by playing the mini–games that would simulate mystical tasks and encounters with magical beings. Another concept was a colorful Mario–style world where players take on the role of a recycling hero that needs to defeat King Trashman to save the princess and the kingdom. The third concept was a post–apocalyptic world where the players would be survivors and would complete missions to try and fix the world.

Even though the concepts for fairytale and Mario–style stories could be fun and entertaining, they might not be as effective as a post–apocalyptic narrative in emphasizing the value of recycling in a way that is more realistic and lasting. As it depicts a society devasted by environmental damage and emphasizes the effects of ignoring waste separation, a post–apocalyptic setting lends a feeling of urgency and relevance. Through this story, players are given a real understanding of the necessity and consequences of actions. By highlighting the crucial role that recycling plays in preventing such a future and motivating players to take action now, it evokes a stronger emotional response. The message of recycling is thought to be more powerfully conveyed through a post–apocalyptic story than the fairytale or Mario–type concepts.

The chosen story concept

The chosen story for the game revolves around a post–apocalyptic setting where the university campus has been flooded with overwhelming amounts of trash. This story emphasized the importance of good waste management and the effects of ignoring them. By playing mini–games that focus on sorting and gathering waste to restore the campus, players are given the task of cleaning up the campus. Players play the roles of survivors who are determined to recover their university campus from the trash apocalypse. The massive accumulation of waste has turned the campus inhabitable. The survivors' goal is to clean up the campus to make it functional again so that students may return. Each mini–game offers a separate set of challenges to educate and contribute to the clean–up. Players gradually change the campus into a clean and sustainable environment as they advance and successfully finish the mini–games. In the end, the story enriches the game–play by reinforcing the value of recycling, caring for the environment, and people's ability to effect change for the better, motivating the players to work towards a cleaner and more sustainable future. The title of this story would be "Trashpocalypse".

5.2 Storyline and storyboard

5.2.1 Storyline

The once–thriving university campus is in ruins due to an environmental catastrophe. The site is now flooded and overrun by mounds of trash caused by years of carelessness and improper waste management. There are still survivors of this Trashpocalypse whose goal is to bring back the campus to its former glory.

Scene 1 (Idle Scene)

The scene shows a landscape of the campus filled with piles of trash.

TEXT ON SCREEN
The world will look like this in 20 years if YOU don't do anything about it.

Scene 2 (Start game)

The scene changes to a different landscape of a trash–filled campus.

TEXT ON SCREEN
Trashpocalypse
Press button to continue

Scene 3 (How to)

The landscape stays the same but now there is a dark box with the instructions overlaying it. There is also now a character that will be guiding the users through the instructions.

TEXT ON SCREEN
How to play
Your mission is to save the university from the impending trash–apocalypse! Compete against your friend in a series of exciting and challenging mini–games to accumulate points and be crowned the survivors of the campus.
Your performance in each mini–game will determine the points awarded which will also be displayed on the LED progress bar above the button.
Each mini–game will have specific controls tailored to its gameplay. You will have to use the big touchscreen or the buttons.
Ready?
Press button to continue

Scene 4 (Story cutscenes 1)

The scene changes to a different landscape of a trash–filled campus.

TEXT ON SCREEN
In 2043 the University of Twente campus is no longer an inspiring place...
Press button to continue

The scene changes to a different landscape of a trash–filled campus.

TEXT ON SCREEN
The once green sceneries are now hidden behind mountains of garbage...
Press button to continue

The scene changes to a different landscape of a trash–filled campus.

TEXT ON SCREEN
Not many people visit these days, these grounds are far from pleasant...
Press button to continue

The scene changes to a different landscape of a trash–filled campus.

TEXT ON SCREEN
But then again, the rest of the world met the same fate...
Press button to continue

The scene changes to a different landscape of a trash–filled campus.

TEXT ON SCREEN
But maybe you, one of the few survivors, can help...
Press button to continue

The scene changes to a different landscape of a trash–filled campus.

TEXT ON SCREEN
By cleaning up the campus, you have to start somewhere after all...
Press button to continue

Scene 5 (Mini–game 1 Intructions)

The scene changes to a different landscape of a trash–filled campus and now there is a dark box with the instructions overlaying it. The guiding character is on the scene again as well.

TEXT ON SCREEN
Mission 1
How to play:
– Memorize which trash belongs in the two bins closest to you and throw them out there after they get mixed up
– Use the touchscreen to drag the items into the correct wastebins
Ready?
Press button to continue

Scene 6 (Mini–game 1 Gameplay)

There are four trash bins on the sides of the screen with colors that correspond to their waste stream. In those waste bins, there are items that correspond to that waste stream. After a couple of seconds, the items are thrown and mixed up in the middle of the screen. The player gets 30 seconds to correctly put back the items into their respective waste bins.

After the 30 seconds, a score panel pops up to show the players how they did in the game.

TEXT ON SCREEN
Player 1 (or 2) won!
6 to 4
Press button to continue

Scene 7 (Story cutscenes 2)

The scene changes to a landscape of a slightly less trash–filled campus.

TEXT ON SCREEN
Maybe with a bit more work life could return to the campus...
Press button to continue

The scene changes to a different landscape of a slightly less trash–filled campus.

TEXT ON SCREEN
But you must still do quire a lot of work...
Press button to continue

Scene 5 (Mini–game 2 Intructions)

The scene changes to a different landscape of a slightly less trash–filled campus and now there is a dark box with the instructions overlaying it. The guiding character is on the scene again as well.

TEXT ON SCREEN
Mission 2
Fish the residual items out of the recycling waste streams! Items like pizza boxes, cans, chip bags, and flowers belong in residual according to the UT waste streams.
How to play:
– Time shooting the hook by pressing the button and catch the residual trash.
Ready?
Press button to continue

Scene 9 (Mini–game 2 Gameplay)

The scene shows two survivors with hooks/claws and four conveyor belts. Waste items move on the conveyor belt from one side to the other. The players must time the hooks to grab the non–recyclable waste from the conveyor belts. The users have 60 seconds to grab as many residual items as they can.

After 60 seconds, a score panel pops up to show the players how they did in the game.

TEXT ON SCREEN
Player 1 (or 2) won!
3 to 2
Press button to continue

Scene 10 (Story cutscenes 3)

The scene changes to a landscape of an almost clean campus.

TEXT ON SCREEN
Thanks to your effort the university begins to look like its former self...
Press button to continue

The scene changes to a landscape of an almost clean campus.

TEXT ON SCREEN
Maybe your actions can inspire more survivors to follow!
Press button to continue

The game ends and the screen goes back into its idle stage.

5.2.2 Storyboard

A storyboard was made to illustrate what happens in order to provide a better understanding of the storyline.

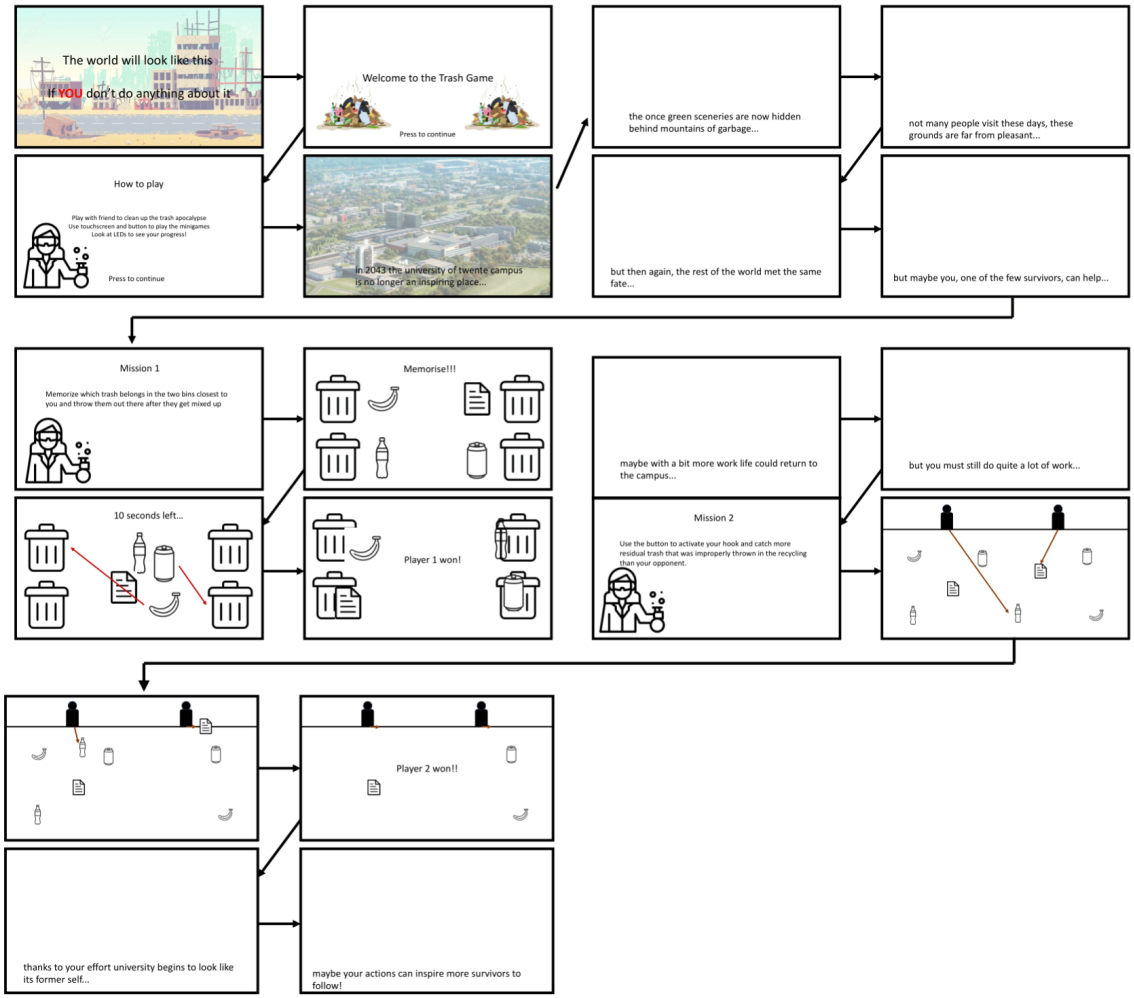

Figure 5.1: Storyboard for the Game

5.3 Persona(s)

User personas were developed to help understand the users of the intervention. This allows for a better grasp of the needs, tastes, and behaviors of the target audience. This understanding aids in the development of an intervention that meets the requirements and

expectations of the users.

