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Development of “Masters contra o Desperdicio”, a game for awareness on Food waste

MASTER DISSERTATION

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MASTER IN INFORMATICS ENGINEERING

UNIVERSIDADE da MADEIRA
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Abstract/Resumo

O desperdício alimentar é uma questão de grande relevância para todos os países do mundo. Muitas entidades e governos trabalham no sentido de encontrar uma solução para diminuir ou minimizar o desperdício desde a sua produção até ao consumo dos alimentos. Uma dessas entidades é o Banco Alimentar da Madeira contra a Fome, que promove campanhas de sensibilização direcionadas a diferentes grupos da população. Realizam visitas de estudo às escolas, mas têm notado um pouco envolvimento e eficácia nestas campanhas direccionadas para as crianças. Em parceria com o Banco Alimentar da Madeira contra a Fome, foi construído um jogo que tem como objetivo sensibilizar para a prevenção do desperdício alimentar. Esta experiência, dirigida a crianças dos 8 aos 12 anos, foi desenvolvida com o Unreal Engine 5 para telemóvel. Foram realizadas pesquisas sobre outras iniciativas para perceber de que forma o nosso trabalho poderia ser uma mais-valia para a área. Foram realizados vários estudos durante o ciclo de desenvolvimento para avaliar a eficácia e o nível de diversão do jogo. O jogo provou ter potencial para uma utilização bem sucedida num cenário real, com a faixa etária definida, em ensinar ações de redução do desperdício alimentar.

Keywords: Desenho de jogos · Serious Games · Redução do desperdício alimentar · Sustentabilidade · Crianças

Abstract

Food waste is an issue of high relevance to all countries around the globe. Many entities and governments work towards finding a solution to decrease or minimise the waste from its production to the consumption of the food. One such entity is Banco Alimentar da Madeira contra a Fome, promoting awareness campaigns for different groups of the population. They conduct field trips to schools, but have noticed a low level of engagement and effectiveness in these campaigns targeted at children. In partnership with Banco Alimentar da Madeira contra a Fome, a game was build that aims to raise awareness to prevent food waste. This experience targets children from ages 8 to 12, was developed with Unreal Engine 5 for mobile. Research was performed in other initiatives to find how our work could be a positive addition to the area. Various studies were conducted during our various iterative steps during the development cycle to evaluate the effectiveness and amusement level of the game. The game proved to have potential for a successful deployment in a real world scenario, for the target age group defined, in teaching food waste reduction actions.

Keywords: Game Design · Serious Games · Food Waste Reduction · Sustainability · Children

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Table of Contents

List of Figures

List of Tables

Acronyms

2D Two dimensional

3D Three dimensional

REDA Recursos Educativos Digitais e Abertos

UI User Interface

USA United States of America

USDA United States Department of Agriculture

UX User experience

1 Introduction

Food waste is referred as the proportion of edible food that goes unconsumed [1], which includes materials for human consumption that are subsequently lost, degraded, discharged, or contaminated [2]. Food waste as more implication in the sustainability and economy of everyone in the planet, because tons of food that needed, water, soil, transport, have a shorter life cycle, thus decreasing its availability specially to people in need [3, 4]. Due to its growing magnitude, complexity, and relevance food waste has attracted several initiatives [5,6] all in the hope that by 2030 food waste is going to be reduced by half [7]. According to Hebrok et al [8], households are considered the major contributing factor to food waste. Household food waste refers to a portion of the overall food losses that occur due to consumers choices, this includes actions like cooking excessively large meals, purchasing excessive amounts of food, and neglecting to repurpose leftover food [9, 10]. Scholars have highlighted the need for more empirical research at the household-level [11] in particular to study effective strategies to engage consumers in food waste reduction [12, 13].

Current research shows that younger consumers are more likely to engage in food waste reduction than their older counterparts [12, 14]. However, initiatives that can teach and motivate students and their relatives to have better food waste management need further exploration [15]. Previous research has shown that playful educational experiences and games show positive effects in a wide spectrum of the development of children's cognitive skills, and facilitates the learning process [16–18]. Hence, we see potential in designing a game for 8-12 years-old children about food waste reduction strategies. A game about food waste can transmit children important life skills such as budgeting, resource management, creativity in using leftovers, and the value of sharing and donating food. Andrés et al, performed an initiative with higher education students, which proved to be successful in changing their waste habits [19]. By designing and developing a game, we intend to capture their attention and make learning about food waste a fun and memorable experience, instead of associating food waste with negative emotions as previously research shows to be very common among consumers [20]. Furthermore, this approach is aligned with the reality of the local context of Madeira where this project is being developed and where the Local Food Bank finds the use of traditional approaches ineffective.

This thesis contributes with the design and implementation of a food waste game for children, to be promoted by the local food bank, and help them teach children about food waste through an entertainment medium. A game that can be shared as part of their dissemination activities within the formal school context but that can be explored by children in informal learning environments, leveraging a long-term exposition of topics related to food waste and best practices to avoid it.

The game's evaluation should also provide more knowledge about the effectiveness of serious games applied to children, and possibly help in future endeavours related to developing games for children in similar scenarios. Two research questions were formed to guide our research efforts: RQ1 - Can a serious game promote awareness towards best practices on avoiding food waste among children?; RQ2 - What game mechanics can effectively teach about avoiding food waste while maintaining high levels of enjoyment.

As such, this work contributes with the conceptual design and pilot evaluation of a game about food waste reduction strategies for children.

1.1 Document structure

The document is structured with the following chapters:

1. In chapters 2 and 3 include all of our research efforts, starting with a more broad look into food waste, serious games, children digital media and games to learn more about these topics. In chapter 3 we discuss various related work to find what was already done in this area and where we can introduce our project.
2. Chapter 4 explains our target audience, platform, design decisions, how the game evolved, show casing the four main steps in the development of the game from prototypes to the current version of the game.
3. In chapter 5 we detail all of our process of development of the game, with requirements, diagrams and implementation of our mechanics.
4. Chapter 6 is dedicated to our target platform and the system requirements.
5. In chapter 7 we present all of our studies performed, with the procedures followed and results for each study.
6. In chapter 8 we discuss our results and the research questions, explaining what was achieved and what was not.
7. Chapter 9 we discusses our limitations and goals of future work.
8. In chapter 10 we conclude what our work brings to this area and the main contributions.

2 Literature review

2.1 Food Waste Introduction

Food waste is all the food, or portions of a food, that can be consumed, but are left unconsumed [1]. This wasted food can originate in many steps of the food cycle from production, transportation, at the supermarket or stored incorrectly in our household. Our focus is in the improvement of the household food waste. Following the goals set by the United Nations Sustainable Development [4] to reduce food waste, different countries have handled this problem in different ways.

When looking at Portugal the Comissão Nacional de Combate ao Desperdício Alimentar, the entity responsible for fighting food waste, shows that although some initiatives, such as M6 "Share good practices, including, guidelines and successful cases" and M3 "Develop awareness campaigns for the population that still attends school" [21], have been made to reduce this problem, there are always improvements that can be done to help with this problem here in Portugal. We can educate children from a very early age so their habits can mature and be part of a future solution [22].

On the other hand, looking at the United States of America as another example, according to multiple news reports collected [7], the majority of food waste comes from big companies and schools.

The agriculture department of the USA estimates that the daily food waste is enough to fill ninety thousand benches from a rugby stadium [7]. Half of the quantity of food waste produced is from children, which is equivalent to the rest of the population, thus this age group is a major factor in the production of food waste. The food waste produced from sales and consumers is around thirty one percent.

It is expected that by 2030 food waste is going to be reduced by half [7] going in line with the goals set by the United Nations [4], however, there are no regulations, nor enough initiatives for that to be a reality. Some laws also bring more damage than profit thanks to legal limitations, since each school follows its own rules in the fight against food waste. There is no common ground for initiatives that can teach and motivate students and their relatives to have better management of their food waste. One such law is USDA's "Healthy, Hunger Kids Act" mandate, which in practice only leads to more food being wasted [23].

As stated by Vieira et al, secretary of agriculture and food of Portugal, food waste education starts in school among the students, since these are the new generation of producers and consumers [3], it is in this perspective that this work looks into what has been done and can be improved. There are a couple of ongoing initiatives that approach the food waste problem and try to raise awareness for this problem among children and their parents [24–28]. In the local context of Madeira island, the Banco Alimentar da Madeira [1], an entity that we are collaborating with, often gives talks and develops activities to educate children to how they can be part of the solution for food waste. However, they find that young children are hard to engage in this problem through traditional approaches such as lectures. Hence, they came to us with the challenge to design a game to raise awareness of food waste and deliver best practices to avoid waste.

[1] https://www.bancoalimentar.pt/bancos/madeira/

2.2 Serious Games

Video games are firmly cemented as a component of the modernized, digital classroom thanks to growing research into their educational uses. For example, environmentally conscious games are gathering the interest of sustainability teaching, leading to research into the educational value of such games is quickly growing in importance [29].

According to Fisher, games can be defined as an interactive experience, where a user or group of users try to achieve certain goals set out inside the game. A set of rules are set out so the player knows how they can work towards the said goal. The aforementioned rules are normally designated as game mechanics since these rules will define how the game gets played out [16].

Games that are built with the intention of having their users learn or practice concepts are referred as serious or educational games. Serious games are mentioned to as being "created for all ages, from kids to senior citizens, on a huge range of subjects, from sex education to military training" [16].

Games are a powerful tool for education because through games children acquire knowledge, enrich their experience, are active participants in their learning process and develop social, cultural and cognitive skills and habits [30]. Serious games can also be defined as simulations of real-world events or processes designed for the purpose of solving a problem [31]. Playful educational experiences and games have shown positive effects in a wide spectrum of the development of children's cognitive skills, and stimulate learning in children [18].

Serious games are defined as games designed with a primary purpose beyond mere entertainment. These games are powerful tools for education, since through gameplay children acquire content knowledge, enrich their experience, and are active participants in their learning process. All while developing social and cultural skills and providing the opportunity for students to tackle real-world problems [31–34].

Gamification is the use of game elements to encourage a behaviour or attitude in a non-game environment. Some of these elements come in the form of rewards, leaderboards, points, among other things, that are part of the mechanics and gameplay used in games [35]. Serious games can benefit from gamification by leveraging gamification inspired mechanics to reward the player for achieving certain goals or following correctly the educational goals.

Previous research, demonstrates that serious games are tools that can facilitate the learning process, providing a better understanding of certain subjects as children are more engaged in the experience [16, 17].

2.3 Children Digital Media and Game Consumption

Following the content mentioned in the previous subsection, this subsection presents some scientific validation and examples of content developed for children, more specifically digital content.

Children are undergoing growth and as such many of their skills are still under development. School is the most common environment for the development of these skills, but the exposition of information is not always the most effective to stimulate a successful learning experience. Janet et al share a constructivist framework for serious games. Constructivism applied to games relates to how the user learns, when the user undergoes a new experience the user takes knowledge from that experience and forms new knowledge [36]. Additionally the learning process is achieved through

social interaction, where the sharing of experiences with other users expands their knowledge [36]. Children can learn through experience by observing, forming a mental model and using problem solving skills. Teachers can provide guidance, while allowing children to explore at their own pace and time the content and acquire knowledge, making children participate in the learning process (active learning). Children can also learn by sharing their experiences with other colleagues, for example in forums with other users who also had some learning and different perspective from the experience [37]. Problem solving skills are developed and practiced when playing video games. This is also extremely helpful as video games can represent real life experiences [17].

Fisher et al mentions that children aged from nine to twelve years old are more susceptible to learning new concepts very rapidly. This comes from the fact that their brain thinks at an increased speed, and they also start to change their preferences in games and media consumption. This age group plays different types of games on different devices, so they are familiar in how to use them. However, unless exposed to it intentionally, they are unlikely to interact with serious games unless shared in a school environment [16].

Additionally Fisher et al [16] reported that between seven and nine start to have more freedom in media consumption. Furthermore, children from nine to twelve years old are enhancing many of their skills (communication, motor skills, social and emotional development, logical thinking) and start to have their opinions and preferences.

Children's early life is fundamentally a period of preparation and socialization leading towards the full citizenship of adulthood. Given that today's children are the future generations whose health and well-being will be increasingly harmed as the stability of social and ecological systems continues to unravel [38]. In the interest of building sustainable futures in collaboration with youth and towards developing empowering pedagogies in the process, inviting young people to learn about the scientific and social dimensions of sustainability is critical, as is encouraging their action [39].

3 Related Work

In this section, we will start by discussing different types of educational resources that can help children to reduce food waste, like books, web pages and blogs. Following a section with projects targeting children. We will showcase how this topic is approached by different games and gamified applications. Followed by a section to get some insight into developing games for children. A section is also dedicated to showing projects that have children as target consumers. Lastly, at the end of this section, there is a conclusion comparing the different food waste resources, their relevance to the subject and different target ages.

3.1 Initiatives aimed at raising awareness about food waste

Food waste is a critical problem in our days and accounts for a substantial quantity of wasted resources [40]. Therefore it is critical to find solutions that prevent and minimize food waste for our well-being and the sustainability of the environment [4]. Pinto et al. implemented awareness campaign in the context of a University canteen and by displaying simple posters with educative messages, and conducting guerrilla actions during the busy lunch hour. The authors verified a reduction in plate waste, and increased the recycling attitude of the users (mostly students) of the canteen [41].

Books are also one of the resources used to prevent food waste. Some explain how to organise visits to the supermarket; how to organise food storage and how to prepare dishes following good food waste practices [25]. In particular, we found a collection of four illustrated storybooks [24] targeted at children. Each book explores different aspects of food waste, with topics about how to organise the fridge to prevent food waste in various ways.
Other mediums used as inspiration for this research were food waste blogs [42], websites [2], social media pages [26] dedicated to finding solutions to this problem, books and lastly academic articles [14,43]. These sources revealed to be very important to get a better understanding of the techniques and mediums currently used to raise awareness towards food waste reduction. A notable example of a complete and vast material that presents and explains a lot about food waste is [25] *Desperdício Zero à mesa com o Pingo Doce*. This book explains how to organise visits to the supermarket; what to look for; in what quantities and how to organise the fridges, freezers and pantries. This aforementioned book showcases how to prepare dishes following good food waste practices, eating habits that besides helping to reduce food waste also help to save money, and finally, it presents mindful recipes using food remains (that we may have laying around) giving them another life in new dishes.

All these were important to get a better understanding of how to decrease food waste and help "fight it", from buying food from the store, storing, and following recipes and tutorials on how to reuse food that would potentially be wasted.

3.2 Children Targeted Projects

In this subsection, some projects targeted to children are presented to share some insight how these projects are making use of digital tools.

An article of relevance [44] about the integration of children in the development of new technologies, focus on the process of involving children and their roles as strong influences and guides of ideas for new technologies. The children's participation also helps in adapting these tools making sure that they are interesting and adequate for other children.

Some relevance needs to be given to REDA program [45] since it provides a lot of content that teachers can use in their classroom. The content was specially useful during the pandemic for teachers, providing extra content with a didactic approach for the children to access at any time cost free. An example of a project developed for this program was "ilha periscópio" [46] which provides content that is usually lectured in mathematics, portuguese and science classes, presented in small and short games so that the students could learn or relearn concepts in an entertaining way.

Nowadays the importance of having new digital tools, developed to teach and involve the youth in becoming more competent adults for the future is more common. The involvement of children in building new tools targeted for future children like them is important, this is why many educational systems and institutions are looking for methods to share these digital goods with the population.

3.3 Serious Games about Food Waste Reduction

In this section we present the related work on serious games for food waste reduction that have in mind younger audiences.

[2] https://www.bbcgoodfood.com/howto/guide/how-reduce-food-waste

A família Consciência vai às compras [27,28] is a game developed for the web. This game was developed to be used in the school context, targeting students with ages ranging from 8 to 12 years old. The authors were especially focused on applying it to the classes of "Estudo do meio" and "Educação para a cidadania". The game was built with cooperative mechanics, which can be used for increasing the number of players, however it was also built as an adversarial based game. The game allows a team of one or two players to face another team of the same size, or a computer. The cooperative mode of the game is also useful for testing it in a class environment. The study lasted for three months where the authors collected data from students and teachers about how food waste was presented as a theme for them to be more mindful of their decisions. Additionally teachers were asked if these tools were a good addition to the classroom when teaching new subjects. The majority of the responses were very positive regarding its effectiveness and children's engagement was high during the whole process.

A game called Tony waste [47], was developed as a serious game to introduce food waste to its players. The creators wrote an article that reports the process of creating this food waste oriented game. The goal of the game is to teach children how to decrease food waste. The designers and developers started by building the main character which was inspired by existing cartoons characters. The character's name Tony is associated with Italy and pizzas, and the central idea of the game is to reduce food waste. The creation of the main character was done with the target public in mind, his head is big so it stands out more, and because he is a chef a chef's hat was incorporated. He also has a moustache which is characteristic of Italian chefs and his facial expression were enforced. The authors emphasise how they made use of low saturated colours for the background and more saturated colours for the interactive components of the game. In the game the player is responsible for managing a pizza restaurant, taking clients orders, remembering them and choosing the ingredients for the pizza. Every mistake in the conception of the food leads to the waste bar increasing and once it is full the player loses.

"Upcycle" is an artefact with an interesting game concept approach, which provided lots of ideas for how the game would end up working [48]. The game concept is presented in a video format, since there is no prototype or any development of such a game. The concept of the game is a narrative that talks about food waste and how it is affecting our world. They mention that the game has three core pillars - first one cooking: when helping people during the story, we are given food spirits that share new recipes. We can then cook in the game and in real life using a companion app. The second pillar is education, which is achieved with the stories that are shared with us by the people that we help in the game or the food spirits. Finally, the third and last pillar is community which functions by people helping each other to make good decisions, by interacting through dialogue which leads to gather more food spirits and having the world of the game less polluted.

Finally, the results in Titiu et al, showed encouraging results for a gamified application, which was still missing partnerships in order to incentivise even more parents in make the right decisions regarding their household food management [49]. Additionally, the games from [27,28,47] proved to be a step in the right direction for involving the youth in the learning process to manage their food waste correctly and becoming a part of the solutions to food waste in the future.

Overall, the described games [27,28,47] show the potential towards involving the youth in food waste reduction. Previous games have employed various strategies including:

1. The use of characters and their stories, to captivate children's attention and influence them [47, 50, 51].
2. Game mechanics that use slice or cut food, prepare meals and storing food are reported as being engaging [27].
3. Additionally, game mechanics that foster collaborative environments between children and their parents are beneficial to support and reinforce positive behaviors related to food waste [27, 28, 49].
4. From the body of work, games that include repetitive actions help with the practice of habits that can later be internalized and executed instinctively. [17, 37].

While these works provide inspiration, further research is needed thus, we propose the design and development of a serious game as an artifact to assess its efficacy in educating children about the best practices for minimizing food waste.