The target group for this project is students, faculty, and staff who use the university's facilities. This group is a diverse community that calls for a careful approach to engage them in more conscious recycling behavior. For the project to be successful, it must be designed with the needs of the UT community in mind. The university community is made up of people of all ages, including the staff and students who range from teenagers to adults in their 60s. The effectiveness of the intervention may be impacted by age diversity since various age groups may have different attitudes toward sustainability and recycling. The community is made up of people from various educational and cultural backgrounds. Given that different individuals may respond better to the intervention. This diversity has an impact on the information provided in the final product. Different parts of the community may have different levels of environmental consciousness. While some people already practice recycling and sustainable behaviors, others may want more information and encouragement to do so.

5.3.1 Persona 1

The first persona, see figure 5.2, is a 19 year old dutch Creative Technology student at the University of Twente. She is a dedicated student and wants to peruse a creative career. She is environmentally aware and actively participates in sustainable habits. However, she does find some items difficult to recycle, such as unusual packaging and coffee cups. She wants to learn more about how to properly these confusing items but does not have the time or energy to do so.

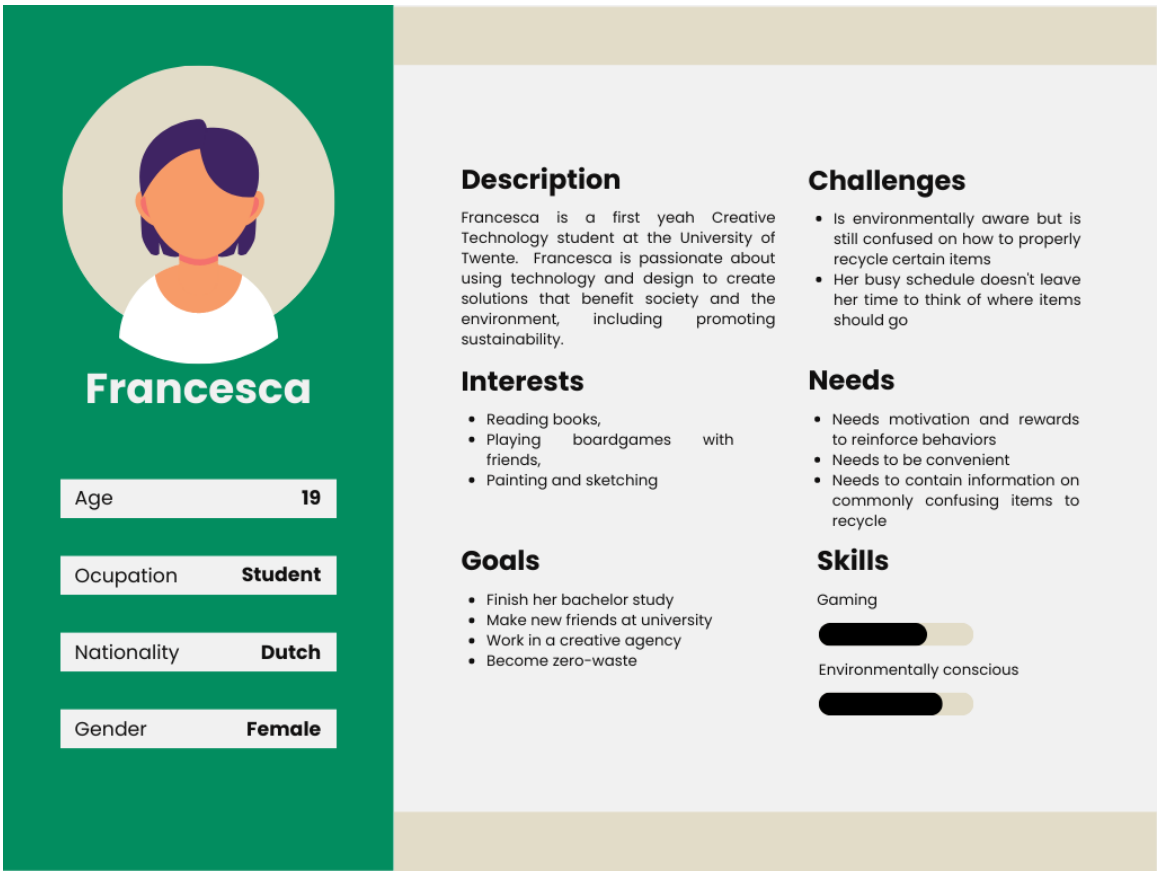

Figure 5.2: Persona 1

5.3.2 Persona 2

The second persona, see figure 5.3, is a 21 year old Computer Science student at the University of Twente that came from Romania. He is interested in technology and programming. He is not environmentally conscious and does not actively practice recycling or other sustainable habits. He does not have the time to commit to learning about recycling because he is a busy student with a demanding course load. He also has trouble comprehending correct recycling methods in the Netherlands due to his different cultural background.

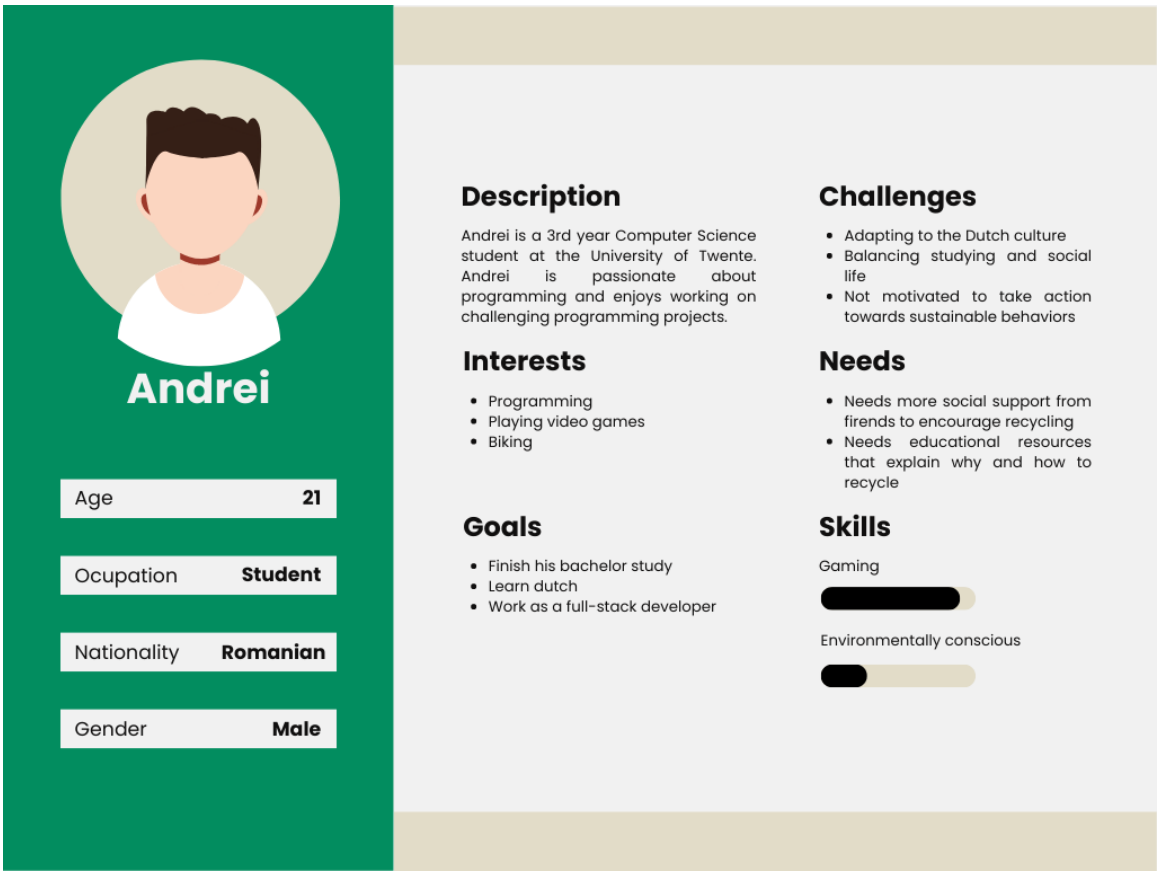

Figure 5.3: Persona 2

5.4 Interaction scenarios

5.4.1 Scenario 1 – Persona 1

Scene 1: Installation idle

Francesca and her friend walk down the hallway, chatting about the upcoming assignment. They just finished a lecture and have 15 minutes until the next one. They see an intriguing arcade–like installation in the near distance. The flashing LED lights and colorful graphics catch Francesca's attention and make her curious about what the installation is. Francesca notices the text on the screen that reads "The world will look like this in 20 years unless YOU do something about it." and she can't help but wonder what kind of game this is.