3.4 Chapter Summary

From the works reviewed so far, we notice that games target a younger audience whereas books, and web pages usually target older audiences. For example, we noticed that the materials produced by "Pingo Doce" [25] target an older age group who buy, store, and cook their food, so they are more mindful of all their decisions. So everything presented is explained in a detailed way with explanations of the advantages and disadvantages of using certain products, how to make the best of the food they buy when it comes to storing properly. On the other hand, the content that is targeted at children, mostly games [27, 28] and books [24] usually present the information through the lenses of memorable characters and their stories. One common approach is to use collaborative mechanics in the gameplay [27, 28, 49] for example in the game by Titiu et al [49] children and their parents both learn about food waste in a collaborative way. Parents, through the completion of quests, give rewards to children, whereas children learn through reminding what the parents have to do and watching them do it regularly. These collaborative experiences are helpful because each person can complement the other learning and help them understand the problem more effectively the repetition aspect is good for practice habits to be later implemented involuntarily.

All these projects have different and unique mechanics that make them interesting tools to teach the population about food waste from which we can learn and take inspiration from. However, we can also identify a gap as there are very few approaches that report on an evaluation and understanding of what is their impact. Therefore, we envisage designing and evaluating a game, so that we can extract guidelines and recommendations for future designers that wish to continue efforts in fighting food waste through serious games.

4 Design

In this section, we present an in-depth look into the different stages of the design process of the game, illustrated in Figure 1. First, we describe some of the decisions made in regards to platform, ideas and concepts inspired by previous work. Secondly, we provide an overview into our first prototype in Figma. Thirdly a look into a small redesigned prototype. The start of the development of the build for our pilot test. Finally, we described the final game's design process. Each section carefully explains the thought process behind each phase.

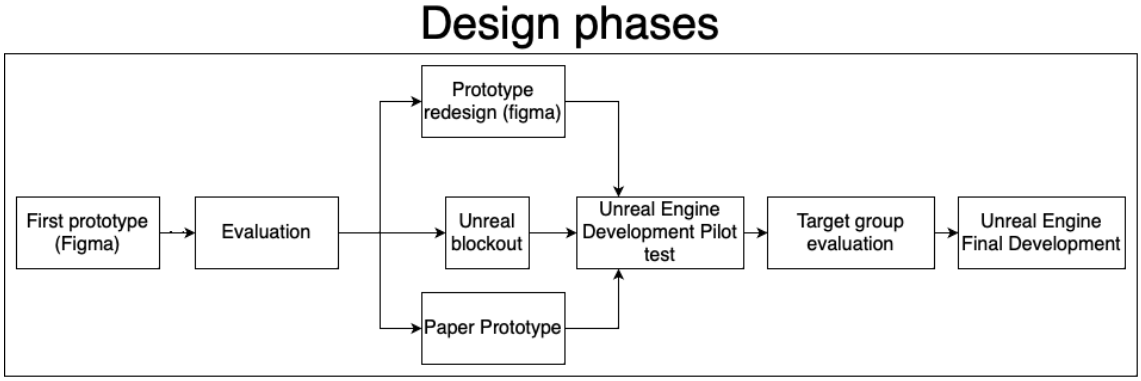

Fig. 1. Diagram with the various design phases performed during the development of the game.

4.1 Target Audience and Platform

We decided to develop a game for mobile devices that appeals to children between the ages of 8 and 12 since most children in this age gap have access to mobile devices. The criteria for this selection is that most of the children in our target group have easy access to this type of equipment, inclusively provided by the school. Furthermore, the use of this equipment provides the opportunity that besides exploring the game in a class context, where the topic of food waste is introduced, children can play the game again in a non-formal school context and share this experience with others, from friends to family members of different ages. Furthermore, Druin et al endorse the use of mobile devices in a school environment, as a simulation setting facilitates the learning of these concepts [52].

4.2 Initial Concept Design

Taking inspiration from previous body of work such as books, games and applications dedicated to this area of research, we shared specific solutions that guided the design of our game.

A game that influenced the development of the game was *Ratatouille* released for the Nintendo DS (see Figure 2 - A and B). This game offered a cuisine chef experience where the player had certain food to slice with a timer for each food they were preparing. The slicing process provided variations on the way you would use the touch screen of the Nintendo DS to cut the food. The player would have to manage the cooking of the food on three pans simultaneously, needing to place the food and be aware of the temperature of each pan. A sign would appear if the user

Fig. 2. Group of games that inspired ideas or mechanics in the game. A - Shows the slicing food mechanic from Ratatouille Nintendo DS game. B - Shows the placing food in the plate mechanic from the same Ratatouille game. C - Shows the organization of food in "Fridge Organizing" game. D - Shows the organization of food in "Fill up Fridge" game.

needed to add more food or finish the cooking. In the third phase, we have a timer to make all the moves necessary on the touch screen to put all the food on the plate.

Another of the ideas for the game was also organising food, as such we conducted research for similar mobile games. As part of this search, two games offered different approaches to organizing food in a fridge: *Fridge organizing* (see Figure 2 - C) offered an example in which colors are used to match the food colors that the player had to place in the specific shelf. The other game *Fill up Fridge* (see Figure 2 - D), offered a different approach to organizing, in this case, the player had different food items to organize in the shelves in the most efficient way. There was also the possibility of leaving gaps between the food storage which could lead to the shelf with less food than if it was all properly organized.

One of the initial ideas involved having a way to teach about each type of food waste action and correct it. This concept proved to be very divergent and not cohesive for the target age audience since they would have to learn and remember many different things in the game. The second idea proposed was being responsible for organizing and preparing the food inside a household. The player would be guided by a helper, which was chosen to be an animal similar to the books about food waste Zambujal et al [24], in this case, a hamster or gave life to a butter dish. The goal of the game evolved from just organizing food in the pantry, fridge, and freezer into helping with the cooking of certain dishes, which in the final version are meant to be real recipes from Pingo Doce's book [25], a local supermarket. While making the correct decisions about food waste, the player earns money and experience which can be used to customize and unlock new tools and cosmetics. This helps the user to feel some sense of progression and achievement for playing the game apart from the learning aspect.

4.3 Game Development

Before building the game in *Unreal Engine 5*[3] an initial prototype was built. This initial prototype for the game was developed with Figma[4] (a platform used to develop prototypes in a fast and effective way) to get a better understanding of what components of the game were useful and which ones were not for the final version of the game. In the next sections we illustrate the overall game design based on this first Figma prototype. A design of the gameplay loop is illustrated in Figure 3.

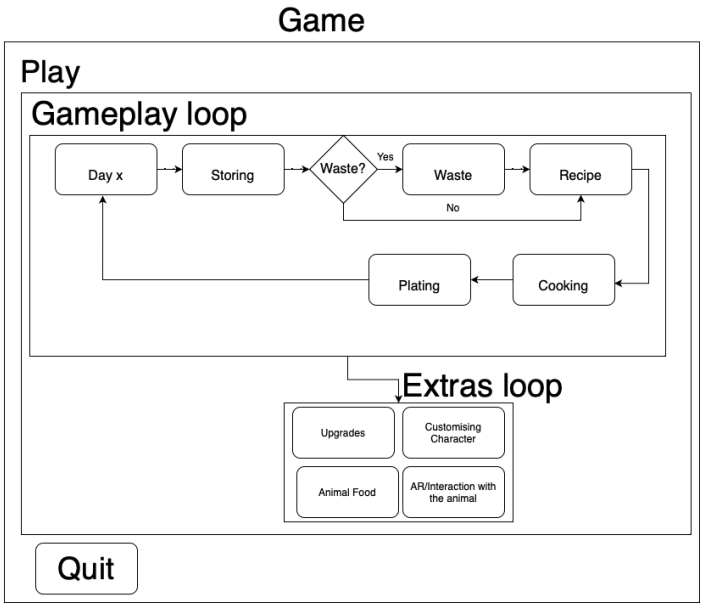

Fig. 3. Initial gameplay loop diagram based in the first prototype ideas.

4.3.1 Figma Prototype

Our goal is to apply some food waste reduction strategies within the familiar setting of a kitchen. Games that are relevant by providing the information within the context of the user, in this case children, can help in the process of transferring skills that are useful beyond the game itself [53].

The design was also guided by a pedagogical approach regarding the content of food waste. As such the educational scope of this game is to focus on the following approaches for food waste reduction: 1) Proper food storage: How to organize the refrigerator/pantry to store food correctly, maintain its freshness, and prevent spoilage; 2) Leftover management: Re-purposing leftovers into new dishes; 3) Meal Planning: Plan meals in advance to avoid overbuying and ensure that all purchased ingredients are used efficiently. Hopefully, through gameplay, children can apply these strategies, understand their relevance/application, and eventually have the opportunity to share the game with other friends and relatives.

[3]Unreal Engine website - https://www.unrealengine.com/en-US
[4]Figma short link - https://shorturl.at/BGI15

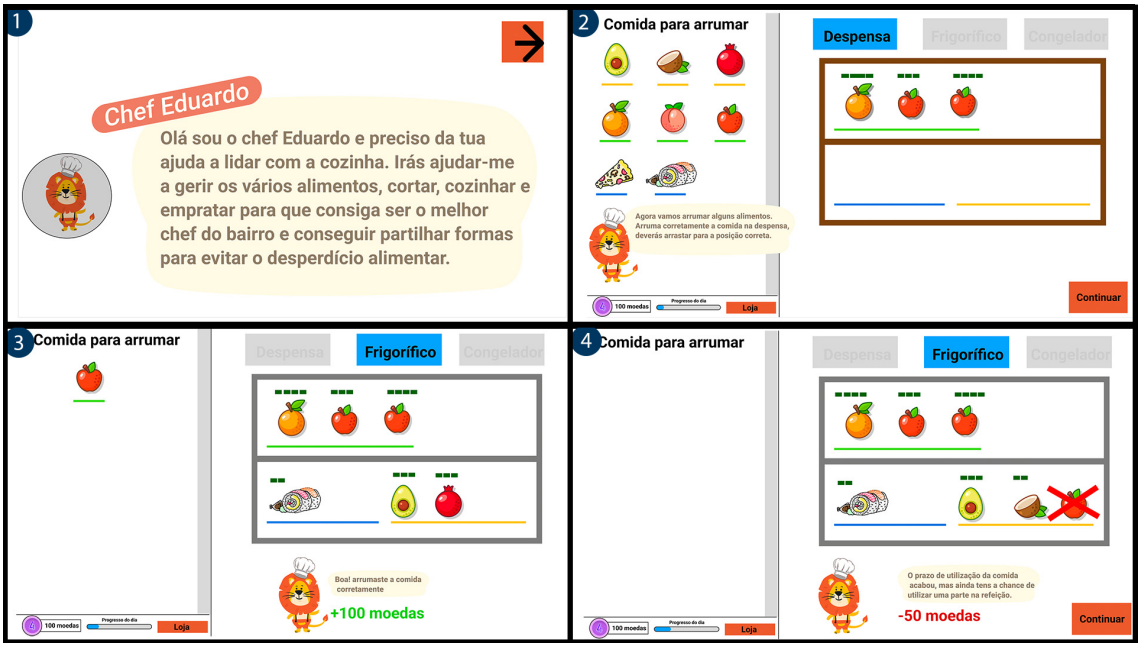

Fig. 4. Screenshots from the low-fidelity Figma prototype showcasing the gameplay. 1 - Shows the introduction message from Chef Eduardo; 2 - Displays the storing mechanic, on the left the player can see the food to store. The colors below indicate the shelf that it belongs to. On the right side of the screen, the app displays the pantry and the respective shelf's. 3 - Shows an example of the food stored properly and Chef Eduardo, above the food assets, the status indicator for its freshness is showcased; 4. Shows an example of food that was stored incorrectly.

4.3.2 Game Narrative ideas

A short narrative was introduced in this prototype to present the users with a general idea of why they were doing certain things in the game. The game starts with an introduction of the main character, Chef Eduardo who was represented on the screen as a lion. The character is responsible for guiding us inside the game and teaching us how to handle everything inside the kitchen according to good principles against food waste. At this phase, the narrative did not have much depth and was merely used as a way for the players to have a character guiding them that was appealing, thus the decision to use an animal.

Each day Chef Eduardo needs help to handle all the activities that go into being a Chef, as such, the user helps him by making sure the food is handled correctly. Eduardo has certain food to organize, slice, and cook, followed by the plating of the meal. After finishing a day, the user is rewarded according to their performance. They can spend their rewards with customization for the Chef's appearance and kitchen tools.

4.3.3 Game Mechanics

The game goal is to develop a long-term engagement while providing educational content. Each day new challenges and knowledge are given to the users and they can learn about food waste reduction gradually over time. For example, the first day of gameplay starts with a type of orientation day, that serves only as a tutorial for the game. Furthermore, the mechanics introduced in the game are meant to resemble real-life actions such as planning the menu, storing and managing the food, cooking, etc. However, along these tasks, the users will be given suggestions on how to avoid

Fig. 5. Further examples from the low-fidelity prototype gameplay; 1 - Cutting food to save the good parts of an apple; 2 - Plating the food to show to Chef Eduardo; 3 - Customization Screen; 4 - Summary of the day's performance, showing the experience points and coins earned.

food waste (see Figure 4). At the end of each day of work the user performance in the kitchen is evaluated and rewarded with experience points and coins accordingly. The experience points will allow the user to acquire new tools for the kitchen and customize the avatar look with accessories, (see Figure 5 - screen 3), this customization was added as Titiu [49] used character customization and proved to be appealing to children. For example, the user is responsible for organising the food in the correct place by deciding to store the food in the fridge or pantry. Then by matching the color of the food with the color on the shelf, the user is given the opportunity to learn how to store food properly in the fridge which is essential to maintaining its freshness, preventing spoilage, and ensuring food safety, (see Figure 4 - screen 1,2). Another example of food waste reduction mechanisms, is when the user is preparing the food for the meals Chef Eduardo advises on how different fruits or vegetables might be spoiled or have a bruised or moldy area, that can still be salvaged by cutting off the affected portion before consuming the rest, (see Figure 5 - screen 1). At the end of the day the user gets a summary of its performance, detailing how much experience and coins were earned from each task , (see Figure 5 - screen 4).

As the game progresses the challenges will become bigger as well as the food waste reduction tips that Chef Eduardo will give. The game reward system takes into consideration several factors: 1) The user's performance in storing the food; 2) whether the recipes to be cooked were chosen based on the quantity needed 3) whether the player had into consideration using food near the expiration date and 4) the food savings from chopping. The mechanic for each point would be: 1) Organising the food in the correct position; 2) Choosing what to cook (recipe mechanic); 3) Slicing the moldy/bruised food in opposition to the fresh ones; 4) Using the sliced food for cooking a meal; the table 1, explains the education goals of these mechanics.

Table 1. Mechanics implemented in the game and their educational goal

Mechanic	Education goal
1)	Learning that food require certain temperatures to last longer.
2)	Make use of the food that is close to expiry first.
3)	Moldy/bruised food can be cleaned.
4)	Moldy/bruised food used for a cooked meal.

4.4 Preliminary Concept Evaluation

The low-fidelity prototype was used to evaluate the concept design of the game. This initial evaluation was conducted in an informal setting with a group of six children ages between nine and thirteen years. Our six participants (1 female and 5 males) were recruited through opportunistic sampling. Children were asked about their interest in participating, and their parents/guardians were contacted and informed of the study. At this point, the children and their parents were informed of the protocol and purpose of the research. Apart from the questionnaire and interview answers, no other personal data was collected and no pictures were taken.

The protocol assessment started with a debrief of the experience, filling out questionnaires, and finally, answering a semi-structured interview.

The interaction with the prototype included: 1) completing the tutorial; 2) playing the game; 3) using the character customization section of the game (purchasing some pants for the character and equipping them). Also, observational notes were taken while the participants interacted with the system. The questionnaire, using a Likert scale with a smiley-meter rating scale [54] asked questions to be rated from 1 (completely disagree) to 5 (completely agree), and were used to gather usability information. The participants were also asked if they liked the game mechanics and the use of gamification elements like coins, experience points, kitchen upgrades, tools, and customization of the character. Finally, the semi-structured interview with open-ended questions were: *What do you think was the final goal of the game? Would you rather be rewarded with coins, points, or both? What did you like the most in the game? Which activity within the game did you like most? What is your opinion about the main character? and finally, If you could change anything in the game, what would it be?*

4.4.1 Results from Preliminary Concept Evaluation

Initial feedback from the observation of the participant's interaction with the prototype showed that the initial part of the gameplay itself was clear and easy. Participants, aided by color cues, successfully organized the food items according to their appropriate positions within the refrigerator shelves. However, when it came to selecting other storage (e.g. selecting the freezer or pantry) the process became confusing, leading participants to revisit the tutorial for clarification. In the third part of the game, selecting the food from the storage to use in the meal preparation, only one participant did not realize they could select food that was going to be wasted. Most users liked the different mechanics of the game, except for one user who was indifferent in regard to character customization. There was one user who did not fully understand some game features, such as the upgrades and how to obtain experience.

The top three favourite features from the game were: 1 - Recover the food from being wasted; 2 - Select the food for the meal and add the food to cook (with the same amount of votes). Lastly, participants understood the different reward systems coins (collected at each task) vs experience

(after storing, preparing a meal, and giving it to the Chef to try). All participants except one understood everything correctly (see Table 2).

Table 2. Questionnaire results

Questions	Totally disagree	Disagree	Neither disagree /Agree	Agree	Totally Agree
The tutorial was clear and easy to follow	0	0	1	1	4
Was it hard to organise the food in the correct place?	3	1	1	1	0
I enjoy saving wasted food	0	0	0	1	5
I liked to slice the food for the meal	0	0	1	3	2
I enjoyed having to cook the meal	0	0	0	3	3
I liked the confection of the food plate	0	0	0	4	2
I enjoyed getting my plate assessed by chef Eduardo	0	0	0	2	4
I understood how the different upgrades work	0	1	0	3	2
I liked to customise chef Eduardo with the clothes purchased	0	0	1	1	4
I understood how to get coins	0	0	0	3	3
I understood how to win experience to level up the game	0	1	0	2	3

Additionally, users were asked about their opinion of Chef Eduardo (main character), and the answers were very similar, saying: "He was cool, funny, and cute". One participant said he was a useful character for guiding the user in the game. Also, the majority (4) of the participants agreed that the lion was appropriate, while (2) were hesitant. Finally, most participants (5) would like to be able to choose from a list of animals the appearance of the main characters. The results of the semi-structured interview showcased that all the participants appreciated the mechanics and aesthetics of the main character, which was perceived as being "cute." The majority (5) of the users enjoyed the current reward system (combination of coins and experience points), one preferred to have just coins as a reward. Only two users noticed that the game goal was awareness about "food waste". One user mentioned that it was about the customization of the Chef, and one mentioned that it was about becoming a "good Chef". Finally, regarding improvements to the game concept, most participants (5) answered to add more characters (to choose from and to customize).

4.4.2 Learnings and Changes for Next iteration

This game prototype has allowed preliminary testing with the target audience. While the study was evaluated with a small sample group, it was very valuable to gather feedback on usability, test game mechanics, and the educational content. Overall, the game seems to be fun for the users and a good strategy to introduce the topic of food waste to children. The use of a character to guide the user in activities was well received. The gamification elements like customization, experience points, and coins were rewarding for the users. In terms of the level and game mechanics, participants felt compelled to try the different tasks (storage, food cut, plating, etc.). However, we also identified several aspects of the prototype that need improvements, namely: the tutorial should be clear; improve the feedback on the food storage placement (by adding visual cues of where the food should be stored); add a button to facilitate the access character customization; increase the items customization offer and add more characters. Finally, we need to clearly convey the message of the game through the game narrative and mechanics, since only two users noticed that the theme of the game was food waste reduction. The feedback from this preliminary study was incorporated

into another prototype with Figma, paper prototypes, and some *Unreal Engine 5* levels for faster iterations and easier implementation of the needed improvements.

4.5 Second Prototype - Redesign and Paper Prototype

After analyzing the data collected from the testing performed in the first Figma prototype, a small redesign was performed to the game mechanics for them to be more engaging and fun. Additionally, there was a need for the game to use more 3D elements, as *Unreal Engine 5* truly excels in these experiences and would otherwise be a waste of the engine's potential. The 3D elements would also be more enticing for the users to interact with, than having a 2D element.

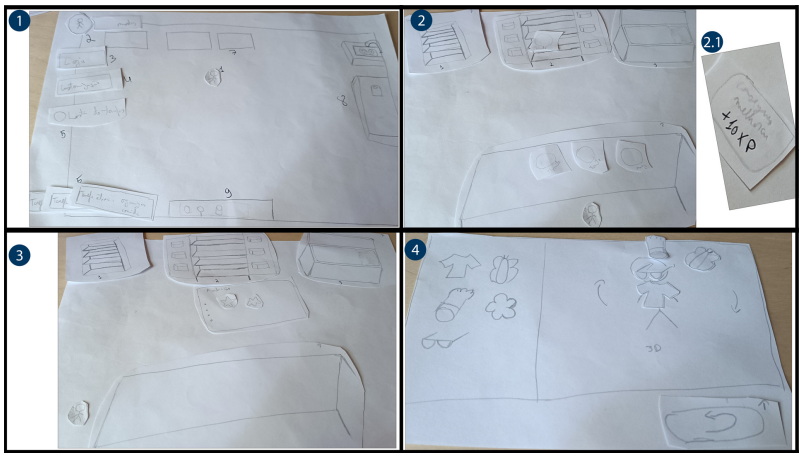

Fig. 6. Collection of scenarios from the paper prototype papers. 1 - Represents the main hub, the kitchen; 2 - Initial layout of the storing level; 2.1 Represents the feedback for a bad score in the game; 3 - End of storing level with an evaluation score, based on stars (2/5) and feedback text; 4 - Shows the initial concept for the character's customization.

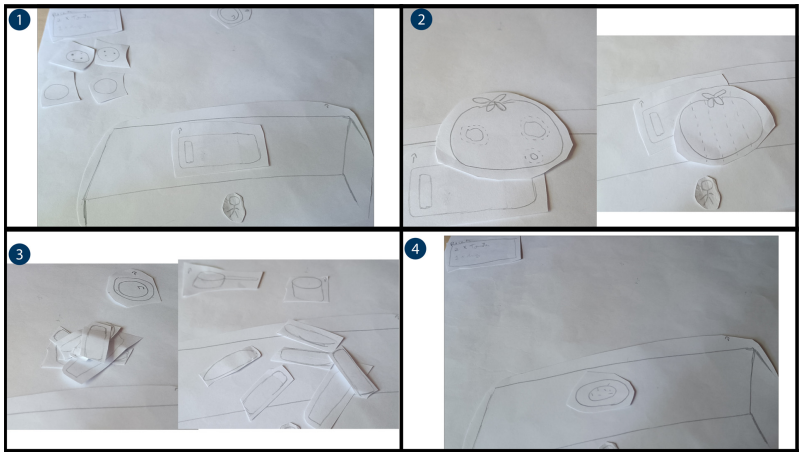

Fig. 7. More scenarios from the paper prototype papers. 1 - Represents the slicing level; 2 - On the left its the first step of taking off the bad parts of the food. On the right the slicing mechanic inside the game with the guidance of where to cut the food; 3 - On the right represents all the slices cut ready to be thrown into the pot. On the left represents the sliced pieces inside the pot; 4 - Shows the dish ready for evaluation.

Given these changes that were required on this new prototype, a new Figma prototype was designed with a simple screenshot from an *Unreal Engine 5* level. Using a new environment allowed us to get a better idea of how things would play out in the final game. Additionally, for a more minutious UI handling and features, a paper prototype was developed, as seen in Figure 6 and Figure 7, this also provided the opportunity to make changes immediately in certain game features. This process was very important for making fast decisions and quickly redesigning the prototype to meet the new needs described. We wanted the experience of storing the food to be more amusing to the user so, instead of having the user press on the location he wanted to store the food, six different mechanics to store the food were made. When choosing the mechanic some special attention was given to make sure the user was not handling the food in an irresponsible way that would go against our food waste concept. An example of this was when throwing food, which still needed to be stored even if in an incorrect way. This was important as leaving the food on the floor would transmit the wrong message to the users. We ultimately ended up mixing two mechanics for the storing mechanic (see Figure 8).

Fig. 8. Storing mechanic concept. - The food in the center represents the food we are currently trying to store, we press it at the moment we want to store it. The bar on the right fills up and clears, this is used to represent which zone of the fridge we are currently going to store. The color represents the different types of food.

This prototype was merely used to better envision how would things be deployed inside *Unreal Engine 5* and to lose less development time when building the first playable version of the game. Additionally, since the game was targeted at a younger audience a decision was made to exclude coins from the game and include only experience. The addition of coins would pose an ethical problem and the experience was enough to handle customization options.

Another decision that was needed with the change to 3D format was how would the camera layout be used inside the game. This decision was only made later when the development using

Unreal Engine 5 started and a better understanding of how the game would need to be built inside the engine.

This prototype made use of the same narrative and characters to handle its storytelling component of the game.

The other elements of the game followed the same narrative and ideas used in the first prototype. Figure 9 and 10, showcase some more elements of this new redesign.

Fig. 9. Screenshots from the redesign game prototype. (Left - Storing tutorial; Right - End of level).

Fig. 10. Screenshots from the redesign game prototype. (Left - Entering storing level; Right - Selecting food to store).

4.5.1 Game Narrative

A more robust narrative was built to help us find the reasoning behind each character's motif and relevance inside the game. Our story is built around an animal world, but when they reach a certain age they have a more human look, while keeping their animal status. In the *Funimal* city, the game's fictional city, the monkeys are seen as lesser Chefs. There is only one monkey Chef who is regarded as a prestige Chef, which is Chef Olivia, who most recently opened a restaurant named *Bananástico*, represented in Figure 11, with the intention of teaching Chef's her ways and better prepare them to deal with food waste related problems, since it is becoming a serious problem in their world. In the game, we follow Edu, a little monkey with great aspirations to follow the example of Chef Olivia and become another prestigious monkey Chef. When Edu was presented with this opportunity to learn with Chef Olivia, he enrolled and that is the timeline in which our game takes place, the start of his learning journey alongside Chef Olivia.

Fig. 11. Representation of the game's fictional restaurant *Bananástico* in game's video introduction.

The monkey was the animal chosen for our narrative, both for the apprentice and the responsible Chef, because of the fact that they are always seen as clumsy and known for throwing food everywhere. Being used to grabbing all types of food, from good-looking to more moldy food, they also have more knowledge on what to do with this food that would otherwise be wasted. This made the monkeys a perfect fit for our narrative, because if a character associated with this stigma can make good decisions in regards to food waste anyone can make a difference in fighting food waste problems.

Chef Olivia, the character on the right of Figure 12, has a human look because she has already reached the age where the animals have a human look. Edu, the character on the left of figure 12, is smaller and is still a monkey because he is still young, Edu is meant to represent our target age group users. Chef Olivia is the authoritative figure in the story, her age refers to a certain experience which is exactly what Edu is looking for as well as some guidance from someone who is very successful in reaching his dreams.

Fig. 12. Edu on the left and Chef Olivia on the right

4.5.2 Game Development

For the implementation of the game in *Unreal Engine 5*, there was the need to set the placement of the gameplay camera in a position that would be favourable to showcase our main character, but at the same time would not take away the focus from the learning activity.

A top-down view, with a third-person perspective, approach was used for the kitchen and customization level, this decision was made to ensure the user would be able to see his character when moving between levels, customizing it, and interacting with the world. Inside each level where the main focus is the activity such as storing or cutting food, we play in first person and we can only see the hands of our character, making changes to the environment which was the main focus. [55] Naftis et al mention how third-person perspective cameras are used for showcasing the character, its movement, and interactions with the world, whereas first-person perspective cameras have a bigger focus on what the player is holding and other hands interactions are in place.

The initial idea for the game was to have a common place to access the different levels, the kitchen, then have three different levels focused in different aspects of handling the food with good practices to increase their life cycle before consumption and give a new life to food that is starting to become not so desired to eat. As such the user would have to first play the storing level, where he would have the chance to learn where to store each type of food. Secondly, he would play the slicing level where he was given the chance to select between a fresh food and one that had moldy/rotten spots in it and then cut out those bad spots. To conclude the experience, the last level would introduce us to the plating of the food that we had used before for our recipe, and the user had to make sure to plate everything in time otherwise that food would be wasted. After these levels were completed the user would present the food to Chef Olivia and get an evaluation with the Chef's feedback. Additionally, the user would be able to access the customization level from within the kitchen at any time between levels to customize Edu.

As said before the use of the Figma prototype, provided us the opportunity to visualize the overall aesthetics and gameplay of the game while our intention was to transfer this knowledge into another game development platform, *Unreal Engine 5*.

The game was developed in *Unreal Engine 5* since it is a very powerful tool that is getting more attention and continuous updates that are making the engine more accessible and powerful for any type of development. Although most of the engine strengths come from the development of big games with a multitude of different and complex systems, it can also be useful for small projects since there are a lot of optimization tools to build a game that is compatible with a lot of different devices.

Character development and environmental 3D assets were created using *Autodesk Maya* and *Adobe Photoshop* (textures), for the more complex materials. Simpler assets were built inside *Unreal Engine 5* since they did not require much complexity.

We wanted to import our character models into the game and give them life, this was easy to achieve thanks to templates and animations already present within unreal engine, copying the same skeletal structure of *Unreal Engine's 5* character's animation, we were able to make use of the default unreal engine character and get all the animations working flawlessly. Chef Olivia's model was added normally with an idle animation since we did not need to make her move.

Unreal Engine 5 provided us with features to implement animations and attach assets to a character with a skeletal structure, and provided character movement and control, which was already implemented. Once we made the skeletal structure match we could transfer the character with *Unreal Engine's 5* retarget, our character could use all the animations from the unreal's mannequin. Additionally, we could add customization options to our character's body with *Unreal Engine's 5* leader pose, which allows us to attach clothes to our character, thus concluding the integration of customization options for our game. All these engine features helped us accelerate the development process.

Most of the UI assets were developed using *Adobe Illustrator*. The final version of the UI elements and their evolution are illustrated in Figure 13.

The first steps were having a UI with the essential details and designing the different levels for the game, adding very rough meshes that represented tables, a pantry, a fridge, a freezer, etc.

Fig. 13. Evolution of the joining storing level message. 1 - First ever implementation of the join storing level message, still using the Unreal's default mannequin; 2 - Later implementation of the message; 3- Current implementation of the message and UI;

4.5.3 Pilot Test Build

Since there was an ongoing learning process alongside the development of the game, there was the need to prioritize certain game elements to be iterated for the final version of the game. The intention was to use a pilot test to validate the game concept. Given these constraints, our priorities for the design of this version of the game were to have elements of customization and focus on the storing level. These topics were critical to teaching and introducing children to good storing principles and educating them about good principles of food waste. The complexity of these levels are a big representation of the final game, so they were very important to be used for validation of the concept.

Storing Level: In this level, the user has to select the food they pretend to store and then proceed to select the storage location. After selecting the food item an arrow moves up and down

within the location (fridge, pantry or freezer) that is currently selected. At this point, the user would have to click on the food in the center of the screen to perform the storing in the shelf that was currently pointed by the arrow. If the food is stored properly forty experience is added to the user and a good feedback message shows up. If however, the food item is not stored properly the user only gets ten experience, and a feedback message is displayed on the screen alerting the user towards the correct choice (Figure 14).

Fig. 14. Storing mechanic used in the pilot test build.

Customization Level allowed users to customize their characters with hats, jackets, and glasses with different colors or remove them from the character. However, in this version, the system did not save the character customization between levels. The character from this version was already equipped with glasses, a pink hat, and a pink jacket, allowing the player to play around with character customization. To unlock new customization options the user needed to get experience and level up. As mentioned before, we could not save the experience between levels thus the pink, blue, and white hats and jackets were already unlocked, leaving the other customization options locked. The UI provided the level required, displayed on top of the customization item as a reminder for the users to level up in order to unlock them.

Regarding the state of the other two levels, the **slicing level** was mostly complete and the **plating level** was still in the phase of concept, but a decision was made to leave it out of this version, as time restrictions will not allow us to evaluate these levels on time for this thesis.

This version of the game was tested in a school setting, which we elaborate on in more detail in the Game Evaluation Chapter.

4.6 Third Prototype - Final Game

After evaluating all the feedback from the users and looking at certain aspects that needed changing in the game, a reevaluation of priorities was done in order to get back on track for the final version of the game. Most of the aspects were already on our list of priorities for things to be added or changed, such as: adding a saving mechanism between levels and adding more levels, like the slicing level, which was almost finished. Other aspects of the game had to do with it being a more developed experience, this was something that would eventually happen since the game would have more features implemented.

The various UI elements for the game were redesigned to provide a cleaner look, making the game more appealing and intuitive. Also, we increased the number of animations in the game, with the food jumping in the storing level both in the basket and in the user's hands.

Additionally, a leveling system was implemented inside the game with certain levels as presented in Table 3.

Table 3. Table with the title attributed to each level inside the game.

Level	Title
1	Principiante
2	Aprendiz
3	Amador
4	Mini Chef
5	Chef de tachos
6	Chef de menu
7	Chef de mesa
8	Chef de sala
9	Chef de cozinha
10	Master chef

Fig. 15. Montage with various iterations of the main level design. 1 - First introduction of dialogue inside the game, levels positions and meshes laid out; 2 - Second iteration with more finalised visual; 3 - Current implementation of the level layout and decoration;

4.6.1 Level Design

Main Level - Kitchen

The kitchen level was the place where the user would be able to see his character customization, as such it was designed in a top-down view. This level is where other levels can be accessed, so carpets with the levels names were added, many furniture was added in the last stages of the game to give some life to the restaurant's kitchen. The evolution of this level is depicted in Figure 15.

Storing Level

Varying components were added to the storing level. Food has an expiry date that goes from four to zero days (see Figure 16), each day the food's expiry date decreases by one, food that is stored correctly has four days of expiry date, whereas food that is stored incorrectly has two days. Only certain foods are used for the recipes and saved. When the food reaches zero it is simply removed from the original storing location, there is no feedback given back to the player. The shelves show their name upon selecting the area in which we want to store the food, an example of the pantry is represented in left image in Figure 16. The game uses the same game loop, as seen in Figure 3, to follow the game's steps, each day the user joins the storing level counts as a new day. The evolution and different iterations of the storing level can be seen in Figure 17.

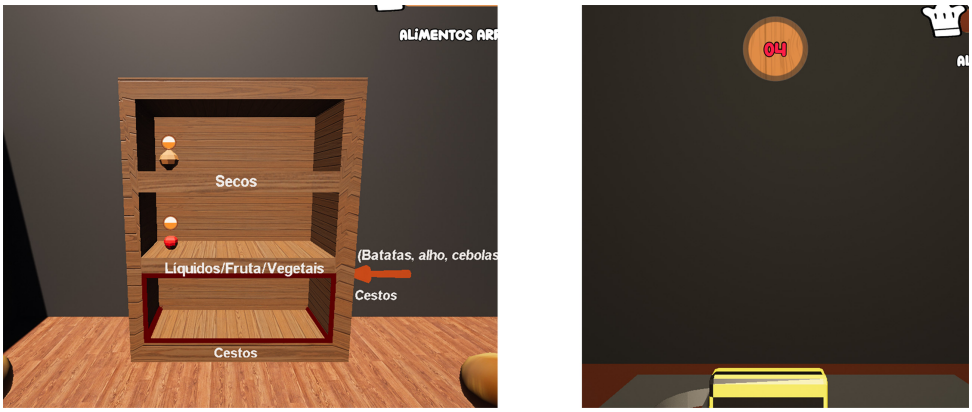

Fig. 16. Figure with the various details present in the game. - On the left the details from the storing level: Food expiry date representation, names on the shelves and in the arrow; On the right details from the slicing level: Timer to slice the food.

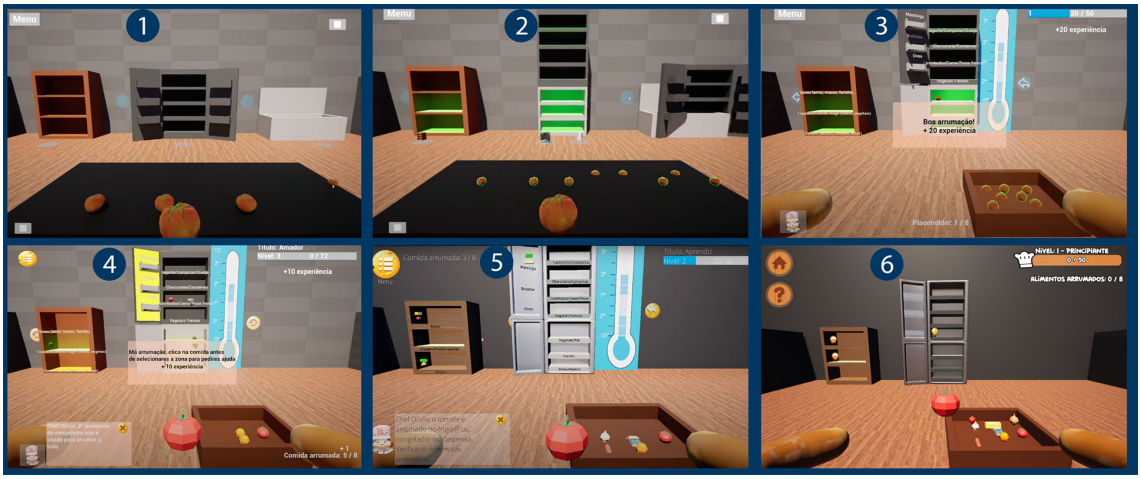

Fig. 17. Montage with various iterations of the storing level. 1 - First implementation of the storing level with non dynamic food spawned; 2 - Iteration with food retrieving the parameters; 3 - Implementation of the score system; 4 - Implementation of dynamic food spawning, final meshes and good/bad zone highlights; 5 - Implementation of the food expiry date; 6 - Most recent state of the level;

Slicing level

After having the customization and character movement, we started looking at implementing the storing and slicing mechanic. It was suggested to use procedural mesh to perform the slicing mechanic inside the slicing level, as such this was implemented inside the game following a tutorial, but since *Unreal Engine 5* was still something new and many things were unknown we could not make it work properly. So the focus was solely in implementing the storing level as the first level of the game. This process started with modeling how our dynamic systems would be implemented, as shown in the High-Level Game Logic Diagrams chapter, and implementing the base of the mechanic inside the game with the selection of the food, storing zone, and the storing mechanic. When the components from this level were complete and all working in a dynamic manner, it was very easy to copy this template to build new levels. The template consisted of the following important elements: a level manager to handle all these dynamic events, a pawn, and components saving the user's decision inside the level, varying data tables and data assets, serving as databases for our game on how were things structured.