Scene 2: Approaching

Francesca encourages her friend to get closer to the installation as she likes playing games and wants to take her mind off assignments. As they get closer, they notice that the installation has LED elements, complete with buttons, flashing lights, and a giant touch–screen. The installation looks fun and makes the friends eager to try it. As Francesca gets even closer to the installation, the installation switches its visuals. The installation uses a distance sensor to pick up the pair's presence and it switches from idle state to being active. They have a choice to hit a button to begin the game.

Scene 3: Start of the game

Francesca thinks that it is a great idea that the game seems to be about recycling. She has been interested in sustainability but found some aspects of recycling a little confusing. As soon as Francesca pushes the button, a brief story segment starts that acts as the game's introduction. It shows a polluted post–apocalyptic world where a few survivors need to clean up the campus to bring it back to life. Francesca is drawn in by the story and wants to continue it.

Scene 4: Mini–game 1

The first mini–game is introduced to the users following the story segment. It involves cleaning up a lab after it was polluted. The aim is to match each waste item with the appropriate waste stream. Using the touchscreen, Francesca and her friend quickly sort the objects and put them in the appropriate bins. Their cooperation and quick thinking helped to recover the lab.

Scene 5: Scoreboard 1

Francesca wins the first mini–game and is able to advance further on the LED strip. She feels successful and looks forward to what the game will bring next. As the scoreboard disappears, an story sequence continues. Francesca watches the scene and reminds herself how easy it is to forget the importance of recycling.

Scene 6: Mini–game 2

The second mini–game is explained to the users. The characters must act like trash miners and fish out improper items from the recycling waste streams. The game is played by pressing buttons on the installation and points are scored for correctly picking out the items and points are lost for mistakenly fishing out the wrong objects. Francesca and her friend play by carefully choosing and eliminating the non–recyclable items from the conveyor belts. The points they accumulate in this mini–game determine the final scores in the game.

Scene 7: Scoreboard 2

The game ends with a final scoreboard that displays the player's results; depending on it, the users move a certain number of positions on the board. In this instance, Francesca wins again meaning she is still ahead on the board. She is happy with how she did and proud of the information she learned from playing the game.

Scene 8: Ending

Francesca and her friend watch an animation at the end of the story that also reveals who ”won” the game. Francesca feels a sense of satisfaction as she leaves the exhibit and is inspired to spread the word about this installation. She was pleased with the fact that she could learn more about recycling in a fun and easy way. She is now also eager to apply what she has learned in her everyday life. When they walk away from the installation, it goes back to its idle state.

5.4.2 Scenario 2 – Persona 2

Scene 1: Installation idle

As a busy Computer Science student Andrei walks down the hallway at the University, he notices an eye–catching installation nearby. He chooses to approach it with his friend after becoming intrigued by the visuals as he is a fan of indie games. Despite his lack of time and concern for the environment, he is attracted to the installation’s graphics and features.

Scene 2: Approaching

The installation detects the presence of the students as they approach and activate, pre–senting a scene with the consequences of waste pollution. Curious to know more, he encourages his friend to hit the button and start the game.

Scene 3: Start of the game

In the game’s brief introduction, a post–apocalyptic campus is affected by pollution. The students find this concept a bit overdramatic but amusing and laugh at the story sequence. **Scene 4: Mini–game 1** The first game starts and the users find themselves cleaning up a lab. Using the touchscreen, he tries to remember which items were in which bins. Anderi has to use his memory as he used to not pay much attention to the rules before the game. Cooperating with his friend they get most of the waste items correctly sorted. **Scene 5: Scoreboard 1** Unfortunately, Andrei doesn’t advance much on the LED strip as he did not win the first minigame. Feeling a bit unfulfilled he wants to beat his friend in the games.

Scene 6: Mini–game 2

The following minigame, where they act as trash miners, challenges him to fish out the improper items from the recycling waste streams. He attempts to recall what he learned in the first minigame and in the instructions. He and his friend press the buttons on the panel, earning points for accurately fishing out the improper objects.

Scene 7: Scoreboard 2 and Ending

When the results of the game are displayed, he is pleased to see that he has won. As he views the final story segments, he is satisfied and starts to think about recycling. He enjoyed the game and appreciated the simple method that thought him more about recycling.

5.5 Visualization Requirements

The development of personas and interaction scenarios offers insightful information about how the installation might be interacted with. The stakeholder requirements, that were listed in Chapter 4.1.3, are now revisited, altered, and translated into both functional and non–functional requirements.

5.5.1 Functional requirements

As mentioned in Chapter 3.3.3 the functional requirements are the criteria that describe what the product should do. Table 5.1 presents the functional requirements grouped by priority using the MoSCoW technique, which was described in Chapter 3.2.2.

Requirement	Priority
The user is able to progress through levels.	Must
The game will be 2D.	Should
The game will have two mini–games.	Must
The text is readable in the game.	Must
The visuals are consistent and have a similar style.	Must
The installation should educate the users about waste separation.	Must
The information provided by the installation is accurate based on the rules of CFM and PreZero.	Must
The game consists of all the elements of Tetrad.	Must

Table 5.1: Functional requirements.

5.5.2 Non–functional requirements

Non–functional requirements describe how the product should achieve its functions as described in Chapter 3.1.3. The non–functional requirements were listed with priority in Table 5.2, which was described in Chapter 3.2.2.

Requirement	Priority
The installation should be visually attractive to attract users.	Should
The game has a flow (clear goals, no distractions, direct feedback, and continuously challenging).	Should
The game should be intuitive and understandable to users.	Must
The installation is non–discriminatory.	Must
The rules of the game should be comprehensive.	Must
The game should not be cheatable.	Should
The game must be max. 5 min.	Must
The game is suitable for a half–public/half–private setting.	Must
The game is supported by a story.	Must
The game sparks social connection.	Should
The game/story is supported by a narrative and characters.	Could
The game incorporates collaborative problem–solving.	Could
The game has parts of surprise and fun.	Must

Table 5.2: Non–functional requirements.

Chapter 6

Realization

The main goal of the realization phase is to realize the product that was imagined during the ideation phase and described during the specification phase. This part will describe the tools used, as well as the components and features made with them.

6.1 The Final Prototype

Figure 6.1: The Final Prototype: The Trashpocalypse Game

The final prototype, shown in Figure 6.1, is an installation called Trashpocalypse. It's an arcade–style waste separation game that focuses on educating the UT community about proper recycling practices. The installation offers an interesting and immersive experience that mixes fun gameplay with an emphasis on recycling education. In a story about a post–apocalyptic campus overrun with trash, players are given the task of recycling and cleaning up the trash in order to rescue the university.

The prototype consists of two parts: the interactive media part, and the physical part. The interactive media part is the game, and the physical part consists of the CTouch screen and the control panel with buttons and LED progress bars. The game is played on the screen through the use of buttons and the touchscreen. The score is updated on the LED strip showing the players how they are doing in the game. The physical part and its integration with the game have been done by Hans Nielen, while the interactive media part has been done by me.

The prototype's user interface has simple controls that make it easy for players to navigate through the game. The game stresses the value of appropriate waste separation through the gameplay. The game's educational components are emphasized in the story and the mini–games. The experience is further improved with sound effects and music.

A full demonstration of the prototype in the form of a video can be found using this link: https://youtu.be/kWeEjo4SWLk

6.2 Workflow

After having designed the game, deciding on a storyline and creating a storyboard (as described in Chapter 5), it was time to begin the implementation. The goal was to develop the game according to the following plan:

1. **Choosing the tools** The first logical step of making a game is choosing the many required tools. This was done by considering the time constraints, system specification and ease of use. A description of the selected and used tools can be found in section 6.3.

2. **Gathering most important assets** To develop an early version of the product, some assets are absolutely necessary for minimal functionality. This step consisted of finding or making some of the used sprites, as well as researching existing solutions that might make the development process easier and faster.

3. **Developing the mini–games** With the required assets and tools gathered, it was now possible to develop the two mini–games. This was done before the story element because it is a much more crucial element of the process but also requires more effort. How the games were created can be found in more detail in sections 6.5 and 6.6.

4. **Developing story scenes** The focus in this step was to create scenes telling the players the story, as well as improved panels giving instructions on how to play the mini–games. This process was much simpler than creating the mini–games themselves and consisted mostly of gathering the right assets, writing the story, and animating the text on the story scenes.

5. **Final improvements** After the game has been mostly developed, the final improvements can be made. This includes improving on the used visual and auditory assets, and animations, and adjusting variables such as the scoring system or speed of trash movement in the Miner mini–game.

6. **Adjustments to user feedback** When testing with the potential users, feedback that we think is valid and can be applied relatively easily was implemented. These adjustments were mostly minor, such as changing a sound effect or the way users receive feedback on whether they sorted trash correctly in the memory mini–game.

6.2.1 Identifying the components

The prototype needs to be divided into smaller parts before it can be created. Doing so generates a better overview that allows the designer to concentrate on the bigger picture and the specifics each component should have to improve that overall product. This also allows for easier implementation. Three distinctive components were used to design and build the prototype:

Story & theme The story and theme needed to be decided the earliest, so that they could be applied to all other elements of the game. They not only decide how the game looks but also how it should feel and what mini–games can highlight the theme further.

Memory mini–game The first mini–game was designed with the goal to educate on the more basic aspects of waste reduction and most importantly to entertain.

Trash miner mini–game The second mini–game could focus on a more specific and overlooked aspect of recycling while still providing an environment for having fun.