During the implementation of the storing level a lot was learned, with these lessons came the understanding of certain elements such as game mode and player controller, this was the reason why the implementation of the slicing mechanic was not working properly. Having the slicing mechanic working as intended and having finished the storing level finished, made the process of creating the whole slicing level in a dynamic manner simple and did not consume as much time as the first time implementing these types of structures. The slicing meshes produced with the procedural mesh did not offer a way to move them separately, as such we were constrained to use only food from the pack that had slices present in them, making the selection of food to be used a bit more limited.

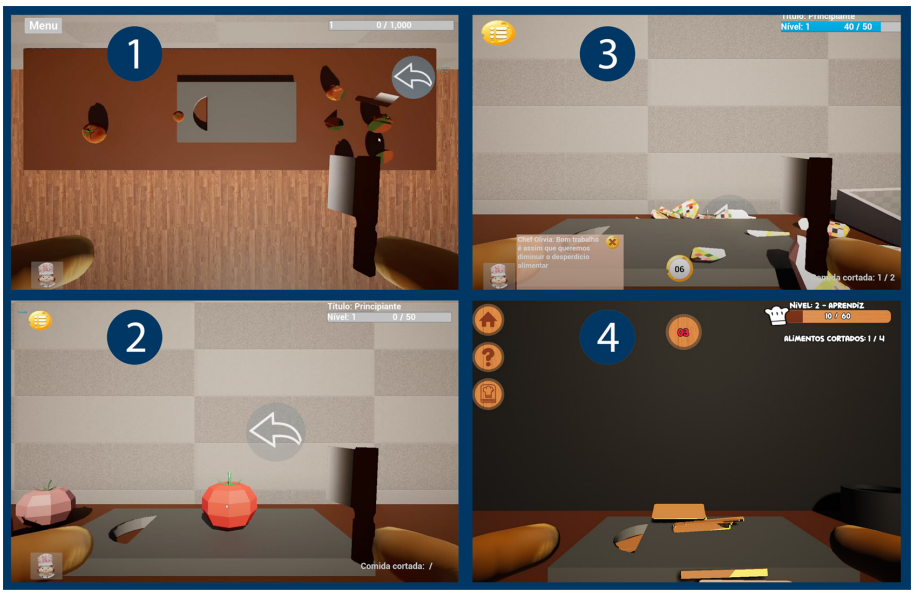

Fig. 18. Montage with various iterations of the slicing level. 1 - First ever implementation of the slicing mechanic; 2 - Implementation of slicing our desired food mesh, with the choice between good and bad food; 3 - Implementation of a timer for slicing; 4 - Current state of the slicing mechanic;

The slicing level and parts of the cooking level were grouped, so the player starts with choosing the cooking tool for the recipe, after that, he gets to select between a good-looking and a bad-

looking food, and then a ten second timer starts where they can cut it however way they desire, timer in the right image from Figure 16. Following the cutting process users get three sliced pieces that are good and three that are bad, each good part they select gives them an extra ten experience, however, if they have one or more bad parts the bonus score is halved. These parts are removed from the table and placed in the cooking tool we selected. To finish the selection of the parts for the recipe a check button is present in the game's wall, the selection of food, cutting, and selection of parts steps are repeated until all the food of the recipe has been done. The evolution of the slicing level can be seen in Figure 18.

Starting with finishing the slicing level, added a more coherent integration between levels, and we added the option to have a recipe selection between the end of a storing day and the start of the slicing level. The plating level was opted out as it was the level that offered the least of teachings in regards to food waste and was almost just merely a continuation of what were the steps to a Chef's abilities inside a restaurant. Lastly, we offer a final evaluation of all the tasks completed in the game and the game starts over. This build also included the saving of experience after completing the levels, customization options would be saved after leaving the level. The UI was refined to match the game's theme and visual aspect, new recipes, and food meshes were also added to the game, and a refinement to the mechanics already present in the game were also added, such as the addition of swiping to store the food, the color of the shelf selected changed and the correct ones would have a green outline instead of the red, the bad food has spots with a darker color of the main color and the same applies to the good and bad slices included in the game.

Figure 19 showcases the levels of the storing level on the left and the slicing level on the right in the current version of the game.

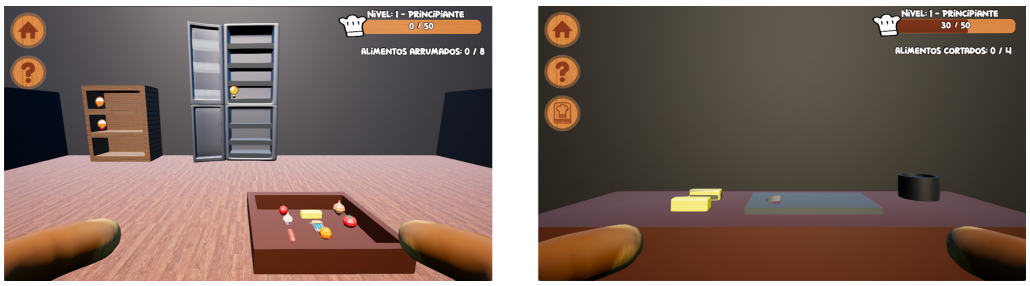

Fig. 19. Current version of the storing level (on the left). Current version of the slicing level (on the right).

Customization

The customization options were very limited initially having only 3 colors of hats and jackets, as well as the glasses, but none of these had level requirements inside the game. Making use of the experience handling the structures from the other levels, a customization manager was implemented alongside a table with every single aspect that was needed for each customization piece. This also made it possible to include a dynamic level-up widget, that would change based on what was unlocked by reaching that certain level, this can be seen in Figure 20.

After the pilot test, our focus was on implementing and fixing the problems that were more re-occurring with users. Thus came the implementation of saving experience, level, and customization options between levels with the use of *Unreal Engine's 5* game instance, Figure 21. This change

Fig. 20. Showcasing the level up message displayed with the items unlocked in that respective level.

Fig. 21. Showcasing the user having leveled up in the storing level and accessed the customization level with the experience acquired.

also allowed us to have different days for storing and slicing levels and further develop the game loop. Up until this point, the food meshes used came from a demo pack, it was during this phase that the new and final food meshes were added to the game. The various iterative steps performed during the development cycle can be seen in Figure 22.

4.6.2 Tweaks and Changes

Some tweaks were added to give more life to the levels, along the development process. Switch actors were added to change certain meshes if the storing or slicing levels were completed, Figure 23. Eventually, some rough idea of the cooking level was idealized, but these were later scrapped and the selection of a cooking tool (plate, cooking pan, or pot), as well as adding water to the cooking, was integrated into the start of the slicing level.

Another feature that only came at this later stage of the development was the implementation of an expiry date for the food on the storing level. This feature came with a lot of issues with the visual representation of the current expiry date. The choice of the recipe option was decided to be a more memorable and physical interaction with the Chef, as such the user would only be able to join the slicing level after having a recipe selected, seen in Figure 24. Only certain foods were suitable for the recipe, due to the recipe constraints explained in the design chapter, as such a boolean was used to tag which foods were valid for the recipe. To complement this saving of food stored in its expiry date, the spawning of food from the previous day was also added to the game, decreasing the expiry date by one for all the food stored from the previous day. A book was added to the choice of the recipe, alongside the meshes of the main food we were choosing to use for the recipe and a UI explaining the details of the recipe. The user could interact with either the UI element or the mesh in the table.

Fig. 22. Montage with various iterations of the customization mechanic. 1 - First implementation of the customization options; 2 - Improvements, added level requirement, and visual representation in the options; 3 - More options and better representation for level required and locked options; 4 - Current state of the customization, with more options added;

Fig. 23. Image showcasing the switch actors from the kitchen level, the storing level was completed, thus having the shelves full, and the slicing level was not completed yet.

This phase was also used to give it a more cohesive and finalized look to our UI, as such every widget suffered some type of change. The font of the game's text was changed, positions, sizes of the experience bar, dialogues, change levels, and pause menus were changed, the end of the day was changed, and the main menu splash screen alongside the apk's icon and loading image, Figure 25.

Other tweaks implemented were in regard to a more intuitive and clearer display of certain information to the user. The storing level mechanic changed from clicking on the food to swiping anywhere on the screen and animations were added to both food in the player's hands and waiting to be stored in the basket. The customization level was integrated in the main kitchen level, alongside its shelves, customization options, and customization manager.

The final evaluation was implemented, and the main loop of the game was finalized with this step, with a reset to the tasks and a start to a new day inside the game. An easter egg was added to the kitchen, and the kitchen was filled with various components to give it more life, such as a little

Fig. 24. Montage with various iterations of the recipe book and recipe selection. 1 - First implementation of the recipe selection mechanic; 2 - Second implementation with the desired visuals; 3 - Addition of the book mesh; 4 - Current state of the mechanic with the updated text and sizes;

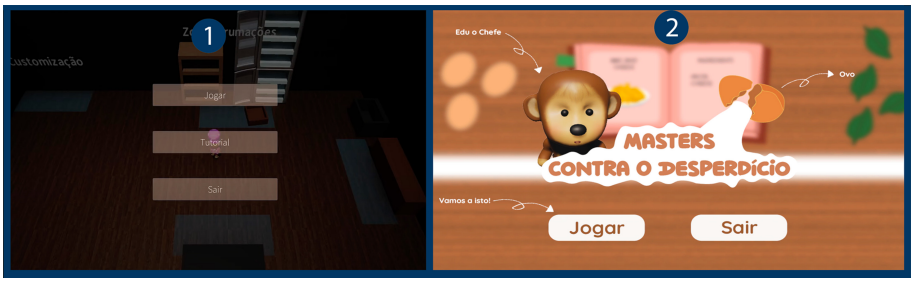

Fig. 25. Montage with various iterations of the slicing level. 1 - First ever image used for the main menu, used in the pilot test build; 2 - Current main menu image;

garden with floors, a table with food, and tables with plates and chairs to showcase that the level took place in a restaurant. Additionally, some floors, walls, and carpets were added or changed, the carpets were used to inform the user which area they were entering inside the kitchen. Lastly, a video introducing the player to our world and story was added to the game and trophies were added as an additional last-minute reward for finishing a day or completing each component of the game with five stars.

The kitchen is used as a transaction location between the storing and slicing levels, the user needs to go with the Chef on the left side of the kitchen to decide which recipe from her book, which was placed in the table in front of the Chef, is the correct option to not leave any food wasted. The selection of the recipe would display on the screen two recipes, one on the left and one on the right, with the recipe name, food of the recipe, and number of days, the user could press on the UI or in the food that was present on the table to make the decision.

After this step, the user would be prompted to enter the slicing level to prepare the recipe chosen. Upon finishing the slicing level the user would find himself back in the kitchen, having to go with the Chef again on the left side of the kitchen, this time to get the final evaluation of the day's performance. The final evaluation would have a score based on the other three actions, from storing level, recipe choice, and slicing level, the message would show each action score alongside a short feedback text.

4.6.3 Game Elements Summary

The game includes 29 food meshes, and also includes some of this food as slices, thus having an extra 12 slices has different-looking food meshes inside the game, making the total of different food meshes inside the game 41.

The game includes 20 customization options, 10 are jackets, 9 are hats and one is a pair of glasses, these options are illustrated in Figure 26 of how they look inside the game. The customization options have a level requirement to be unlocked, Figure 27 showcases three level six clothes unlocked, hence they are properly visible and the level is fully opaque, and four clothes locked which require levels nine and ten to be unlocked, so they are barely visible and the level required is not fully opaque.

Fig. 26. All the customization options available in the game.

Fig. 27. Customization representation of locked and unlocked options with the level required on top. The clothes on the left are unlocked, the clothes on the right are locked.

The game includes nine different recipes, shown in Figure 4, seven out of the nine recipes were from Pingo Doce's book [25], and the tomato sauce was a simple recipe so it was included, and the banana cake recipe was chosen since it is a local recipe. These recipes were chosen with the food that was present in the game, the recipes include only the most important ingredients for the recipe.

The food inside the game was chosen to match the lower polygons and simple geometry present inside the game, as such a food pack was used. This decision saved us time and resources in

Table 4. Table with all the recipes and ingredients present in the game.

Food					
Recipe	Tomato Sauce	3 x Tomatoes	1 x Garlic	1 x Onion	
	Apple Puree	3 x Apple	1 x Butter		
	Orange Jam	3 x Orange			
	Mashed Potatoes	3 x Potatoes	1 x Butter		
	Peach Jam	3 x Peaches			
	Banana Cake	3 x Banana	1 x Butter		
	Bread Flan with Apple	2 x Bread	2 x Apple		
	Bread Pie with Fish	2 x Bread	1 x Tomato	1 x Onion	1 x Tuna
	Fish Balls	2 x Salmon	1 x Bread		

choosing which food would be present inside the game and with the overall design decisions that would be necessary for building these from scratch. However the pack offered only a select set of food models, thus some of the decisions with what recipes were going to be used in the game and what ingredients were present. Additionally, for the slice level, there was the need to use slice meshes, this is explained in a more detailed manner in the Models chapter, inside the slicing level, and the pack included only a small sample of these, as such these were also taken into consideration when choosing which food were part of recipes.

For the slicing level, there was the need to have food with bad spots, these bad spots were created inside *Unreal Engine 5* with the use of its modeling tools. Inside the engine we were able to select certain polygons and add an extra texture that had the look of a moldy spot in the food, these are shown in Figure 28.

Fig. 28. All the food used inside slicing level with bad spots in them.

The game includes ten different levels, in order to get a bigger sense of progression and owning their skills inside the game, titles were attributed to each level. The game level titles are the ones present in Table 3.

In summary, the game includes three different activity levels, two being first person, the storing and slicing level, and one, the kitchen, being third person with a top-down perspective. The storing

level included food to be stored in three different locations (pantry, fridge, and freezer), with different shelves, stored food would have an expiry date, represented with a circle and certain food would be left in the same location if it was a recipe option. The slicing level included a section for choosing the tool to cook, then the recipe would ask to choose between two of the same food, slice it, and choose which slices would go in the cooking tool, this process would repeat until all the food of the recipe was sliced. Upon completing the storing and slicing level, the player would go back to the kitchen level, and select the recipe or get the plate evaluation, respectively. The kitchen level also allows the player to customize the character, see the trophies earned, and change to the storing and slicing level. The player's actions give them experience to level up, subsequently unlocking new customization options. At the end of the storing, slicing level, and upon completing the day, players have a score from 1 to 5 based on their performance inside the level. The player moves the character inside the kitchen level by placing their finger in the place they want them to move.

5 Game Development

This section showcases how the system was implemented and what decisions were taken to reach its current state. The following sections are filled with requirements that explain our design decisions, models that represent how certain systems function, using flowcharts, and how these systems interact with each other. An introduction to how *Unreal Engine's 5* blueprints function is also present in this section, alongside an explanation of the most important blueprints in the game. To finish an additional section lists the final game's target platform and its system requirements are listed.

5.1 Functional and Non-Functional Requirements

A list of requirements was created to guide us with the development of the game, but also to ensure everything that was added to the game would add something meaningful to the goal of the game. The requirements list ordered from highest priorities to lowest priorities was the following:

Functional Requirements:

Educational Gameplay:
FR01 - Include interactive and educational elements to inform players about the impact of food waste;
FR02 - Provide tips and suggestions that translate into reducing food waste in real life;

Game Levels and Progression:
FR03 - Allow players to unlock new levels as they progress and achieve specific goals related to food waste reduction;
FR04 - Design multiple levels that escalate in complexity;

Challenges and Missions:
FR05 - Introduce challenges and missions within the game that encourage players to apply real-world solutions to reduce food waste;

Kitchen Management:
FR06 - Implement a virtual kitchen environment where players can manage their virtual food inventory;
FR07 - Include features such as, meal planning, and proper storage to teach responsible food management;

Feedback Mechanism:
FR08 - Provide feedback on player performance, offering suggestions for improvement;
FR09 - Include in-game notifications or tips to guide players toward better food waste reduction practices;
FR10 - Provide a tutorial or introduction explaining each level;

Narrative:
FR11 - Offer a narrative with a playable character;

FR12 - Allow players to customize their character;

Non-Functional Requirements:
Performance:
NFR01 - Ensure the game runs smoothly on various devices and platforms;
NFR02 - Optimize loading times and minimize lag for a seamless gaming experience;

User Interface:
NFR03 - User interface should be clean and compatible with mobile screen;
NFR04 - Use a color scheme that is visually appealing to a younger audience;

User Experience:
NFR05 - Represent day to day activities performed in the household context;

Development and Distribution:
NFR06 - Ensure the game is easily distributed in school visits;
NFR07 - The game must be developed in *Unreal Engine's* most recent version;
NFR08 - Support as many mobile platforms as possible, including tablets and smartphones;

Design:
NFR09 - Use a stylized lower polygons look with easy to recognize meshes.

5.2 High-Level Game Logic Diagrams

To have a better level of understanding of how each level would change with the user input and the world. Given this necessity flowcharts were built, and changed when needed, to represent how each level would evolve with the user's input. The core game loop is represented in Figure 29, it represents how the game evolves with the user's interactions.

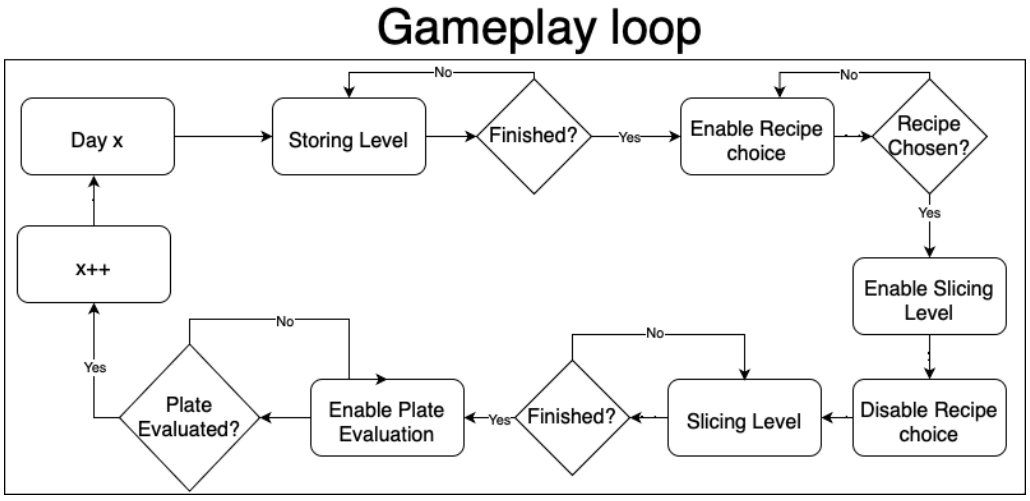

Fig. 29. Gameplay loop of the various components in the game.