6.3 Tools

Unity

Unity [55], a popular game development engine, was used to create the game for this project. Unity provides a great set of tools and frameworks which make game development much easier. The engine also has a very active community, which provides a great amount of support, tutorials, and free–to–use games and components. It was clear that Unity

would make the experience simpler and faster, allowing more evaluation and improvement between iterations of testing.

Figure 6.2: Unity workspace

Visual Studio Code

Unity uses scripts in the C# language to control the elements of the game and add functionality beyond the basic engine frameworks. Visual Studio Code (VS Code) [56] is a popular source code editor with broad language support that was used to write and edit these scripts.

Illustrator

Most of the graphics for the game were created using Adobe Illustrator [57]. Due to its vector graphics capabilities, Illustrator is a very good tool for making graphics for video games. It allows for scalable artwork, enabling seamless adaptation to various screen sizes and resolutions. Its diverse toolkit makes it possible to create a variety of game elements, including icons, characters, backgrounds, and UI components. Additionally, Illustrator provides export choices for different formats including PNG and SVG, making it easier to integrate into game engines.

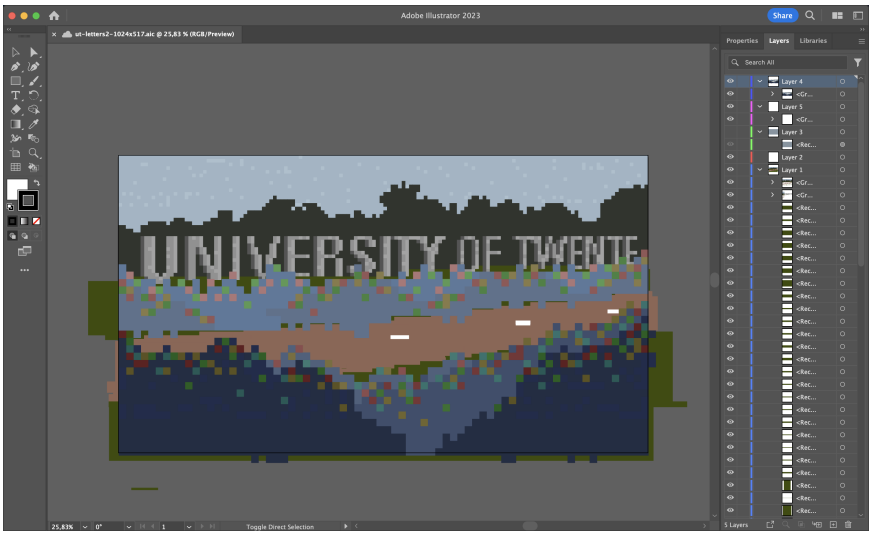

Figure 6.3: Illustrator workspace

Other tools

Other utility tools were used throughout the process of developing the game. One of the tools was Pixel It [58] – an open–source image–to–pixel art converter. This tool was used to convert images of the UT campus into pixel art backgrounds for story panels in the game, as well as some of the trash pieces. Another tool used was Adobe Photoshop [59], which was sometimes used to quickly edit the colors of the assets, as well as, make sketches or mockups for the first iterations of the game.

6.4 Game Assets – Illustrations, Animations, and Sound

The game requires many types of assets – visuals such as background, sprites for trash pieces, sprites for playable characters, and UI elements, but also auditory elements such as sound clues or background music.

6.4.1 Visual

Pixel art has a unique and nostalgic visual charm that resonates with a lot of players. Its retro aesthetic adds authenticity and evokes nostalgia, making for an engaging and immersive gaming experience. Adobe Illustrator, which was described in section 6.3 were used as the tool to create the pixel–art assets. To make the art, a tutorial was watched to figure out how to make pixel art in Illustrator [60]. The first step is to set up a pixel grid using the rectangular grid tool and use a reference image as a template. Next, to paint the pixels the live paint bucket tool is used. After the pixel art is finished, the live paint group

is expanded, unnecessary layers are removed, and the artwork can be then exported as a transparent PNG file with anti–aliasing set to "none" to preserve sharp pixel edges.

Backgrounds

Figure 6.4: Idle Screen

Multiple backgrounds were made by me, including the Idle Screen, the Main Screen, the How–To Screen, and most of the mini–game backgrounds. Figure 6.4 showcases the Idle Screen which was made referencing a picture of the UT letters located at Drienerlolaan. The process of making this background followed the one mentioned above in section 6.4.1. First, the reference image was chosen [61], then the pixel grid was set up. The pixels were then filled in using similar colors to the original picture. In order to make the art feel more organic and artistic, additional color pixels were added. After the landscape was complete, abstract piles of trash were placed. Lastly, the whole artwork was then exported and added into Unity.

Figure 6.5: Story Scene 1

Although initially, the goal was to make custom pixel art backgrounds based on the UT campus (such as the one on the idle screen and the main menu), it became clear that due to time constraints, this approach was not feasible for many story panels. Taking that into account, the rest of the backgrounds were made by taking various photos of the University of Twente campus and using an open-source image-to-pixel art converter, which was described in section 6.3. Then, a photo of a pile of waste was also converted to pixel art and was placed over the background to create an image of the campus after the "trashpocalypse" in theme with the story of the game, as seen in Figure 6.5.

Trash pieces

Figure 6.6: Trash pieces used from OpenGameArt.org [62]

Figure 6.7: Examples of other trash pieces used

The majority of the assets used for the trash pieces in the game were sources from OpenGameArt.org [62]. OpenGameArt.org offers a vast library of publicly accessible gaming assets. By utilizing these assets, which are seen in Figure 6.6, a significant amount of time was saved to utilize in other areas of the game. Other waste items were found on Vecteezt.com [63] or NicePNG.com [64], for example, the banana and flower in Figure 6.7. Some items were made by taking images of trash and pixellating them using Pixel It [58], like the chip bag in Figure 6.6. The tea bag in Figure 6.6 was made by pixellating a free vector image of a tea bag found on Vecteezt.com [65].

Player characters

Figure 6.8: Player 1 Character

Figure 6.9: Player 2 Character

The characters were made using the same process that was described at the beginning of this section 6.4.1. Using Illustrator, the process of creating these characters involved setting up a pixel grid, drawing the characters' outlines with basic shapes, choosing colors, and using the live paint bucket tool to fill in the pixels. Shading and refinement were added to give them character. Next, rope spools were made using the same technique.

Others

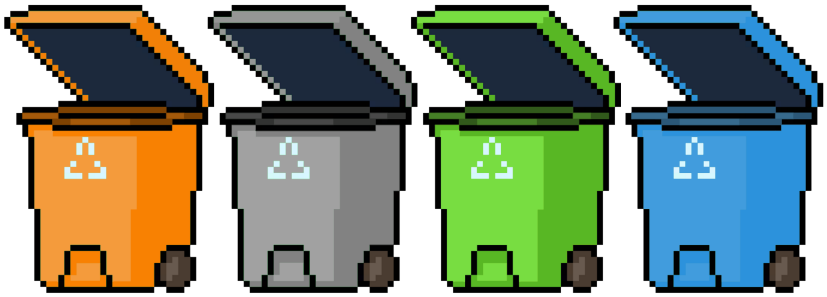

Figure 6.10: The trash bins used in the first mini–game.

The trash bins used in the first mini–game, the memory game, were made by using an assent from Shutterstock.com [66]. That asset was then recolored using Adobe Photoshop as seen in Figure 6.10. The colors of the trash bins had to represent the same ones used by the UT in their waste islands.

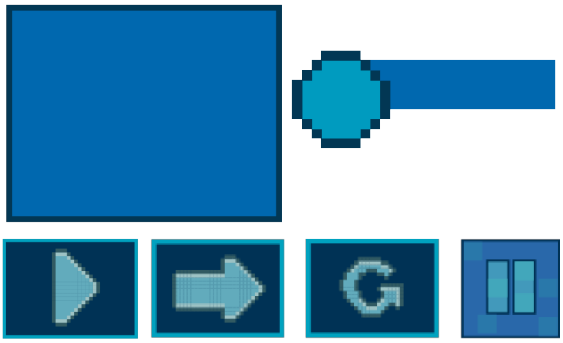

Figure 6.11: Example of the UI elements

All the UI elements were made using Adobe Illustrator. For bigger simpler shapes such as a win panel or button backgrounds, the rectangle tool was used. The more difficult shapes such as circles or triangles were made using the pixel art technique that was described earlier in section 6.4.1.

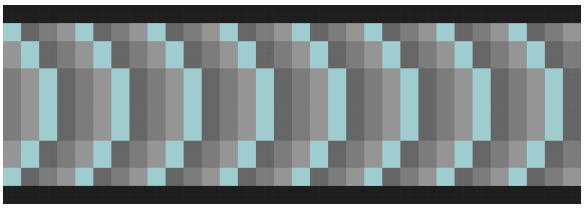

Figure 6.12: One of the conveyor belt frames

The first step in creating the animated conveyor belts from the second mini–game was to create the art itself. The style of the conveyor belt was taken from Pixilart.com [67] and was remade with the appropriate colors. Four frames had to be made with the colors shifted by one pixel in each frame. After the frames were made, they were put into an Animated GIF Maker [68]. To have the gif play continuously in Unity a tutorial was followed [69]. Once the GIF was made it was converted into a "Spritesheet" in PNG format [70]. After that, the sprite sheet was downloaded and imported into the Unity project. In Unity, the animation settings were configured appropriately and the sprite was scaled up.