5.2.1 Kitchen Level Diagram

The first flowchart, represented in Figure 30, is the kitchen level one. This level is the intermediary level between each of the day's activities, it is responsible for introducing the user to how the game functions within a top-down third person perspective. The level also includes the customization options in a small room, a final evaluation room with Chef Olivia, and a table that will have a book in it, if we have finished the storing level and need to select the recipe, or a plate, if we have finished the slicing level and will receive the final day evaluation to finish the day. Additionally, the level includes two classes responsible for changing the game level to storing and slicing levels, respectively.

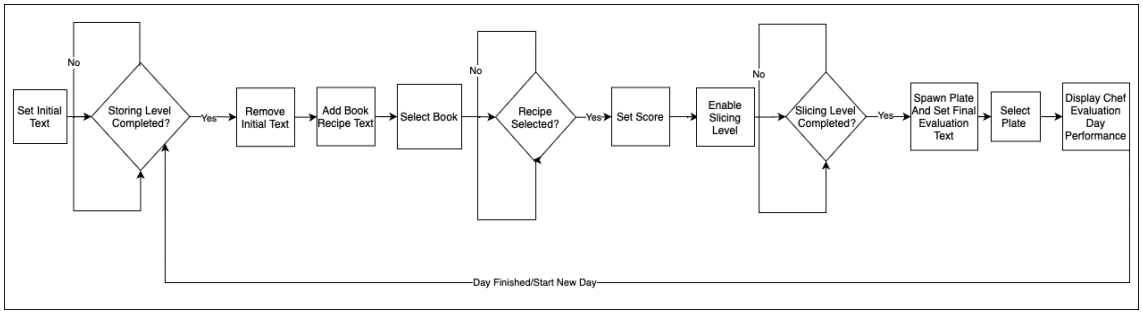

Fig. 30. Kitchen level flowchart. - Representing how the kitchen level functions.

5.2.2 Storing Level Diagram

The storing level flowchart is represented in Figure 31, it demonstrates how the storing level changes and is currently looking if all the food has already been stored. The user must first select the food from the basket, then proceed to select the storing zone (pantry, fridge, or freezer) and lastly, the user must wait until the arrow reaches their desired storing zone, when that happens he must swipe anywhere on the screen. Each time the user stores correctly they are rewarded 30 experience, for a wrong store they are given 10 experience and a feedback message from the Chef. Once the user has stored all the food from the level he will get a score with starts from zero to five depending on his performance, along with couple of feedback messages with mistakes performed in the level, if the user scores five stars he will only get an excellent work message and a bonus 60 experience.

5.2.3 Slicing Level Diagram

Lastly, the slicing level flowchart is represented in Figure 32, in this level the user has to follow the instructions present in the recipe button shown under the dialogue button. The first step starts with selecting the cooking tool, which can be a plate, cooking pan or, pot, the right selection would award the user with 30 experience, whereas the wrong selection with 10 experience. If the selected tool is the pan or the pot, the user has to fill it with water, in the case of the plate this step is not included. After these steps the user starts the slicing food loop, he is presented with the same food but one has a bad look with black spots and the other one is just a normal version of the same food, making a good decision rewards him with 30 experience, that is choosing the food that has a bad look, the other choice gives him 10 experience and a bad feedback message. Following this step, a timer starts giving the user ten seconds to slice the food in any way he wants, this happens

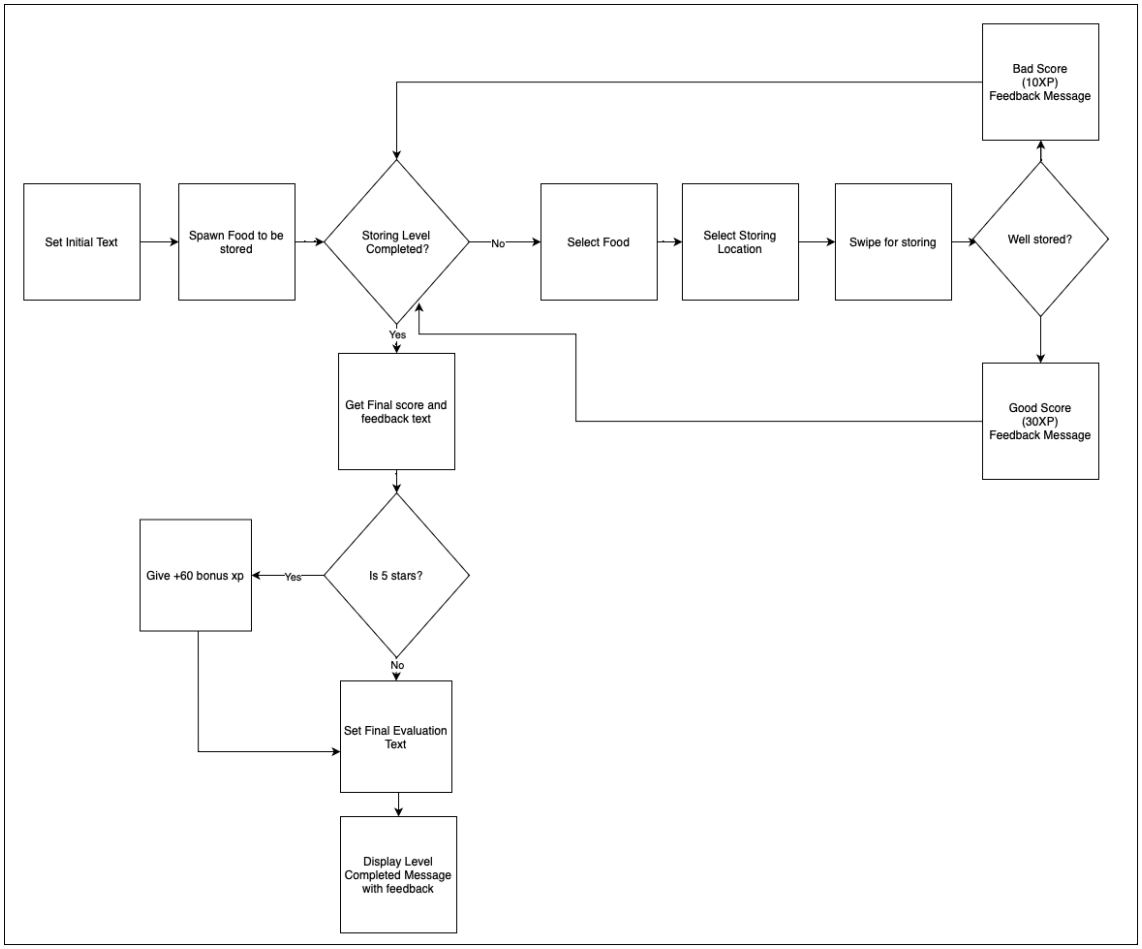

Fig. 31. Storing level flowchart. - Representing how the storing level functions and changes with user's interactions.

no matter what type of food was chosen and is simply for fun. When the ten seconds end six slices of that food are spawned in the table, three of which are good and the other three are bad, additionally a confirm button is added to the wall, and pressing any of the slices drops it into the cooking tool, when the user is finished he needs to press on the confirm button and the slice loop repeats until all the food is sliced. Each good slice the user selects gives him an extra 10 experience per slice, if however he has selected one or more bad slices his bonus from any good slices is halved. When all the food has been sliced the user is given a score from zero to five and feedback messages. The feedback message always includes a message about the slices that are present in the tool, the bad slices are counted and mentioned in the message, if there are no bad slices the message simply says there are no bad slices. The feedback message can also have the wrong tool selected, or bad food selected in the feedback messages. Just like in the storing level, if the user scores five stars he will get an excellent work message and a bonus 60 experience.

5.2.4 Models

When organizing the various components used to build the various game modes, levels, and interactions, models were used to describe how things are connected and what elements are present in the classes and other components built for the game.

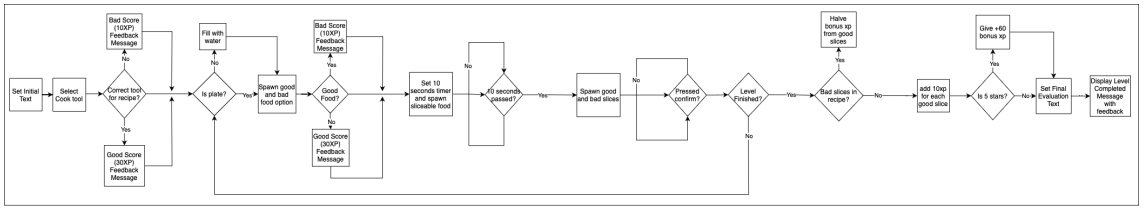

Fig. 32. Slicing Level Flowchart.- Representing how the slicing level functions and changes with user's interactions.

The game modes present in the game are shown in Figure 33, these game modes are important to set the different values of the different game pawns or characters, player controllers, and other components that need to be changed for a different set of interactions from the user.

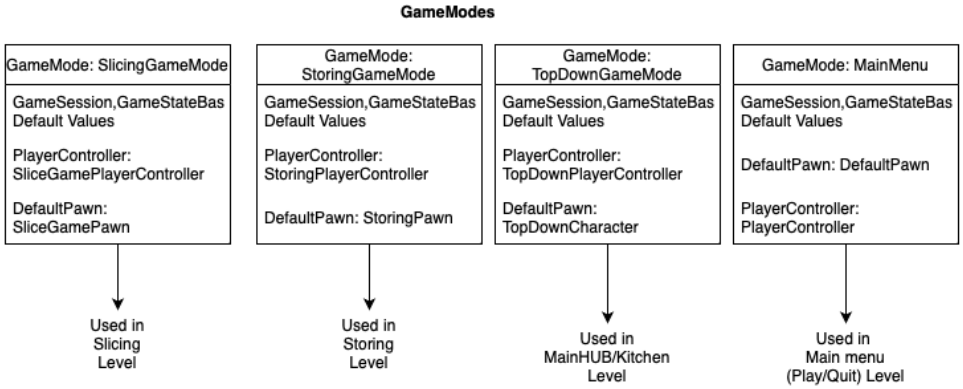

Fig. 33. Game modes used in the game.

In the kitchen level, called $TopDownGameMode$ in the game modes figure, there are two managers, the first manager $MainHUB_Manager$ is responsible for handling the switch actors inside the level, changing the dialogue of presented and spawn the class $RecipeBook$ or $EvaluationPlate$, depending on the state of the world. Switch actors are actors inside the game that can have an array of multiple states, this is useful for having a mesh that can be swapped for another mesh. In our game this is used for the pantry, fridge, and freezer and a small basket in the level, at the start of the game the basket is filled with food and the other locations are empty, when the storing level is completed the basket is empty and the shelves are filled with food. The same is used for the cutting table entrance, it starts with various foods to be sliced and upon completing the level the food appears sliced. As presented in the kitchen flowchart in figure 30, the $RecipeBook$ spawns upon completing the storing level and the $EvaluationPlate$ after completing the slicing level. Additionally, this level includes the character's customization, which is handled by the other manager $Customization_Manager$ responsible for handling the customization options which are locked or unlocked. The $GameInstance$ is present in the game for every level, the $GameInstance$ is responsible for saving certain values between levels, and the only variables saved for the customization are the variables MFace, MHat, and MJacket. The diagram presented in Figure 34 represents how each class interacts with each other inside the level.

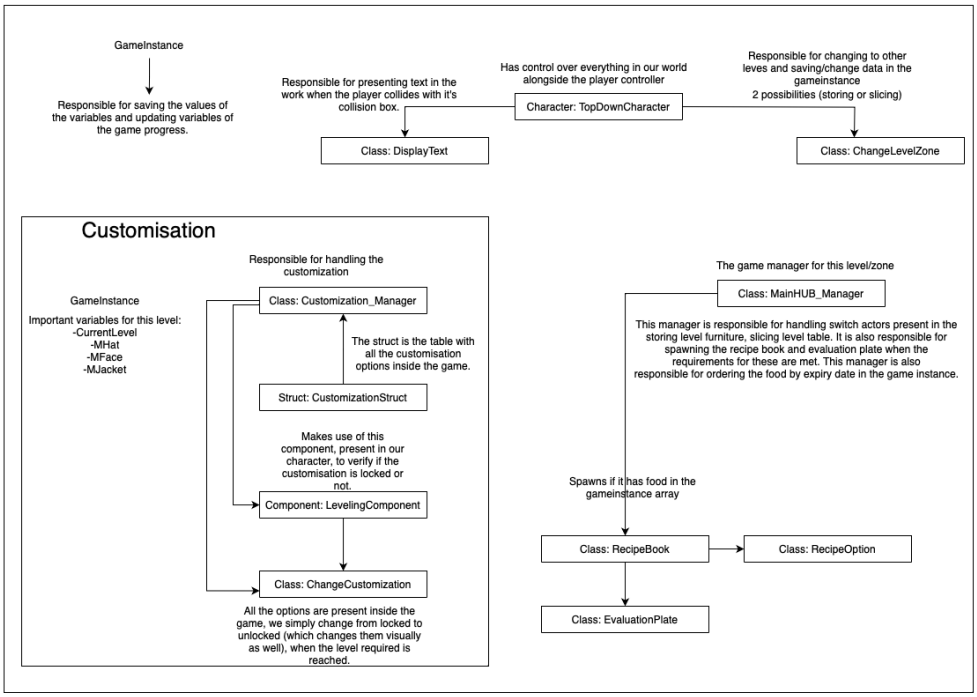

Fig. 34. Kitchen level diagram. - Demonstrates how the level makes use of the classes.

In the storing level, there is a manager, *StoringManager*, which is responsible for checking the current status of the world and updating some parameters. Since this was the first level, a lot of the core loop of the interactions was built inside the game's storing pawn, as the manager only came out at a later phase of the development of the level. The classes *SelectFood* and *StoredFood* make use of the data from the *FoodDataAsset*, the pawn has many variables because it is responsible for a lot of actions that the manager would handle.

As such the manager is not responsible for every component of the level loop, represented in Figure 35, like the other levels. For implementing the food inside the game to be stored and stored on the shelves, a data asset was built, *FoodDataAsset*. A data asset inside unreal designates a structure for which we can create multiple children that always use the same variables. The *StoringComponent* is responsible for saving the user's progress such as score and error text for the errors committed. The structures *StoringDay* and *StoringStruct* are used by the manager, respectively, for handling the food to be spawned for that day, and for evaluating if the shelf that the food was stored is correct or not. The *SelectArea* class is used for the user to select the designated area that they want to store, the *StoringZone* class represents each shelf and lastly the *StoringArrow* is spawned whenever we select the area we want to store, it moves up and down, the *StoringZone* it is overlapping is the one that is currently selected.

The slicing level was initially used only for slicing, having only the *SlicingManager*, but since there was the need to blend the cooking level with the slicing level, there was the need to include some functions that were already implemented in the cooking level. Given these needs the cooking manager, *CookingManager*, was added to the level, having the responsibility for the cooking components of the level, whereas the slicing manager handles the slicing loop of the game, which is the majority of the level. The recipe is present in the *GameInstance* and comes from the *RecipeDataAsset*. This time the manager is responsible for dealing with the core game loop,

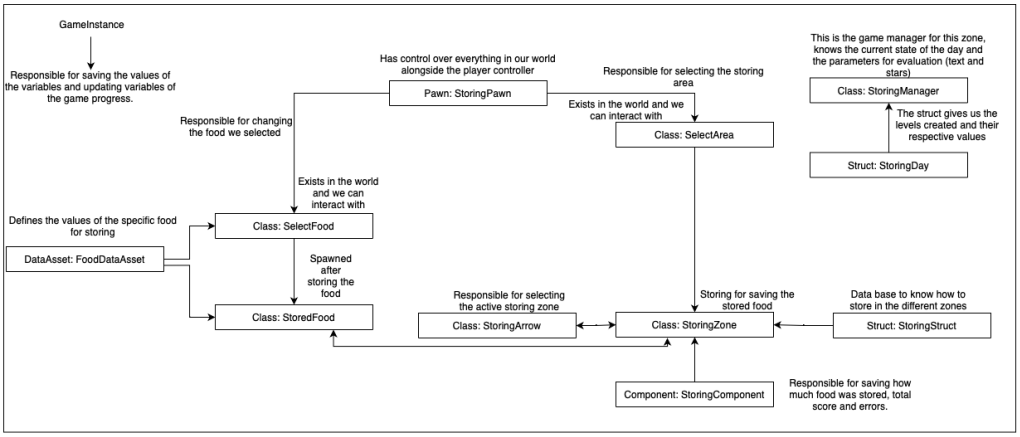

Fig. 35. Storing level diagram - Demonstrates how the level makes use of it's classes.

present in Figure 32, for this level, contrary to every other level, the controller assumes an important role, it is within the controller that the slicing mechanic was built. The class $NewProcComp$ is our procedural mesh, which we can slice, the classes $SlicedFood$ and $SelectSlicedFood$ are responsible for, respectively, selecting the food to be sliced, getting the information from $SliceFoodDataAsset$ structure, thus spawning an actor from $NewProcComp$, upon finishing the timer spawn slices from the class $SelectSlicedFood$, which takes the necessary information from $SlicedFoodToSpawn$ structure.

The cooking manager is responsible for starting the level with the $SelectCookTool$ class, the slicing manager can only start handling the level after the variable in our level pawn, $SliceGamePawn$, $CurrentStep$ reaches the value of two. The slicing manager uses the variable from the game instance, to find the recipe in the $SlicingDay$ structure list, spawning the $SlicedFood$. When presented with the selection of the slices of the food to be placed inside the cooking tool, the user needs to press the confirm button shown on the wall, which is an actor from the class $SelectAreaSlicing$. Similarly to the storing level, the $SlicingComponent$ is responsible for the scores and errors texts, but this one includes if there is any bad food inside the cooking tool, if so how many, if the cooking tool selected was the correct one and lastly if there was at least one bad choice of food to be sliced. The diagram representing how these classes interact with each other is present in Figure 36

Additionally, inside *Unreal Engine 5*, the UI components are built with an actor class named *widgets*, and all the widgets and their respective variables are presented in Figure 37. $CommonUI$ is the most important widget as it is the one that is present in every level from dialogue to buttons.

Some widgets have a long list of variables, such as the $CommonUI$, $LevelCompleted$, $LevelUp$, $DayCompleted$ and $AddScore$ because they are built with a lot of visual elements, the variables that do not have a public or private tag are visual elements in the UI.

Other classes were used, but the ones presented in this section are the most important ones for our level's core functions.