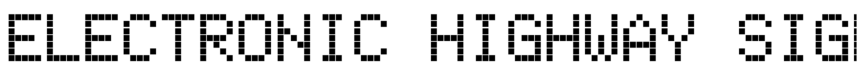

Figure 6.13: Electronic Highway Sign font

Figure 6.14: 04b_30 font

Figure 6.15: VCR OSD Mono

Prioritizing pixel–friendly designs with clean edges and readability was important when selecting fonts for the game. To guarantee a seamless incorporation into the game's design, font styles were kept in the pixel art family. All the fonts used were found and downloaded from daFont.com [71]. The most used font was the Electronic Highway Sign as seen in Figure 6.13 [72]. This font was used in almost all scenes including the story scenes, the instructions, and the start screen. The second most common font was the 04_30 font which is presented in Figure 6.14 [73]. This font was used for the title of the game in the start scene and in the titles for instruction scenes. The least used font was the VCR OSD Mono

font displayed in Figure 6.15 [74]. This font was used for the timer and scores displayed in the mini–games.

6.4.2 Audio

Integrating 8–bit music and sounds into the game can add a nostalgic and immersive element to the experience. The chiptune style of music complements the retro visuals, creating a cohesive gaming environment.

Music

There are two music tracks in the game. One for the idle state and one for the active state of the game. The idle game uses a track called "Gamer 6969" by HoliznaCC0 [75]. It was added to the game by adding an empty object called "Music" to the idle scene, which includes an audio source component with the appropriate song. When the game goes into the story the song changes to a track called "Broken Drum Machine" by Godmode [76]. This was done by adding an object called MusicSource to the first story scene. This object had two components: the Audio Source and a script to make sure the music continues even when the scene changes to the next one.

Sound effects

Because the miner game was clearly lacking real–time feedback on whether the players are choosing the residual trash correctly or not, auditory feedback was added. A sound [77] was added to be played when a player pulls a piece of residual trash correctly, as well as another sound [78] when they pull up something that could be recycled. It is very rare that both players finish pulling up a piece of trash at the exact same moment, so confusing overlapping audio should not be an issue.

6.5 Memory mini-game

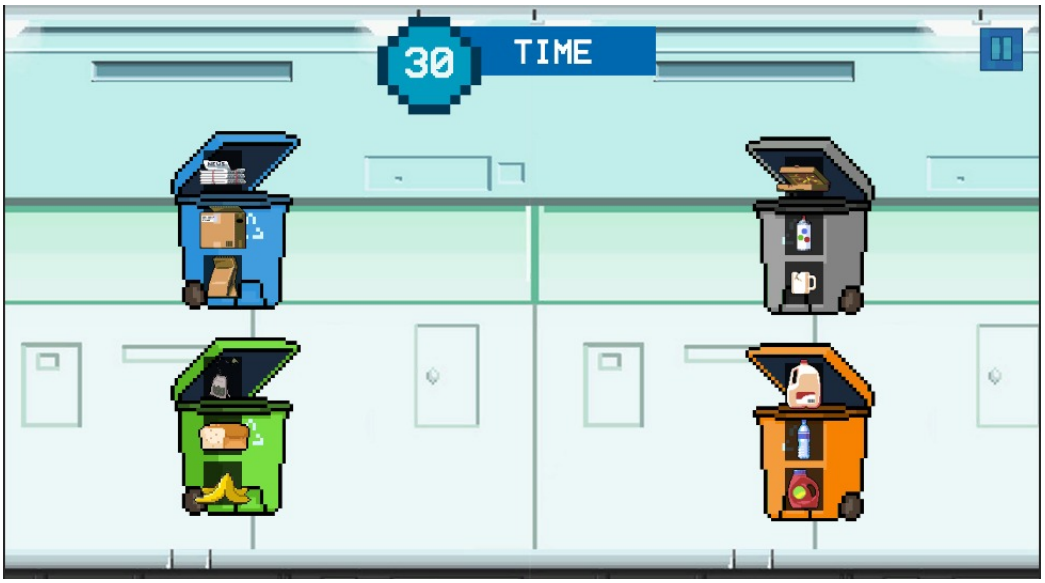

Figure 6.16: Initial screen showing where the trash will have to be sorted correctly

Figure 6.17: Memory game right after the pieces of trash are placed randomly around the middle of the screen

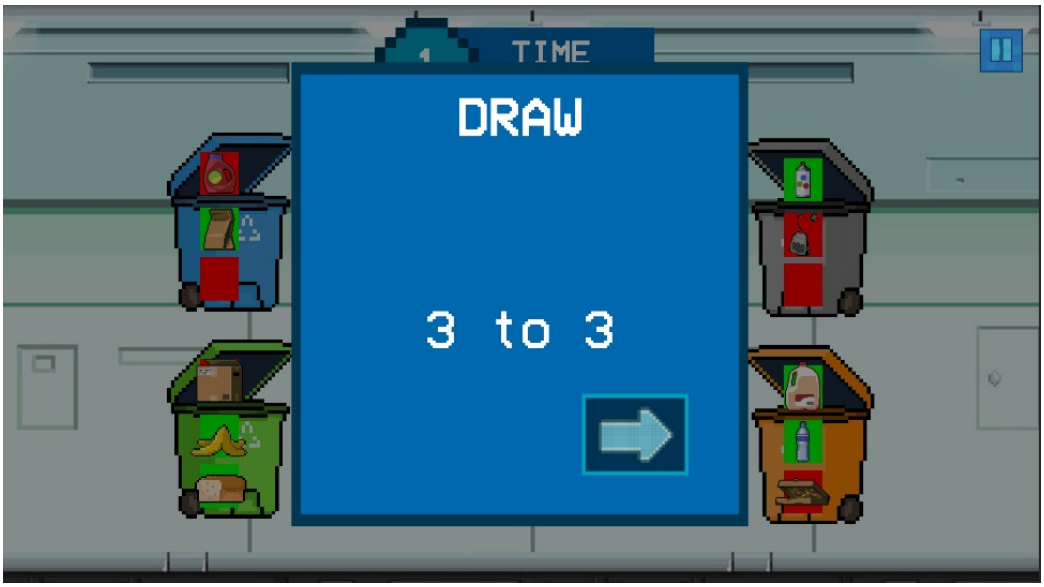

Figure 6.18: End screen showing the result and which trash was sorted correctly

Technical description

This mini–game consists of 4 recycling bins. Each of the bins has 3 pieces of trash of the correct type (3 different plastic containers for the orange plastic bin for example). At the beginning of the game, the trash pieces are briefly shown sorted correctly into the bin they should be placed in but are then scrambled and moved to a random location in the middle of the screen. The 2 players are assigned two of the bins each and their goal is to sort the pieces of trash into their bins as it was shown before. After 30 seconds, the background of the correctly sorted trash highlights green, and the background of the incorrectly sorted trash highlights red, and the score is shown on the screen.

Realization

The first step of making the first mini–game was finding appropriate assets. The required graphics were the sprites for trash pieces, trash cans, and the background. With the assets imported to the Unity engine, the interaction with them was scripted with the help of a YouTube tutorial [79]. The bins were also added with 3 slots each and the trash piece script was adjusted for them to be droppable into a bin slot. It was also made possible to take out the opponent's trash and disturb them from achieving the goal in the spirit of competition. The last element of the mini–game was adding a mechanic of disabling user input in the beginning for a few seconds to show them where the trash should be sorted and then randomly displacing the different pieces of trash.

6.6 Miner mini-game

Figure 6.19: The miner mini game

Figure 6.20: The end screen of the miner mini-game showing the results and which player got more points

Technical description

This mini–game was inspired by the 2000s browser game called “Gold Miner” [54]. Traditionally, the game (in its two–player mode) consists of two miner characters with a hook swinging constantly from left to right. The goal is to use the correct timing to drop the hook so that it attaches to a piece of gold, which will then be pulled up and an equivalent amount of money is added to the score. In the “Trashpocalypse” version, the miners are replaced by the scientist–adventurer characters, and their goal is to drop the hook so that it grabs the residual trash out of other, recyclable, trash pieces. Another added element is that the trash pieces move to the left or right at a constant rate and new trash appears throughout the mini–game. Since the game is competitive, the player’s goal is to catch more residual trash than their opponent.

Realization

Since this game is more complicated in execution, an attempt was made to find an open–source implementation of Gold Miner and adapt it to the Trashpocalypse version. Although the found implementation worked well [80], adaptation was difficult because a large part of the code (most variable and function names) was in a foreign language. The first step was removing all unnecessary elements of the original game, such as all but one level, and the scene for the main menu and a shop. Then, in the level that was remaining, the sprites were changed together with the Unity 2d colliders. Then a second player was added since the original was only meant for one player. This was a challenge due to the code that was difficult to understand. Then the scoring system was changed so that the player would be rewarded for the residual trash only rather than different amounts for different categories of trash. The next step was to add a conveyor belt in the background with animation and add a script moving the pieces of trash. Finally, a sound effect was added as an indication of whether the piece of trash was correctly identified as residual or not.