5.3 Unreal Game Engine

Unreal Engine 5 is an engine developed by *Epic Games*, the first iteration of this engine was private and came out in 1998. The engine is always being updated, but each major release changes the main version number, thus beginning a new era. In *Unreal Engine 4* the engine started to be open

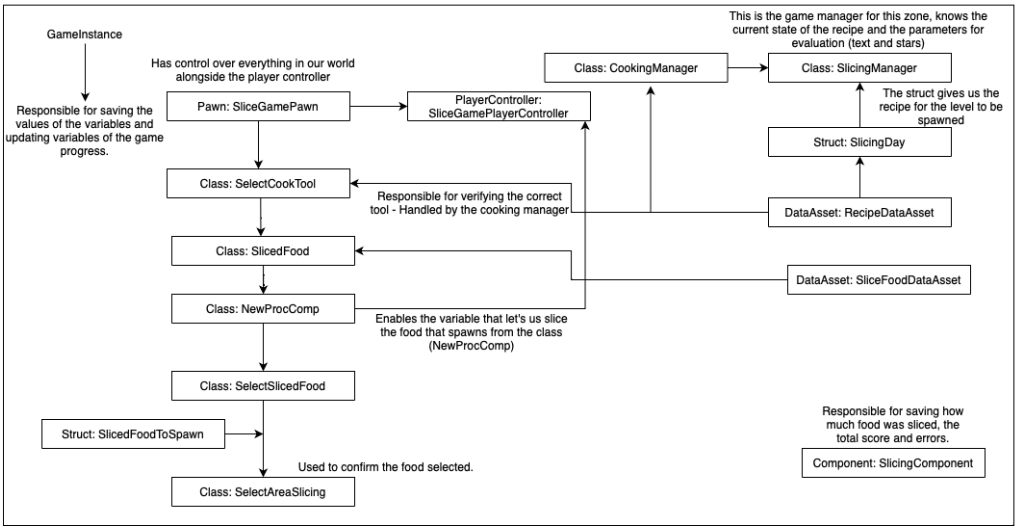

Fig. 36. Slicing level diagram - Demonstrates how the level makes use of it's classes.

to anyone to use, at the start of this project the first version of *Unreal Engine 5* was released. At the start of the development of the game, the most recent stable version of the engine was version 5.1.1, this was the version that we opted to use since only towards the end of the development of the game engine version 5.2 released, but version 5.1 was updated with small fixes. This version was chosen because it was the most recent, offered many new technologies that were intriguing for the game development area, and supported some of our mobile platforms.

As previously stated the game was developed with *Unreal Engine 5*, the engine allows us to follow a visual script paradigm or a programming-centric paradigm, but it is within a balance between these two paradigms that this engine truly excels. Given the scope of this project and the steep learning curve to learn *Unreal Engine* with both, a focus was given to visual scripting, known as blueprints, since these are more manageable within the time of the project and when understood properly make the transaction to $C++$ much easier.

5.4 Implementation using Blueprints

5.4.1 Introduction to Blueprints

Blueprints are a visual representation of the engine's functions and classes, it uses the same object-oriented principles approach as some programming languages. This system is visual and requires the user to connect nodes to create their gameplay [56]. Blueprints make use of the same $C++$ classes implemented in the engine, however, these do not run natively, but instead, run in a visual environment decreasing the game's performance, but for a small-scale game the development time decreases the trade-off is justified. An example of the class *SelectSliceFood* is shown in Figure 38, the white lines represent the execution line that the class will take for each type of input. In this case $EventBeginPlay$ will execute when the class is part of the game's world, and $OnInputTouchBegin(StaticMesh)$ will execute when the user starts touching in the mesh associated with this class, which would be a food.

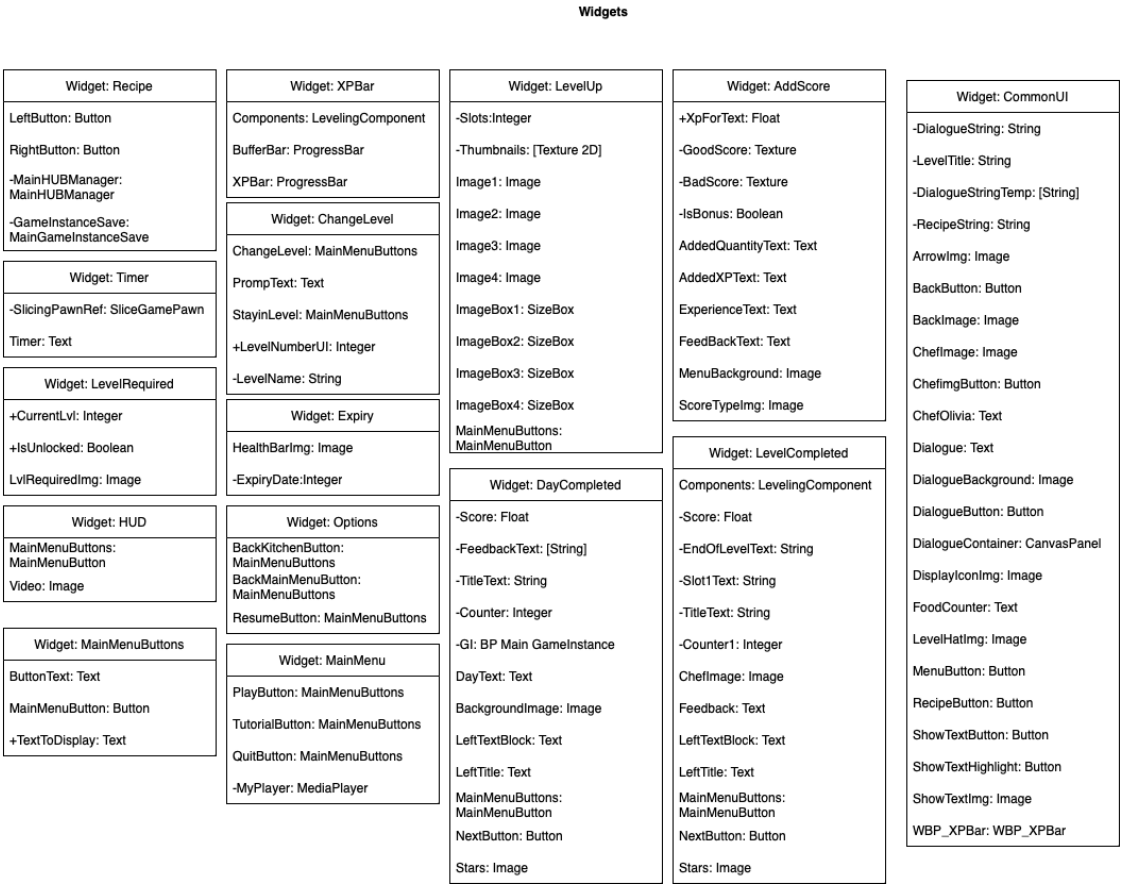

Fig. 37. Widgets - All the widgets used inside the game.

5.4.2 Main Blueprints

In the development of the game, more than 60 blueprints were created, with some of them being actors, structures, data assets, widgets, components, controllers, characters/pawns, and game modes. Some blueprints were already in the engine so the exact number of blueprints used can not be determined.

In this section we are only explaining how the most important blueprints for our game work, some blueprints were merely to enrich the experience visually, thus not being necessary to be explained in this section.

In the kitchen the logic followed is presented in Figure 39, the level starts with the manager gathering the data from the food that is present in the game's instance, sorting in ascending order of the expiry data value, if they exist. If there are two or more food data in the game instance, the recipe book will be spawned with a spawn recipe book function and both recipe options to choose from will be saved in the manager, with added recipe options. The functions check switch actors and show unlocked trophies are used to change the visibility or appearance of aesthetic elements in the level. A delay is used to set the dialogue, this is done because there were some scenarios in which the manager would be loaded in the game before the UI elements like the dialogue. The set-up dialogue function handles the introduction dialogue, the check storing day completed changes the dialogue depending if the user has finished the storing day. Additionally, the same function is

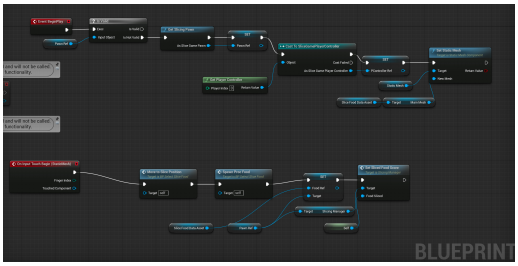

Fig. 38. Blueprint example - Blueprint of the class *SelectSliceFood*.

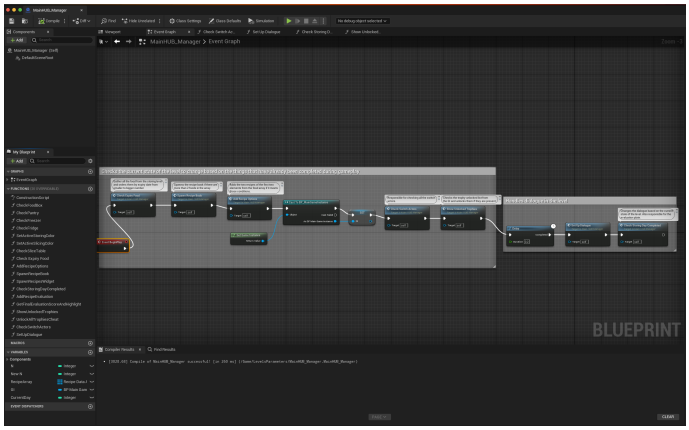

Fig. 39. Section from the blueprint MainHubManager - This section is the event graph, where the event begin play is present, this is the first thing the class does when it is created in the level. It showcases the logic that is used at the start of the kitchen level.

responsible for changing the dialogue, deleting the recipe book, and spawning the evaluation plate for the end of the day, if the slicing level has been completed.

The customization manager coexists with the MainHub manager, the logic it follows is demonstrated in Figure 40 and a small routine that is active all the time is in Figure 41. From the moment the manager is active in the level it gathers the level of the player, which does not change while he remains in it, saves it then proceeds to check every single customization option and unlocks it or leaves it locked depending on the player's level. The function check x position is used to keep the manager checking every 0,01 seconds if the player has surpassed a certain x-axis threshold, demonstrated in Figure 42, to increase the field of view of the player and decrease the z-axis of the walls. When the player is back to the red line of Figure 42, the field of view is back to normal alongside the z-axis of the walls. Moving the walls is done to avoid occluding part of the floor in the customization section and the increase in the field of view is for players to have a better look at their customization choices. These actions need to be only performed once each time the player is above the value or below the value, but it must happen every time they do this, so a do once node is used for both the types of values with a reset happening to the opposite value that is currently active.

In the storing level, only the storing manager is used, it was the first manager created. The addition of this manager to the storing level only came out when the logic of the level was already defined, as such the Figure 43 is small and the logic is present in the storing spawn with Figures 44, 45, 46, 47.

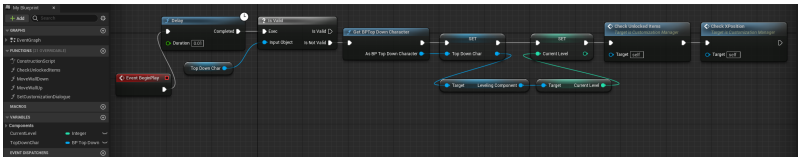

Fig. 40. Section from the blueprint CustomizationManager - This section is the event graph, where the event begin play is present, this is the first thing the class does when it is created in the level. It showcases the logic that is used at the start of the kitchen level, alongside the MainHubManager.

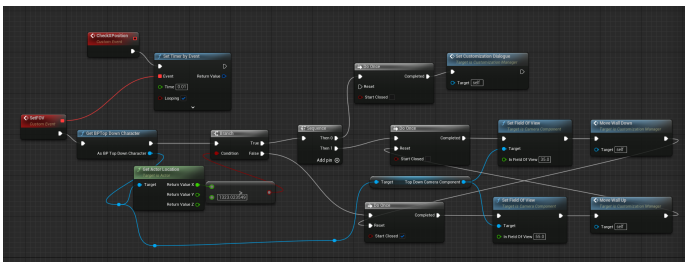

Fig. 41. Check event from CustomizationManager - Is responsible to be constantly checking if the player is above the position 1323 in the x axis.

In Figure 44 the swipe mechanic is represented, it tracks the value of the location of our finger and then calculates the length if it is above the value we set, it counts as a swipe and performs all the steps required for the storage of the food if the player meets the requirements to store it.

The Figure 45, showcases a portion of the storing mechanic. It starts with verifying if the player is in any of the areas, by checking if there is any storing arrow in the level, if there is none, the game simply adds the suggestion of how to store the food. Otherwise, the game will check if there are slots available to store on that shelf. The food from the basket changes position to the same position as the player has in their hands, the hand moves, and the food is removed from the player.

In Figure 46 the steps are continued, with the game throwing the food, disables the physics of the thrown food for it to not be rolling randomly in the game, spawns a new class of type *StoredFood*. Checks if the food stored was a good or bad score, sets the expiry date of the food, and clears the outlines of the last shelf selected.

Then in Figure 47 the game removes the storing arrow and clears the variable of the food we stored, sets the score type for the manager, gets the player back to the starting position, and checks if the level is finished.

The clicked once variable is used, to only allow the player to store that food once, otherwise the player could store the same food, while the process was not complete.

This manager is responsible for handling all the dynamic elements of the game, from gathering the day that is currently active, spawning the food of the level dynamically, assisting in saving the locations of the food with their expiry date, collecting all the scores from the food stored and lastly checking if all the food has been stored to conclude the level, which is showcased in Figure 48.

For the slicing level, we start with selecting the cooking tool, so we make use of the cooking manager first, only later we stop using the cooking manager to only use the slicing manager, but both coexist at the same time in the level. The cooking manager logic is simple, as can be seen in Figure 49, since there are not many tasks for the cooking component.

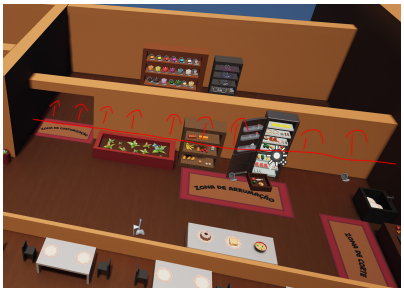

Fig. 42. Kitchen level top down look - The red line is the position described in the previous figure, if the player is above that position the manager will change field of view and position on the z axis of the wall between the customization and kitchen area.

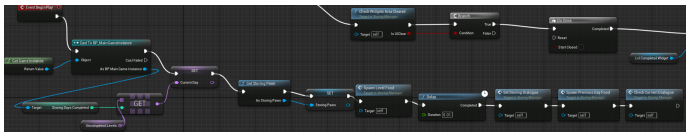

Fig. 43. Section from the blueprint StoringManager - It showcases the logic that is used at the start of the storing level.

The actor select cook tool is responsible for the transaction between the cooking manager and the slicing manager starting to handle the slicing level. This is done following the player selecting the cooking tool, the slicing pawn has a variable called *currentstep* which is also used in the slicing manager in the function represented in Figure 51. Upon *currentstep* reaches the value one the level starts using the slicing manager for all the logic.

A timer is used for players to slice their food, the logic behind this timer and what happens before, during, and after the timer is present in Figure 52. This process is repeated thus there are three execution pins coming from the sequence which has the note of reset sequence.

The slicing manager includes the same dynamic elements as the storing manager, including the score of the selection of the cooking section of the level, to avoid duplicating certain components unnecessarily. The slicing manager checks if the level is finished after the player confirms the slices to be placed in the cooking tool selected. This verification process can be seen in Figure 53.

The final evaluation was implemented, and the main loop of the game was finalized with this step, with a reset to the tasks and a start to a new day inside the game. An easter egg was added to the kitchen, and the kitchen was filled with various components to give it more life, such as a little garden with floors, a table with food, and tables with plates and chairs to showcase that the level took place in a restaurant. Additionally, some floors, walls, and carpets were added or changed, the carpets were used to inform the user which area they were entering inside the kitchen. Lastly, a video introducing the player to our world and story was added to the game and trophies were added as an additional last-minute reward for finishing a day or completing each component of the game with five stars.

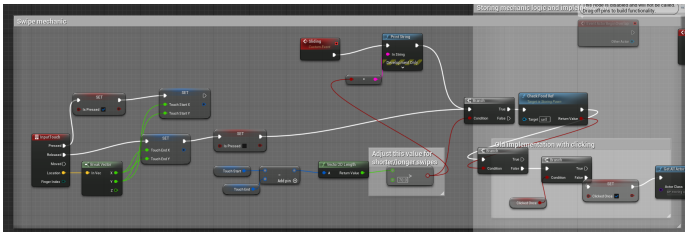

Fig. 44. Implementation of the swipe mechanic for the storing level, present in the storing pawn.

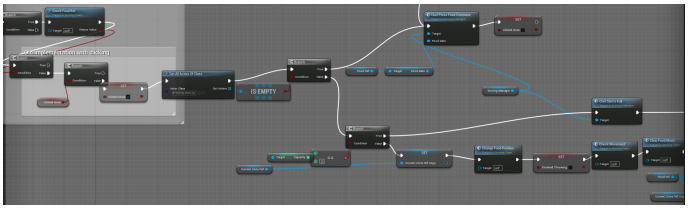

Fig. 45. 1 - Implementation of the storing mechanic for the storing level, present in the storing pawn.

6 Target platform and System Requirements

The game target platform is android, since it was simple to setup and would offer a wider range of devices available for testing. In regards to the android system requirements[5] to play the game these are the following:

1. Operating system: Android 8 or higher.
2. A 64-bit Arm-based CPU.
3. Compatible GPUs:
   (a) Mali T8xx, G71, G72, G76, G77, G78 and G710 series.
   (b) Adreno 5xx, 6xx or 7xx series.
   (c) PowerVR GM9xxx series.
   (d) Xclipse 920.
4. Compatible Graphics APIs:
   (a) OpenGL ES 3.2 .
   (b) Vulkan supported on Android 10 or later devices with compatible drivers.

[5] https://docs.unrealengine.com/5.1/en-US/android-support-for-unreal-engine/

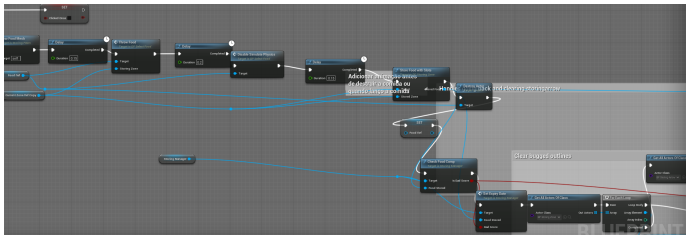

Fig. 46. 2 - Continuation of the implementation of the storing mechanic for the storing level, present in the storing pawn.

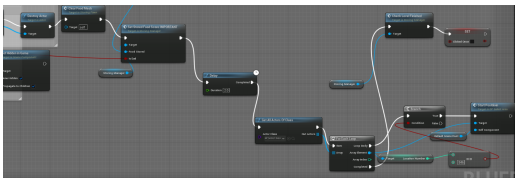

Fig. 47. 3 - Continuation of the implementation of the storing mechanic for the storing level, present in the storing pawn.

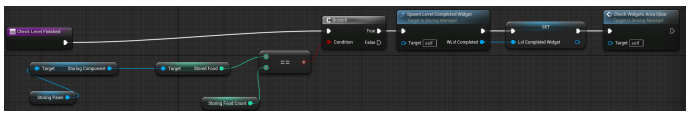

Fig. 48. Function responsible for checking if the player has met the conditions to conclude the storing level.

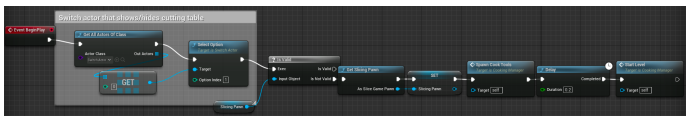

Fig. 49. Section from the blueprint CookingManager - It showcases the logic that is used at the start of the slicing level.

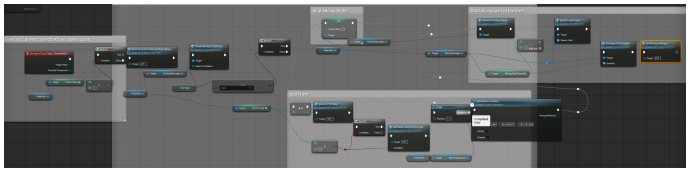

Fig. 50. Logic present in the blueprint *SelectCookTool*, which handles the separation between the cooking and slicing components of the slicing level.

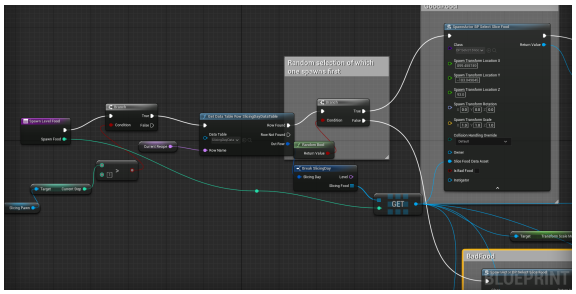

Fig. 51. Slicing manager function spawn level food - This function is responsible for spawning food from the recipe to be chosen between a good food and a moldy or bruised food.

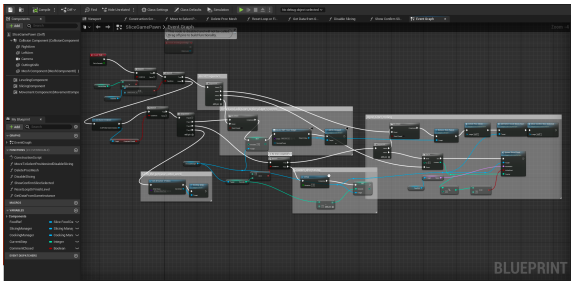

Fig. 52. Function responsible to handle all the events that occur before, after and during the timer for slicing the food.

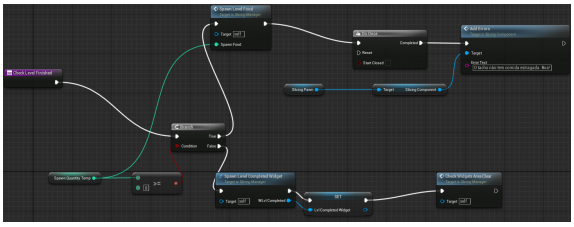

Fig. 53. Function responsible for checking if the player has met the conditions to conclude the slicing level.

7 Game Evaluation

Two research questions were formed, and they will guide us in our studies, which we will use to validate the use and effectiveness of our artifact: 1) Can a serious game promote awareness towards best practices on avoiding food waste among children? 2) What game mechanics can effectively teach about avoiding food waste while maintaining high levels of enjoyment?

After our initial concept design evaluation, we iterated the game and conducted several small studies, which we describe in this section. The studies are presented chronologically, this first one was performed in a school setting, which was our goal, but was only from a small sample of the game. It was used to validate our work effectiveness in our target age group. The other two studies made use of the same version of the game, which was a more developed version of the first study, the second test was made with varying users to test usability. The third test was evaluated by our client in a focus group setting to gather some of their feedback on the product.

7.1 Pilot Test Evaluation in School Context

After validating our concept design and conducting some iterations, we had the opportunity to conduct a small study with our target group on a public school.

We gathered the participation of 22 students from “Escola Básica e Secundária Ângelo Augusto da Silva" in Madeira. The study was part of a school activity dedicated to the week of technologies, where as computer science teachers invited the researchers to showcase the game.

Days before the study, a consent form was sent to gather the children’s parental/ guardian permission (signature) to participate in the study. The document explained the activity (time and date), and research protocol and provided information about confidentiality and the participant’s image rights.

7.1.1 Protocol and Measures

Procedure Steps: 1) Debrief of Activity; 2) Participants arrangement; 3) Pre-questionnaire; 4) Gameplay; 5) Pos-questionnaire; 6) Feedback-Questionnaire; 7) Interview in some groups;

1) Debrief: The procedure started with a small introduction of the activity. Where the users were informed on how they would have the chance to contribute to the process of creating the game.

2) Participants arrangement: The participants started by going to one of four tables. The groups were split according to the equipment used to interact with the game (computer, tablet, or mobile devices). Each group had 6 participants and sat on a table according to the equipment used. Since we had 22 participants, one of the groups (of a total of 4) had only 4 participants allocated on a table dedicated to mixed devices. Each group was accompanied by one researcher, who provided the equipment with the game previously installed and took observation notes as the participants interacted with the game.

The group with the mobile devices had 5 out 6 devices hooked up to a computer recording the mobile screens simultaneously, for a more in-depth analysis to understand user’s interactions, struggles, and any bug that would go unnoticed, and get a more detailed look at these issues, such as how long it took, and how it was presented.

3) Pre-Questionnaire: Before the interaction with the game, the participants had to fill out a questionnaire that inquired about their knowledge of how to organize a refrigerator and pantry leading to an increase in the life cycle of such food (see Figure 54). This questionnaire was created using the same elements and aesthetics that are within the game.

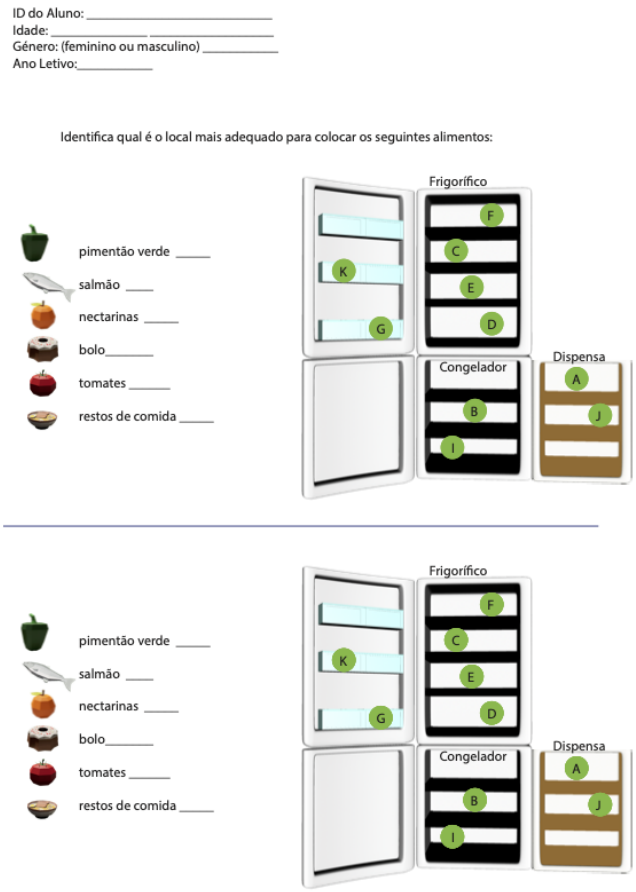

Fig. 54. Questionnaire to evaluate users storing knowledge.

4) Gameplay: The users played the game on their respective devices for a duration of 12 minutes, none of the users had to wait their turn, and everyone was playing at the same time.

5) Post-Questionnaire: The same questionnaire had to be answered by the participants once they finished interacting with the game. In this way, we could assess the effectiveness of the game as a tool to educate the participants on how to organize food and avoid food waste. As such an evaluation criteria was developed to have a fair and correct system to score the pretest and posttest results, following the good principles.

Evaluation Criteria: For food stored in the pantry and freezer, the right food was able to be stored on any shelf, whereas in the fridge there were only two shelves that had a bit more flexibility, everything else had to be properly stored. A good score would give the user “1” point, and a bad score would give the user “0” points. Both tests included six unique foods to be stored, as such the maximum score was “6” points.

6) Feedback-Questionnaire: A questionnaire was also used to identify the existence of some usability issues (see Figure 55) in the game, the following questions were asked: Was Olivia, the Chef, useful for you to understand the gameplay? Were you able to use the back button? Were you able to understand the function of the arrow (to identify the selected shelf)? Did you find anything else that made the game difficult to use? Please indicate:

1. The selection of the food items;
2. Select the areas to store the food;
3. Storing the food;
4. Understanding the correct place to store the food;
5. Other;

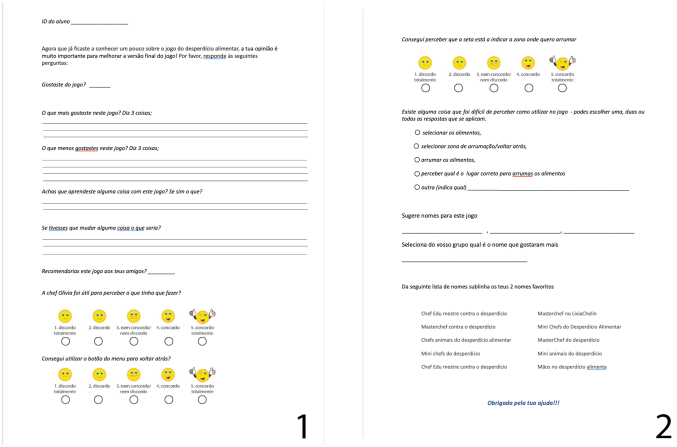

Fig. 55. Questionnaire used to gather feedback from the game.

This information was gathered using a Likert scale of 5 levels - "1" for totally disagree and "5" for totally agree. The Likert scale was accompanied by a smileymeter [54] (a pictorial representation of the emotions) to help the participants answer the questions accordingly.

We also gathered qualitative data using open questions to help improve the game, the questions were asked individually in the questionnaire: What did you like the most about the game? Please indicate 3 things, What did you least enjoy? Please indicate 3 things, Did you think that you learned anything with the game? If yes, what? And finally, If you could, what would you change in the game?

As for the engagement of the participants, these questions were asked: *Did you enjoy the game?* and *Would you recommend this game to your friends?*

7) Game's name questions:

There were three different instances where the users were asked to help with choosing the game's name. The first users were asked to vote from a list of ten names, which ones they liked most. After that question, users were asked to suggest three new names for the game, the users from each table would share the names with the other elements of the group and decide on which name would be used in that group.

8) Interview: To gather extra information from the users, some of them were asked in groups to elaborate on some of the questions from the feedback questionnaire. This was useful to better understand some of the issues that were mentioned previously and to understand how strongly attached they felt to these issues (as it was easier to understand with the tone of their voices). It was useful to have users share their opinions with one another and come to a consensus in regard to certain questions. This method made the process richer, allowing the users to explain why they thought it was a problem.

The study took around 70 minutes, of which 12 minutes were dedicated to the game's interactions.

7.1.2 Results

7.1.2.1 Demographics

We had a total of 22 participants. Most of the participants were male (n=17) and 5 female. Also, most of the participants were eleven years old (n=12) and the remaining (n=10) were ten years old.

No nationality data was collected.

7.1.2.2 Quantitative Data

The results of the usability test showcased, in the left pie chart from Figure 56, that 41 % of the users answered 5 - Totally agree (n=9) when asked if Olivia, the Chef, was useful to understand the game, additionally the remaining users answered positively to this question.

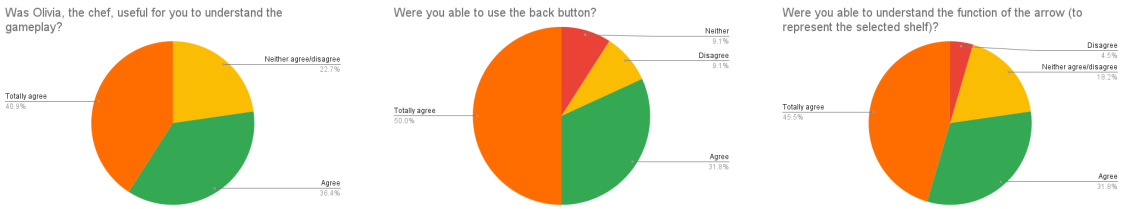

Fig. 56. Left pie chart - Results from questionnaire question "Was Olivia, the Chef, useful for you to understand the gameplay?"; Center pie chart - Results from questionnaire question "Were you able to use the back button?"; Right pie chart - Results from questionnaire question "Were you able to understand the function of the arrow (to represent the selected shelf)?"

When asked about the use of the back button, center pie chart in Figure 56, 50% of the answers were 5 - Totally agree (n=11), the second most common answer (31,8%) was 4 - Agree (n=7), but the remaining users answered 2 - Disagree (n=2) and 3 - Neither agree nor disagree (n=2).

To the question were you able to understand the function of the arrow (to represent the selected shelf), in the right pie chart from Figure 56, the most common answer (45,5%) was also 5 - Totally agree (n=10), the second most common (31,8%) answer was 4 - Agree (n=7).

When asked about which aspect made the game difficult to play, the results showed that "Storing the food" was what most users had difficulties with, secondly "Understanding the correct place to

store the food", thirdly "The selection of the food items" and lastly "Selecting the areas to store the food". Additionally, one user selected the other option with the answer "moving the character".

The learning outcomes were calculated using the participant's scores from the pretest and post-test scores results.

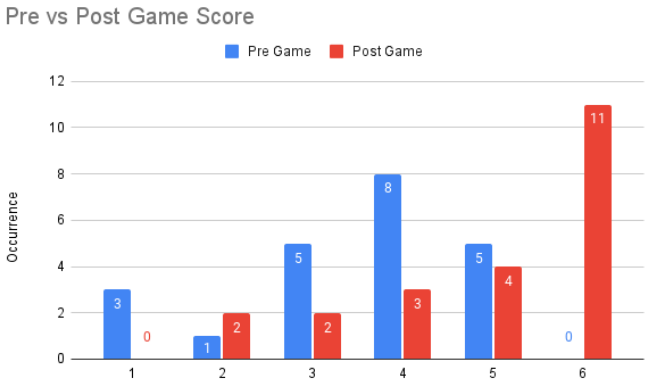

Fig. 57. Evaluation score of storing exercise from before and after using the game - On the horizontal we have the possible scores, on the vertical we have the amount of times that score happened for pre game in blue and post game in red.

When comparing results from the pretest and post-test, see Figure 57, user's knowledge about how they can store the food in their household increased. This can be seen from the number of occurrences the lower scores (1, 2 and 3) decreased and the higher scores (4, 5, and 6) increased. This column chart represents an improvement on 14 cases out of 22. Additionally, the platform was taken into consideration when analyzing this data and the type of platform did not seem to affect these results.

Out of the 22 tested users, 21 (95,5%) of users agreed they learned something from the game, when asked about what they learned most answers could be grouped into four different types as shown in Figure 58.

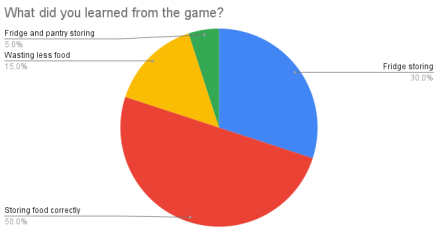

Fig. 58. Pie chart with results from questionnaire question "What did you learned from the game?"

When users were asked if they liked the game, or learned something from the game in the interviews all of the students interviewed mentioned they liked the game; all of the students interviewed mentioned they learned with the game;

In the questionnaire (95,5%) 21 users who answered the questionnaire mentioned they liked the game.

(95,5%) 21 users who answered the questionnaire mentioned they learned with the game.

(95,5%) 21 users mentioned they would recommend this game to their friends.

(36%) 8 users who answered the questionnaire mentioned they would not change anything in the game;

7.1.2.3 Qualitative

In general, users were receptive to the experience and seemed to enjoy themselves playing the game, they were always asking for more details about the game, exploring everything in the game to find every feature and possible interaction. They also appeared to have learned food waste concepts with the game and that they would be more mindful of their decisions.

The results from the observation notes, interviews, and open-ended questions from the questionnaire showed that users were very enthusiastic to play the game at the start, but towards the last minutes, they were tired of repeating the same tasks and had already found problems with the game, such as not saving the characters customization between levels. In the interviews, users were very vocal about which things bothered them when playing the game.

Two users helped their parents or had some knowledge of how to store the food, "I help my parents store the food, I know how to do it!", the other four did not know anything, "I never store the food in the fridge at home!".

Initially, three users had some difficulty understanding how to play the game, but the users that were quicker to understand the interactions helped the other colleagues and they would share their learnings with others. Generally, the users were frustrated at the beginning of the game for not understanding how to play it, one user asked "Where should I store the green bell pepper", when they figured out they were a bit more relieved, one user said," Ah, I understand now I have to store them on the shelves! And it is based on the temperature". Four users were also frustrated towards the end of the session, the users were bored as they kept repeating the same level and wanted something new to try out as they started getting the maximum storing score in the game. Two users tried to get to the other side of a wall in the kitchen which had the Chef, when they could not move through the wall they became frustrated, they commented, respectively, "Why can I not go to the same level as the Chef"; "I want to get out of this level, this is a prison" the same user was really frustrated and spent 3 minutes trying to get to the other side of the wall.

Five participants during the interview mentioned they ignored Chef's text, "Ah I did not even read anything, I just pressed on things". They also said that only read the text when stuck doing something. All users were also sad when they noticed that game elements such as experience, "we lost our level", and character customization did not save between levels. One user said showing frustration: "I lost the jacket I chose?!, I don't understand"; another user said: "I changed the monkey's clothes, it was cute, but then he lost its clothes".

There was a disagreement about the game graphics, some users seemed to like them, and others did not. While a participant expressed his dislike and wanted a more refined and realistic approach, another one said "I liked them and think the graphics were spectacular". Note that the comments were provided by users with different equipment, while the participant using the mobile phone was

pleased and the one using the computer was not. There were also problems with the lights in the game aspect which users with tablets and computers noted as problematic.

The common points mentioned in the interviews and things that they would change or add to the game were: Having more and different activities to do in the game; more guidance in the beginning; more customization options (colors, types of clothes); saving levels/experience and customization; more levels inside the kitchen; more realistic or refined graphics; more explanations about the story of the characters in the game, having a more meaningful story with secret recipes, helping friends, and becoming a master chef; multiplayer mode; changing the storing interaction process; building a restaurant; better and easier mobility with the character, adding a joystick on screen was also suggested; making the pointing arrow be clearer, in regards to how it worked to store the food; it was also a somewhat common answer that they would not change anything; Adding doors to change between levels.

We have grouped the results from observations in the following themes to facilitate the reading of the qualitative results:

Most appreciated features

The users seemed to enjoy themselves with the character customization, "I like this pink jacket"; "The monkey is naked!" then laughed, additionally they seemed to be very happy with the stars they were given at the end of the level based on their performance, especially when they were able to get the maximum score. Some users competed between them to see who would get the best score. It was common for the majority of the users to be frustrated and lost in regards to two foods that they had to store, a bowl of food and a cake.