6.7 Full game

Figure 6.21: The game's main screen

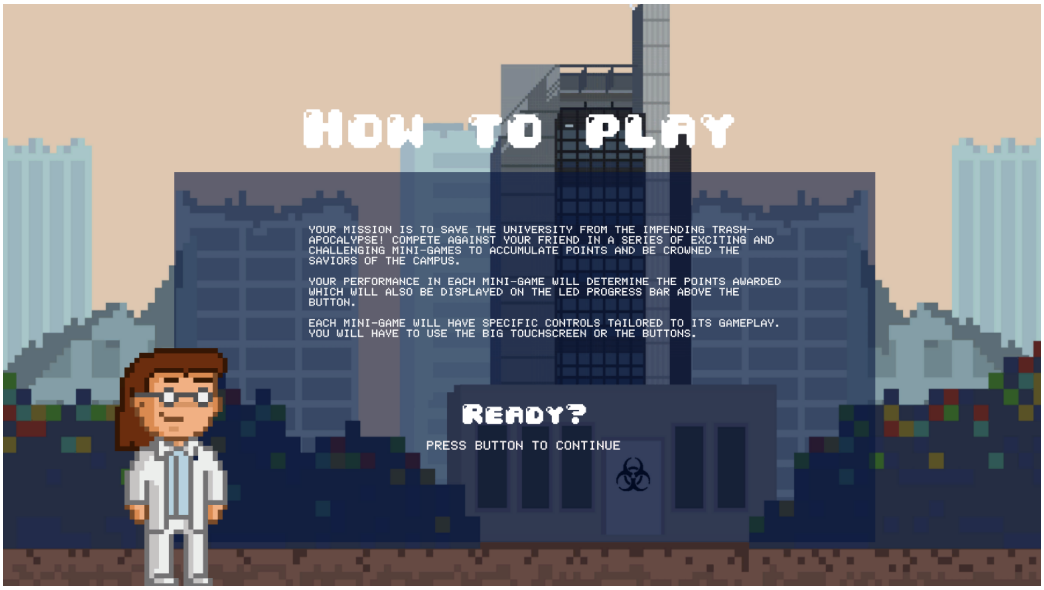

Figure 6.22: The "How to play" screen

When the installation is not in use and the game is not being played, an idle screen (Figure 6.4) is shown. When a user walks up to it, they are shown the main screen (Figure 6.21), from which they can proceed to a "How to play" screen (Figure 6.22). Further, the game consists of story panels as found in Appendix A. Each panel has a background image, a black bottom bar and white text telling the story of a trash–ridden UT campus to the user. After telling a part of the story the user is shown an instruction screen for the mini–game which will follow it. The scene order has been made according to the storyline described in Section 5.2.

6.8 Functional Requirement Evaluation

After the prototype was made, it was assessed using the Chapter 5 functional require–ments. Table 6.1 displays the functional requirements and their fulfillment. The table demonstrates that the majority of functional requirements were met.

Requirement	**Priority**	**Requirement Fulfilment**
The user is able to progress through levels.	Must	Yes
The game will be 2D.	Should	Yes
The game will have two mini–games.	Must	Yes
The text is readable in the game.	Must	Yes
The visuals are consistent and have a similar style.	Must	Yes
The installation should educate the users about waste separation.	Must	Yes
The information provided by the in–stallation is accurate based on the rules of CFM and PreZero.	Must	Yes
The game consists of all the ele–ments of Tetrad.	Must	Yes

Table 6.1: Functional requirements evaluation.

Chapter 7

Evaluation

Evaluation of the final prototype made during the realization phase is the last step in the design process. This step involves testing the final prototype with a sample of the target audience. It will be determined whether the non–functional requirements provided during the specification phase have been satisfied. Through user testing, these non–functional requirements were evaluated.

User testing was done with 33 participants from the target group. The testing was conducted physically in the FlexOffice in June 2023. To complete the user testing, a survey, and structured interviews were done, providing the interviewer the chance to ask predetermined questions to ensure that different components of the product were assessed. The topics of the educational aspects, enjoyment, and experience with the game were tested during the user testing.

7.1 Evaluation set–up

All user testing was done physically on the campus of the University of Twente. A semi–public setting was chosen which was a room on campus. The evaluation began with a greeting, an explanation of the evaluation process, and the consent process for using the interview data. After then, the participants would go through a playthrough of the installation. Following the playthrough, a survey was provided to the users on laptops, after which an interview was done. During the playthrough, the researchers would observe the game and the participants.

7.1.1 Procedure

The following was the user testing process:

1. The participants were invited to the table and were given the information letter (Appendix C) and ethical consent forms (Appendix D). The participant was instructed to

read the information letter and ask questions when needed. The consent form would then be completed and signed by the participant.

2. After signing the consent form the participants were instructed to interact with the installation.
3. While the participants were interacting with the installation the researchers would observe how the users were acting.
4. Once the participants have finished, they were offered a survey to complete on a laptop.
5. After completing the survey, the participant would be interviewed by the researcher.
6. The participants were then thanked for their assistance and input into the study.
7. For the following participants, the researchers would prepare the setup once again.

7.2 Evaluation Results

The Trashpocalypse Game was discussed generally, based on its content, and based on its usability during various user–testing. The next sections offer an overview of each discussion topic to give readers a better understanding of the participant's responses.

7.2.1 General feedback

In general, everyone who took part was really enthusiastic about the Trashpocalypse Game. They appreciated the idea of the game being able to offer education in a fun and accessible way and believed that, after being further developed and improved the game would be an excellent way to teach the community about waste separation.

7.2.2 Observations

During the user testing sessions, the researchers carefully observed the participants while they interacted with the installation and played the game. Overall, it was clear that the users were enjoying themselves throughout the experience. The game positively engaged in friendly competition with each other, adding excitement to the game. Although there were moments when participants would help each other and undertake conversations about recycling. However, there were times when users were confused, especially when the mini–games began, which could mean they did not fully understand the instructions. This moment would also show a sense of cooperation to help each other out. When someone was confused or uncertain about what to do, the other person would give directions, promoting a supportive atmosphere. Notably, users were seen reading the story segments in an over–dramatic way, finding amusement in the storytelling elements

and laughing together. These observations provide valuable insight into the users' engagement, understanding, and enjoyment of the installation, which can help inform future improvements to enhance the overall experience.

7.2.3 Survey

The survey's questions and results are shown in Figure 7.1. The chart with the average scores from each question is shown on the left and the questions are shown on the right. The participants were asked to assess the installation on a scale of 1 to 5 once they had finished the playthrough.

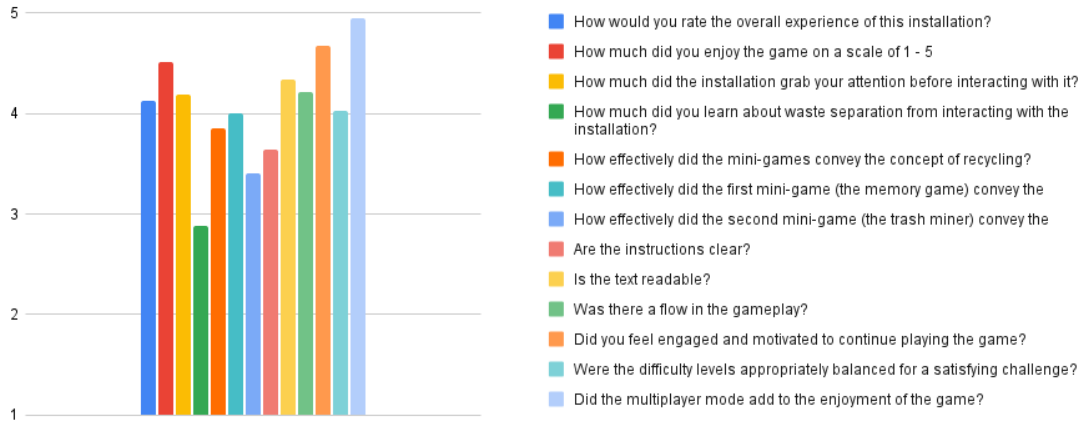

Figure 7.1: Results of the survey.

The general experience of the installation received positive ratings from the participants, with most respondents giving it a rating of 4 or 5. A few individuals gave it a lower rating of 3, signifying a slightly less positive experience. The majority of participants thought the installation was interesting overall. According to the responses, the majority of players thought the game was enjoyable overall, with many giving it scores of 4 or 5. Based on the results the installation mostly caught the participants' attention before they interacted with it. Most participants gave it a 4 or 5 with a few individuals who gave ratings of 2 or 3, which indicates a lower initial interest. The survey responses showed a large range in the participants' learning experience of the installation. The majority of participants gave the educational experience a 3 or 4, indicating an acceptable level of learning. Some participants gave their learning experience a lower rating of 1 or 2. While some participants did learn a fair amount about waste separation from interacting with the installation, it can be said that there is still room for improvement in terms of enhancing the educational aspect of the game.

The effectiveness of the mini–games in communicating the idea of recycling varies, according to the responses. Some participants gave the effectiveness of the mini–games a lower rating of 2 or 3, indicating that they could be improved in terms of explaining the recycling concept. However, other participants gave the mini–games a higher rating of 4 or 5, suggesting that they were successful. While the mini–games generally did a good job of explaining the idea of recycling, there is still potential for improvement to ensure a more effective and consistent way of communicating the message to all participants. The users scored the first mini–game between 4 and 5, while the second mini–game had ratings ranging from 1 to 5 with the mean being 3.4 for its efficiency in explaining recycling. While the first mini–game (the memory game) successfully conveyed the concept of recycling, further improvements may be needed to enhance the consistency and effectiveness of the second mini–game (the trash miner).

Participants' ratings on the instructions' clarity varied, with ratings ranging from 2 to 5. While some participants thought the instructions were clear, others thought they could use some work. It is important to consider this feedback to provide a clear and understandable experience for all players. Ratings for the text readability ranged from 2 to 5, with the mean being 4.3. This means that most participants found the text readable but it could be beneficial to look into additional changes to the font size, style or color in order to make the text easier to read. Most users gave the flow of the game a rating of 4 or 5, meaning most of them enjoyed the gameplay and thought it flowed well.

The results of the survey suggest that the majority of the participants felt engaged and motivated to continue playing the game, by giving ratings of 4 and 5. This implies that the game was successful in capturing their attention and motivating them to keep playing. The ratings for the difficulty level for a satisfactory challenge gained the average of a 4. This suggests that the difficulty level was generally regarded as satisfactory, hitting a balance between being too simple and too difficult. For the last question of how did the participants enjoy the multiplayer mode of the game the opinion suggests that the multiplayer option significantly added to the enjoyment of the game. This feature was scored a 5 by the majority of player. The multiplayer component most likey enhanced engagement, competition, and social interaction.

Based on the survey's responses, it can be concluded that the players usually had positive ratings and had a good time playing the game. The installation was visually attractive grabbing people's attention before they had interacted with it. The game had a solid flow, was generally simple for players to comprehend despite some suggestions for improvement like making the instructions clearer. Players like the story component and thought the game was educational, learning about waste separation through engaging gameplay. The mini–games did a good job of explaining recycling, although there were varying opinions on the effectiveness of each individual game. The game was greatly enhanced by the multiplayer mode, which promoted interaction and competitiveness among players. The results of the survey show that the installation was generally well–liked and had a positive impact on the participants' experience.

7.2.4 Interview

Following the completion of the survey by the user testers, the following open questions were asked to get more in–depth information about the experience:

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

Interview feedback

While playing the game, a few participants experience technical issues. These issues included the button not functioning properly, inconsistencies or its responsiveness, the second's mini–game hooks incorrectly grabbing or tossing objects, and difficulties with picking up trash in close proximity in the first mini–game. However, some players stated that they had no bugs or technical difficulties while playing the game.

Participants had various responses to how the game made them feel about the concept of recycling. The game did not dramatically alter the attitudes of some participants because

they were already aware of and knowledgeable about the concept of recycling. Others appreciated the game's ability to inform and remind players about recycling and found it captivating. Some users liked how the game focused on particular recycling topics. A few players said that the game has helped them identify their knowledge gaps and inspire them to look up more information about recycling. Others have a neutral or unchanged attitude towards recycling, while some participants found the game to be entertaining and exciting. In general, the game was regarded as an effective and entertaining approach to encourage recycling and increase awareness of its significance.

Participants found various aspects of the game enjoyable and engaging. In the second mini–game, in particular, the competitive nature of the game increased the enjoyment and excitement. The multiplayer mode was highly appreciated because it improved the game–play experience. Some players liked the interaction and competition with other players, and some found the cooperative aspects of the game also fun. It was also noted that the aesthetics, graphics, and music were pleasing components that enhanced the whole ex–perience. The second mini–game gathered compliments for its difficulty and the chance to observe closer the passing objects. The Minecraft–inspired setup and the nostalgic feel of the game resonated with some participants. Particularly mentioned positive features included the big screen, hitting the button, and the pixel art aesthetic. Overall, the game's multiplayer mode, rivalry, engaging gameplay, and appealing visuals were singled out as being especially engaging and enjoyable.

Participants encountered various difficulties while playing the game. Some players complained that they had trouble quickly sorting and recognizing the items in the first mini–game because the slots or icons were difficult to see or were not always clear. The instructions provided in the game were sometimes confusing or unclear, causing uncer–tainty about the specific tasks or actions. A tutorial or clearer instructions were requested by some participants. In the second mini–game, some players had trouble controlling the hook because they found it too slow or challenging to aim precisely. Bugs or inconsis–tent functionality with the button were also reported. In all, there were issues with unclear instructions, recognizing or grabbing objects, and controlling the hook.

Participants had mixed opinions about whether the game sufficiently educated or raised awareness about recycling. Some users believed that the game did increase awareness and had educational value because it showed the negative effects of not recycling and taught them how to properly separate trash. They value the explanations offered in the game and focus on identifying different waste types. The game was thought to be a fun and interesting way to learn about recycling. Some users, however, thought that the game did not offer much new information or did not address the realistic consequences of not recycling. The participants advised increasing the number of rounds, providing details about specific items, and including real–world effects like plastic pollution. While the game was mostly regarded as increasing awareness and having some educational value, some participants had varying opinions on the extent of its effectiveness.

The game's multiplayer mode was well received by the participants. Playing against another person was more interesting, engaging, and entertaining for them. The element

of competition increased the excitement and encouraged better performance in the game. According to some participants playing with a friend improved the experience and allowed for discussions about the game and recycling. A few participants, however, believed that the multiplayer mode caused them to rush through the instructions or pay less attention to it. The multiplayer mode was generally seen by many as a useful feature that increased the game's enjoyment and immersion while promoting competition and social interaction.

There were instances in which participants were unsure or confused about what they should do in the game. Particularly in the first game, some users found it difficult to recall which items belonged in which bins. Confusion has been mentioned as being caused by the instructions given, especially at the beginning of each game. Participants also expressed uncertainty about the second mini–game rules, including whether they should grab or avoid certain items and whether to utilize the buttons or touchscreens. Some players felt uncertain about the game's rules or goals, while others got lost as a result of distractions or failing to pay close attention to the instructions. A few participants brought up technical issues such as the button getting stuck or unclear controls. Overall, there were a few instances of doubt or confusion, but they mostly happened early on in the game or whenever particular rules or features were not immediately obvious.

Regarding whether the game motivated them to change their attitudes on recycling or take action in their own lives, participants' responses varied. Some players said that the game taught them new information or clarified specific recycling rules and that they would become more mindful and precise in their waste separation now. Some users claimed that while the game was a reminder of the importance of recycling, it did not dramatically change their behavior because they were already mindful of their recycling practices. Some participants thought that the game was too short or did not provide enough information to have a significant impact on their recycling practices. In general, despite the game's varying levels of influence, it helped players gain a better understanding of recycling guidelines and encourage them to be more aware and attentive to their waste management practices.

Participants liked the overall atmosphere and mood of the game. The pixel art and music added to the enjoyment and engagement, which the users thought were fun. Even though it was a bit extreme, the post–apocalyptic theme gave the game an interesting and compelling element. The story and theme within the game were well–liked by the players and provided them with information about recycling in an entertaining way. Some users said that the game exceeded their expectations and others thought it was fitting for a game with a recycling theme. Participants found the balance between education, humor, and dystopian elements to be appealing. As a whole, the players enjoyed the game's mood and atmosphere which added to the overall experience of the installation.

Overall, the responses show that many of the participants would be interested to play the game again if they came across it in a public setting. The multiplayer mode, competitiveness, and enjoyment of the game were key factors that would motivate them to want to play it again. Some participants, however, suggested that adding more visual clues or advertising may be useful in grabbing their attention and encouraging them to play again.

Participants offered insightful recommendations for improving the installation. They suggested adding new mini–games, increasing the variety of waste items, and making the instructions more concise. Suggestions included adjusting text size and improving the LEDs for better visibility. Additionally, participants recommended improving the explanation scenes, giving more clear feedback, and including illustrations as examples to help understand the instructions. Others suggested adding difficulty settings, including facts about recycling, and adding rewards. These recommendations intend to improve the game's enjoyment, educational value, and overall impact.

In the end, participants provided positive feedback on the installation and expressed appreciation for how entertaining and engaging it was. They complimented the visuals, multiplayer and competitive aspects. Some participants recommended enhancing the picture quality and adding different sound effects for each player's score. The big screen, nostalgic aesthetic, and touchscreen capabilities were also appreciated. Users mentioned the game's potential for educational purposes and also suggested placing it at conventions or business events. The game was described as fun, engaging, and well–designed.

In conclusion, the feedback from participants about the installation was generally positive. The game was seen as fun, engaging, and visually appealing, with its retro art style and multiplayer mode being the highlights. Participants enjoyed competing against one another and values the competitive aspects. The educational value of the game was recognized as it provided new information about recycling and raised awareness about waste separation. It was suggested to add more mini–games, more items related to different waste streams, improve the instructions' clarity, and increase the text size and LED visibility.

7.3 Evaluation of the non–functional requirements

The questions posed during the user evaluation were constructed such that the participants' responses would provide insight into whether the non–functional requirement was satisfied. Based on the results of the user testing, Table 7.1 demonstrates whether the requirement is satisfied or not.

Requirement	Priority	Fulfilment
The installation should be visually attractive to attract users.	Should	Yes
The game has a flow (clear goals, no distractions, direct feedback, and continuously challenging).	Should	Yes
The game should be intuitive and understandable to users.	Must	No
The installation is non–discriminatory.	Must	Yes
The rules of the game should be comprehensive.	Must	No
The game should not be cheatable.	Should	Yes
The game must be max. 5 min.	Must	Yes
The game is suitable for a half–public/half–private setting.	Must	Yes
The game is supported by a story.	Must	Yes
The game sparks social connection.	Should	Yes
The game/story is supported by a narrative and characters.	Could	Yes
The game incorporates collaborative problem–solving.	Could	No
The game has parts of surprise and fun.	Must	Yes

Table 7.1: Evaluation of non–functional requirements.

In the end, while some areas may benefit from further improvement, the participant feedback suggests that the installation met most of the non–functional requirements and provided a fun and engaging experience. Participants found the installation to be visually appealing and liked the nostalgic aesthetic. The game provided a fun experience with a good flow. The game was completed within the given time, and the feedback showed no signs of discrimination or cheating. The game encourages social interaction and seems appropriate for a semi–public setting. It was also said that the game has provided aspects of surprise and excitement. However, there were some recommendations for improvements in terms of making the game more user–friendly and clear for players, as well as making sure the rules were comprehensive. Some participants indicated that there were times when the game was confusing or difficult to grasp, which is why it should be improved to be more straightforward to the users. Additionally, participants suggested that the game rules could use some work in terms of making them more clear and concise. These areas are areas for improvement to provide players with a more smooth and user–friendly experience.

7.4 Evaluation conclusion

To understand how the system performs in practice, a user evaluation was conducted as described in the previous subsections. The evaluation of the realized systems aimed to establish the following:

Educational aspect Since one of the main goals was educating the users on waste separation, it is crucial to measure how effective the system was in the educational aspect.

Entertainment To make the system attractive, gamification was applied to make it more entertaining for the users. This is therefore a crucial aspect of the installation and was evaluated to the same extent as the educational aspect.

Raising awareness Even if the degree to which the installation educates users varies, it should still bring the topic of waste separation forward, encouraging the users to be more aware of it in the future.

Technical and Visual quality Although all the previous aspects can be rated highly by the users, the technical and visual quality impacts not only the durability of the installation but also plays a role in the users' experience. For that reason, feedback in this area is very valuable.

In combination, the evaluation of all elements of the installation provides a good overview of the overall value of the system to the target group. The expected result is that the system is helpful in answering the proposed research question, which, based on the received feedback seems to be the case.

7.4.1 Education

The average score given to the question "How much did you learn about waste separation from interacting with the installation" was 2.9 as shown in Figure 7.1. Participants generally gave a positive response when asked if the game sufficiently educated or promoted awareness about recycling. Some people, however, stated that they were already familiar with recycling, therefore they would require more information than what was provided by the games to determine how certain items should be disposed of. Additionally, many mentioned they needed more time or multiple tries to fully understand everything.

The participant feedback indicated varying effectiveness in conveying the concept of recycling through the mini-games. The first mini-game, the memory game, was generally well-received, effectively presenting recycling concepts and engaging participants in the gameplay. The second mini-game, the trash miner, received mixed ratings, with some players expressing uncertainty about its impact. To increase the game's instructional value, it was suggested that more examples or explanations are added to the game to enhance the educational value.

7.4.2 Entertainment value

The overall experience, enjoyment, motivation, and multiplayer aspects received ratings above 4 in the survey as shown in Figure 7.1. Most players gave favorable responses when asked about the game's concept, multiplayer functionality, and replay value. They complimented the game's aesthetic and plot and expressed that they would want to play it again. Some users, however, complained that the multiplayer element occasionally caused them to rush, possibly missing important information or instructions.

The participants had a fun and playful experience thanks to the game. They enjoyed the engaging gameplay, goals, and visuals that helped the game flow. Particularly well–liked was the multiplayer mode, which promoted friendly competition. Participants expressed enthusiasm for playing the game again, indicating its fun and ability to capture their interest. The installation successfully created a playful atmosphere through its immersive storytelling, visuals, and interactive elements.

7.4.3 Raising awareness

The game's impact and participants' motivation to take action regarding waste separation varied among individuals. Some users expressed feeling inspired and motivated to think about their recycling practices and make changes in their lives. They recognized the educational value of the game in raising awareness and promoting proper recycling. Furthermore, those who were already practicing proper recycling methods found the game to be a good reminder of their habit. To increase the game's impact and motivation, some participants proposed adding more educational content, such as facts or reminders about the importance.

7.4.4 Visual and Technical Aspects

Visual elements played a significant role in enhancing participants' experience. Positive feedback on the game's graphics and retro art style both contributed to its appeal and enjoyment. The installation's technical aspects, such as the buttons and usability of the touch screen were less than ideal. A number of participants encountered minor difficulties, especially with the buttons, stressing the importance to create a smoother user experience. There were also ideas to make the LED progress bars more understandable and clear.

7.4.5 Conclusion

In conclusion, the evaluation offered comprehensive insights into various aspects of the installation. The system achieves great results when it comes to user engagement and entertainment, and was seen by the participants as a fun social experience. The visual aspect, the theme, and the story were also viewed favorably by most users.

Regardless, there are areas where improvements could be made. The installation should be more clear in how it should be used (especially how the games should be

played) and could educate more clearly. Especially for participants more familiar with waste separation concepts, the game could include more difficult elements which would encourage more education as well. Additionally, for further use, the technical issues with the installation should be addressed. By taking into account these suggestions, the game could give players a more memorable, impactful, and engaging experience.

Thanks to the evaluation results, the impact of the installation on answering the posed research question can be discussed further in Chapter 8, but also many potential future improvements based on the feedback provide a good start for considering future work in Chapter 9.

Chapter 8

Discussion and Conclusion

It was discovered that the waste separation practices on the UT campus do not support the sustainability and recycling goals of the CT–CFM. According to the analysis done in 2020, the residual waste bin contains significant portions of recyclable materials, with 32% being PMD, 18% organic waste, and 18% paper waste, leaving only 32% as actual residual waste. In order to address UT's waste separation problem effectively, this project aimed to find a solution by answering the research question **"How to educate the UT community in a playful manner using Interactive Media?"**.

To understand this problem extensive background research was done. The main finding of the research, was that individual pro–environmental behavior is influenced by attitudes, knowledge, and awareness of consequences, as well as demographics and personal values. Furthermore, overcoming barriers to these behaviors can be achieved through education and raising awareness. One possible way to effectively promote recycling and educate about waste separation is gamification. These findings, combined with an extensive state–of–the–art on existing interventions and technologies were then used as inspiration in the ideation phase of this project.

In the ideation phase, based on the analysis of the key stakeholders' needs and through multiple brainstorming sessions a solution concept was proposed. Combining many previous ideas was an arcade–style installation with mini–games tied together with story segments. The goal of the installation is to educate the user on where to dispose of the waste but also make the users aware of the consequences of not doing so.

The next phase of the project was the specification. The main results of this stage were deciding on a post–apocalyptic university story and theme and designing a miner mini–game and a memory mini–game for the educational and entertainment aspect. Then, based on created personas and an interaction scenario both functional and non–functional requirements were identified, ensuring that the product would meet the desired specifications.

After the prototype was created based on the specifications, a comprehensive evaluation was conducted through user testing. A total of 33 users participated in the study at the end of June 2023. After a playthrough of the installation, the users completed a survey

and were asked questions to evaluate the experience.

This process, and especially the evaluation phase is highly valuable in answering the posed research question. What is clear, is that Interactive Media can be used to educate the UT community on waste separation while also entertaining using an arcade game–like installation. The evaluation shows, that this application of gamification provided an attractive experience for the users. The added social aspect of a two–player competitive game was also appreciated by the participants of the evaluation, which is something that is rarely utilized in education. Although the educational element of the game is recognized by the participants, many of them stated that they feel as though they already had the knowledge conveyed by the installation. That being said, having already achieved high participant satisfaction with regard to the playfulness of the installation, adjustments can be made to amplify the teaching aspect. That could include adding another more complicated mini–game or redesigning the existing games to include more advanced knowledge on waste separation.

If more iterations of design, realization and evaluation can be completed, an improved version of this installation could be used to educate the UT community on waste separation in an effort to reach the goal of the CT–CFM. Another advantage of the installation is that if it is entertaining enough, it can be placed in a UT building with minimal maintenance and attract students to interact in their free time between courses. It could also be interesting to conduct a long–term study on the impact of such an approach on correct waste separation.

Overall, the results of this study are relevant to the goal of an environmentally–friendly university campus and provide an answer to the posed research question, showing that gamification has been applied successfully, but also that the system can have a real impact on the community.

Chapter 9

Future Work

According to this research, the Trashpocalypse installation is a successful prototype, although there is still an opportunity for additional improvements.

Adding more educational content

To enhance the educational aspect of the installation, additional content can be incorporated into the existing game. Throughout the game, recycling and environmental fun facts could be incorporated. Players could learn more information while playing the game by seeing these facts in the story, between the instruction and mini–game, or as pop–ups while playing. Another way could be to include tooltips or pop–up windows that offer brief explanations for the objects in the game, that the players could tap to learn about a specific waste item. One more way to provide more educational content in the game could be by providing a link or QR code to more information for the players that wish to find out more about waste separation.

Adding more mini–games

Expanding the game with additional mini–games can greatly enhance its fun, replayability, and educational aspects. By introducing mini–games that focus on different waste streams, more difficult items to recycle, or the processes involved when items are thrown out, the gameplay not only becomes more interesting but also more educational.

Making the instructions clear

To make instructions more clear, multiple methods could be applied. These consist of using clear, brief language, adding illustrations to support the text, breaking down complicated institutions into smaller ones making sure that the formatting and presentation of the instructions are consistent and concise.

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Appendix A

Story Scenes

Figure A.1: Title screen

Figure A.2: Story Scene 1

Figure A.3: Story Scene 2

Figure A.4: Story Scene 3

Figure A.5: Story Scene 4

Figure A.7: Story Scene 6

Figure A.6: Story Scene 5

Figure A.8: Story Scene 7

Figure A.9: Story Scene 8

Figure A.11: Story Scene 10

Figure A.10: Story Scene 9

Appendix B

Instruction Screens

Figure B.1: Instructions on how the game works

Figure B.2: Instructions for minigame 1

Figure B.3: Instructions for minigame 2

Appendix C

Information Letter

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

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

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

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

Appendix D

Informed Consent Form

Consent Form for Creative Technology

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
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 observations about my interaction with the installation as well as recording my answers to the interview questions.	○	○
Use of the information in the study		
I understand that information I provide will be used for Graduation Theses.	○	○
I agree that my information can be quoted anonymously in research outputs	○	○
Future use and reuse of the information by others		
I give permission for the data that I provide to be anonymously archived in the Creative Technology Thesis Repository so it can be used for future research and learning.	○	○

Signatures

_____	_____	_____
Name of participant [printed]	Signature	Date

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

_____	_____	_____
Researcher name [printed]	Signature	Date

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