When users were asked what features they appreciated the most in the questionnaire, the following points were mentioned: the game's graphics, story, characters, instructions and Chefs feedback, storing the food, customization and clothes, the creativity, moving around in the game, everything, learning how to store the food, the main character, competing with friends.

Aspects to Improve

When users were asked about what things they did not like or needed improvement, they mentioned these aspects: the bugs, poor performance, the delay in user input, missing back arrow, graphics and light inside the game, not saving the experience, and customization selected between levels, not enough levels, little variety (levels and customization), not being able to go to different divisions within the main kitchen level. Some aspects such as poor performance, and the lights in the game were common issues for the computer and tablet users, as such it may have degraded the user's experience with the game.

Technical Glitches

The game crashed on two computers, and the users noted performance problems and a sub-optimal experience with the game, when pressing the food to be stored they would miss due to this problem. Some tablet users, also shared some of the problems with the computer users, the game also had some performance problems. For mobile users a recording of 5 out of 6 phones was performed and later analyzed. They did not note any issues with the game in terms of graphics or performance, but when analyzing the recording there were two bugs found, one in regards to the lighting to one user, which did not affect the user's experience, and another which made the user be able to store 9 food out of 8 available.

Each group voted for the table chosen name, and the results were: *Arrumação da cozinha da princesa Olívia*; *Chef Olivia's Kitchen*; *Arrumar a comida*; *Master Chef.*

For the pre-defined list of names the results, from most votes to least votes, are present in Table 5.

Table 5. Names pre-defined suggestions voting results.

Title	**Votes**
Masterchef contra o desperdício	10
Mini animais do desperdício	7
Chef Edu Mestre contra o desperdício	6
Mini chefs do desperdício	6
MasterChef no LiviaChelin	6
Mini Chefs do desperdício alimentar	4
Mãos no desperdício alimentar	4
Chefs animais do desperdício alimentar	2
MasterChef do Desperdício	0

Whereas none of these games ended up being the final name for the game, these were very useful in focusing on which keywords were used more often and how they could be used to pick the final name of the game. The game's final name ended up being *Masters Contra o Desperdício.*

7.1.3 Discussion

This pilot test performed included only a selection of two levels of the game, and provided us with the opportunity to test the game on a real scenario to prove its effectiveness towards our research questions, 1- Can a serious game help the learning of food waste concepts to children? 2 - Can this game have fun mechanics while educating towards good food waste principles?

The results showcased that the grand majority of the users had a positive experience in regards to both questions, since (95,5%) 21 of questionnaire users answered positively when asked if they liked the game, if they learned anything from it, this was also reflected with their enthusiasm during the test. Some aspects were confusing for the users as they were not explained properly, but users also mentioned that Chef Olivia was useful for their understanding of the game, so these elements are going to be used to explain to the users more things about how to interact with the game. Certain foods were not perceptible to the users and where to store them, as such a stronger emphasis is going to be given towards it being the first thing the user learns when he selects that certain food. Users found the experience fun when they were getting as many stars as possible and customizing their characters, even though they were frustrated when these changes were not being saved. The users enjoyed walking with the character after customizing it, trying different options and wanted to unlock more options, as Titiu [49] identified with its customization options.

Additionally, the results from the pretest to post-test showcased an improvement in their knowledge which further helps prove that the users did in fact learn with the game.

Some of the devices, tablets, and computers, had less than optimal performance which unfortunately affected the experience of users, which led to more frustration during the session. A priority was given to having more devices for having a bigger testing group, otherwise, a more careful selection would be done for the devices to be used.

While the game was not easy for the users to understand to begin with, the learning process did not take too long, and the mastering of the game mechanics was achieved fairly quickly through repetition, as mentioned by Lacasa et al and Obiwelu et al [17, 37].

In regards to bugs, two were found, one related to lighting which does not affect the user's experience, and another one with the storing interaction which makes users able to store more food than what is available in the level, this one is critical as it breaks the game's rules.

When suggesting things that needed change within the game, users were very vocal about having a saving system to save data between levels, such as experience and character customization, adding more customization options, adding more levels, and greater variety. These were already part of our priorities for the final version of the game, but having the proper validation with the users, and that it had this level of relevance to them was very useful to understand just how much they valued these rewards and sense of accomplishment with what they do inside the game. Other suggestions are out of the scope of this project or scheduled for a final interaction where the core of the game is more solid, things such as optimization and eventual visual bugs.

Although the final name decision was not made directly from the user's suggestions or votes, they were very helpful in guiding towards which keywords were important to have in the final name of the game.

7.2 Usability Evaluation of the Beta Version

For this section, we will describe the steps that were taken after having the current beta build ready for testing usability.

To be sure that everything that was implemented in the game was working as intended, the mechanics implemented were intuitive, and in order to find issues a usability test was performed.

For this study users were recruited opportunistically, and this led to 26 users that agreed to test the game, however from this sample group, one user did not complete the questionnaire due to time constraints.

7.2.1 Protocol and Measures

The protocol consisted of five different steps, with the gameplay being split into two different moments: 1) Debrief of the steps; 2) Participant's consent; 3) Gameplay; a) Following in-game instructions; b) Performing the tasks asked; 4) Questionnaire; 5) Interview;

1. **Debrief:** In this debrief users were introduced to the purpose of the test, testing usability, the game's target age group and theme, how long the test would last;
2. **Participants consent:** The participants were given a consent form describing everything in more detail, what data was going to be collected, the compensation given for participating, and all the details in regards to the test;
3. **Gameplay:** Play the game for fifteen minutes;
   (a) **Following in game instructions:** First, the user would have to follow the game's tutorial to reach the end of the day;
   (b) **Performing the tasks asked:** Upon completing the day he would have to complete three tasks given:

i. Customize your character;

ii. Find the easter egg;

iii. Find the trophies;

4. **Questionnaire:** Fill a post questionnaire, this questionnaire would ask to evaluate certain game aspects in a quantitative manner. This evaluation followed the same Likert scale values, from 1 to 5, and the same nomenclature, but the smileymeter was not used this time [54].

   Additionally, users were asked which components from the game were not intuitive, or they had difficulties understanding them;

5. **Interview:** Lastly, the users would be asked to answer some open questions about the storing and slicing level, another mechanic for the storing arrow, new additions to the game that would enrich the food waste theme of the game, two questions regarding rewards, customization, and trophies and for the final question users were asked about the end of level or day usefulness.

7.2.2 Results

7.2.2.1 Demographics

The range of ages testing the game was from 10-19 years old to 40-49 years old, as seen in Figure 59. Out of the twenty five users, fifteen were male, nine were female and one user preferred not to mention. For the user nationality, twenty four of the participants were Portuguese and one user was Spanish.

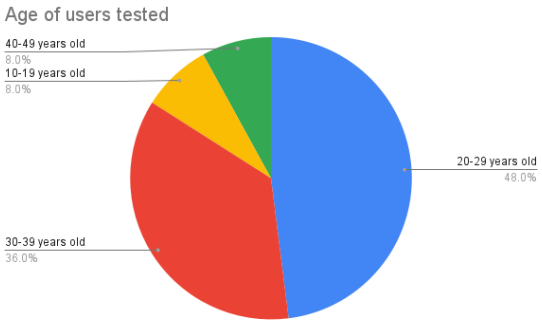

Fig. 59. Age ranges of users tested.

7.2.2.2 Quantitative Results

Users were asked to grade from 1 to 5 how good was the integration between levels, with 5 being totally agree and 1 being totally disagree. For the last question 5 is for liked it a lot and 1 is for disliked it a lot, the results are present in the Table 6.

All the twenty six interactions with the game were timed, the longest test that completed all the tasks lasted 14 minutes and 54 seconds, the shortest lasted 7 minutes and 40 seconds, one user did not finish all the tasks within fifteen minutes and the average of the twenty five tests finished was 11 minutes and 23 seconds.

Users were asked to rate how fun was the game, using a score from 10 to 1, results are shown in Table 7. Table 8, showcases the options selected for which components from the game were not

Table 6. Questionnaire evaluation results.

Answer (5 - Totally agree/Liked it a lot | 1 - Totally Disagree/Disliked it a lot)	5	4	3	2	1
Question					
The change from the introduction of the game to the storing level was well implemented	13	7	5	0	0
The change from the storing level to the recipe choice was well implemented	13	10	2	0	0
The change from the recipe choice to the slicing level was well implemented	12	10	2	1	0
The change from the slicing level to the final evaluation was well implemented	10	10	5	0	0
What was your opinion regarding the customization	12	9	4	0	0

intuitive to the users. Additionally, the users were asked to explain what of the components were not clear. Most explained how the storing mechanic, food movement, and overall interaction at the storing level were not intuitive, and possible solutions to the problem. The selected options also help us understand that a bigger effort needs to be made in order to improve the components from the storing level, this improvement can come in the shape of better guidance and visibility of how the user needs to interact with the level components or a redesign of the level mechanics.

Table 7. Results from the questionnaire question "How fun was the game?"

Score	**Occurrences**
10	1
9	4
8	14
7	5
6	1
5	0
4	0
3	0
2	0
1	0

Table 8. Results from the questionnaire question "Which of the following game components were not intuitive?"

Option	**Occurrences**
Selecting the storing zone	14
Storing mechanic	14
Storing arrow	11
Selecting the food to be stored	10
Slicing the food	7
Selecting the sliced food for the pan	4
Selecting the cooking tool	4
Selecting the food to be sliced	3
Recipe instructions	2
Returning to the previous level	2
Selecting the recipe	2
Final evaluation	1
Character movement	1

7.2.2.3 Qualitative Results

Following the problems with the storing level, which was a component we knew needed improvement before starting this testing phase, a question from the interview asked the users how would they implement a storing mechanic inside the game. The majority of the users pointed to a drag-and-drop or a point-and-click system, (n = 16), but the more creative solutions or additions to the current mechanic were: Having a book that the player had to memorize how to store; Having the food flying at random times and speed where we have a timer to press them in order to store them; Having a height based on the momentum of the swipe; losing health if it is the wrong option; Being able to group the same type of food to be stored all at once; Having a slingshot. This exercise helped us find new solutions and what the users expected from the game's interaction. When asked about additional aspects that needed improvement the most pressing one was that the tutorial messages were too cumbersome and needed to be complemented with gameplay. Only one user did not find the easter egg, because the user ran out of testing time.

Observation notes and comments during the tests pointed out that when trying to store the food out of the 26 user's tested: 23 users tried pressing in the zone; 20 tried users to press on the food; 18 users tried pressing the arrow; 6 users tried to store them after grabbing the food from the basket; 5 users tried to swipe and release in their desired area. These users interactions reflected that the storing mechanic was not intuitive for the user.

Additionally in the storing level, 4 users tried to switch to the fridge while being in the freezer; 12 users tried to change the storing position after having stored the food; 6 users did not know what food they were storing; 4 users would always start with the freezer. There seemed to be some confusion in how the mechanics functioned.

For the recipe choice and recipe follow-up: 19 users selected the recipe by clicking the UI; 8 users selected the recipe by clicking on the food in the table. The user's main point of attention and focus was the UI and the food on the table was not noticeable enough. Note one user had a bug in the game that prompted them to choose the recipe again, the first time this user used the UI, but the second time pressed on the food on the table, this explains the 27 options recorded.

1 user was lost before selecting the recipe; 4 users were lost after choosing the recipe; 6 users made use of the recipe button. This should not have happened since Chef Olivia instructed them where to go before and after choosing the recipe.

For the slicing level: 7 users tried to swipe for slicing the food; 2 users tried to drag the slices to the pan. Given that only this small portion of the tested users used swipe, the instructions and overall interactions with this section were intuitive for the rest of the users. 6 users wanted to know how they received the trophies, so either the remaining did not care much about them or they needed more highlights in our game.

Additional points that various users mentioned or were observed:

Positive aspects:

1. 7 users liked to slice the food;
2. 5 users said they liked the customization;
3. 3 users liked the easter egg;

Aspects to improve or additions:

1. 5 users wanted to have curiosities when leveling up, mentioned how much food they saved, planned meals, and avoided buying too much food;
2. 4 users noted the lack of sound effects and visual effects, especially in the slicing of the food;
3. 4 users wanted the addition of composting to the game;
4. 3 users wanted to have new recipes;
5. 2 users wanted the game's leveling system to require more experience;
6. 2 users wanted zooming options, especially for the customization;
7. 2 users wanted the game to be more challenging;
8. 2 users wanted a highlight of the three different sections in the storing level;
9. 2 users wanted to freeze the food cooked;
10. 1 user wanted to wash the dishes;
11. a user mentioned how the game's language would benefit from a language more directed to the children.

Difficulties from the users:

1. 3 users mentioned that the trophies and customization from the top shelf were hard to see;
2. 2 users mentioned that the names on the fridge door and the arrow not going all the way down are confusing;
3. 2 users were heading with the Chef, but were hesitant due to the carpet saying "final evaluation";
4. 2 users mentioned that their storing habits influenced them in the game's storing level;

7.2.2.4 Discussion

The storing level was very confusing for the users, it was the level with the most issues and that happened more frequently with the users tested. Following the analysis of the time recorded for each activity, the storing level was the one that had the most variability in time used for playing, which further demonstrates how nonintuitive some aspects were. Users found the slicing, customization, easter egg, and character movement to be very funny and entertaining. Most users suggested a lot of varied additions, and while they enjoyed the experience by most of the votes users wanted to have more additions to the game, but especially for it to be a more refined experience. Some users also mentioned how the theme of food waste was not so present in the game, thus asking for more messages and reminders of the good actions they were doing that were helpful for food waste. Levels needed to be further flushed out, having more complexity and having a slower level progression, which in short means a longer game experience with additional steps and level progression that would lean harder on users needing to have a good performance to unlock more customization. A lot of elements, such as the trophies, were not properly explained so there was a bigger emphasis on these elements. The instructions of the game should be more visual and introduced more gradually because users were very confused and would not absorb all the level instructions.

7.3 Focus Group with the Local Food Bank

In order to inform our client of the state of the game and gather some feedback regarding points to be improved and added to the game, a focus group was performed with 5 users from the local food bank. This focus group made use of the same version of the game as the usability test.

7.3.1 Protocol and Measures

The focus group protocol had four different steps: 1) Debrief of the activity; 2) Consent Form; 3) Gameplay; 4) Feedback.

1. **Debrief of the activity:** Users were debriefed on how the focus group works, the reason behind this testing, and the procedure of this activity;
2. **Consent Form:** A consent form was handed to each one of the users to be informed and ask for their consent to what data was going to be collected and handled. Permission for recording the audio was asked in the consent form but was also done verbally to make sure everyone agreed.
3. **Gameplay:** At this moment the audio would start to be recorded. One smartphone was used by the same user, this smartphone was connected to a laptop for the remaining users to be able to see the user's interaction. After the interaction the moderator would give more context into the mechanics and game elements, this was done in order to get users to engage in a discussion regarding these aspects.
4. **Feedback:** At the end of the test, users were asked to give feedback on everything from the game, the same levels integration was asked, positive and negative aspects from the game, what elements from food waste were missing, how were they planning to implement this in their school visits.

All data collected was done with comments and observation, as such the data collected is merely qualitative.

7.3.2 Results

7.3.2.1 Demographics

There was no demographic data collected, but out of the 5 users tested three were female, and two were male. Additionally, the users that participated in this test were workers from the *Banco Alimentar da Madeira*, working in distribution, finance, and public relations.

7.3.2.2 Qualitative Results

There were some questions that were prepared to ask the users to get them to express their opinion about the game, however, most of these questions were not needed as they were very active in providing their opinion. The users answered the questions with positive and negative aspects of the game, and what was missing from the food waste theme, describing them more thoroughly, without the need to be asked about them.

The points that the users mentioned that needed improvement were:

1. Fix grammar issues and errors;
2. The recipe icon, was not intuitive and the message presented was not perceptible, maybe adding a highlight or pointing to its location was a suggestion given;

3. For the storing level it would be better a drag-and-drop approach;
4. Having a language balance between technical terms and a language more directed at children of this age group;
5. Possibly the recipes with fish and vegetables were not desired by the children;
6. One user mentioned that the way the storing level played out was very confusing and was not educative enough, as such this user suggested we start this learning process by first being introduced to the storage of one of the three storing locations, then learning the others;
7. Addition of a small video showcasing the storing as an example, then users would have to memorize and store themselves, this would be beneficial to their involvement in the action and lead them to think more about their actions;
8. The addition of music and sound effects;
9. Since the game has a sink with plates, we could be given the chance to wash the dishes and gather all the food that was left on the plate for composting and use it in our small garden;
10. The addition of the previous point could be a small activity and upon completion, the user would receive a feedback message explaining why it was a good action;
11. Having people in the restaurant to eat or waiting for their food;
12. The addition of a plating level and explaining what percentage would need to be filled with vegetables, hydrates, etc;
13. In the slicing part the good for the recipe and the bad parts for composting.

Positive aspects:

1. The users enjoyed and found the customization amusing;
2. Users enjoyed the gameplay, especially the character's movement.
3. Users were very pleased with the topics approached in the game.
4. The users enjoyed the graphics and level of detail in the game.
5. The users enjoyed how filled the kitchen level was and even assumed certain activities could be performed inside it.

Participants were asked how good was the integration of the various levels, and they answered they found it good between all the levels.

In the end, when we asked if they would envisage this experience being offered in the school settings during their interventions. Participants mentioned that using this game would be valuable to showcase the importance of avoiding food waste.

7.3.3 Discussion

Since the game version used for this test was the same as the study in the previous section, the usability evaluation, there were similar types of problems that arose from the user's feedback. For the storing level, the users gave suggestions of it being drag-and-drop, phasing out the learning process for each of the storing locations, addition of videos to introduce the mechanics. This suggestion is very helpful, especially for our research question (*What game mechanics can effectively*

teach about avoiding food waste while maintaining high levels of enjoyment). The users from this focus group were very helpful in suggesting new additions and changes to the game with them being very detailed in the implementation of such things. While a lot of work is still required to refine the game, the client mentioned that they are very enthusiastic about this project and see a lot of potential for the use of this tool in school visits.

8 Discussion

The preliminary testing with the prototype built helped us validate the initial concept of the game and which areas needed improvement. The results from the preliminary testing were indicative of a useful educational experience and amusement with the customization and characters. However, there was still a need to validate our work with a functional version of our proposed game tested with a large group from our target age group.

Developing and listing the requirements, building models, and idealizing how things would be implemented for the final product, helped us streamline all the processes and in having a firm direction in the development process. Additionally, prioritizing which features were more relevant for the final version of the game, how long these would take to implement, how would each component interact with the other ones and lastly what features could be left out without diminishing the game's core experience.

The use of a conjunction of paper prototypes and a quick prototype to refine the issues from the first prototype was extremely useful, not only for the game concept but in providing more time to start the learning process of *UnrealEngine*5. Some aspects of the game took more time, or were not implemented in the most optimal way since this was the first experience with the engine, looking back, many things would have been done differently.

Following the dissemination of relevant material from food waste projects targeted at children and other digital experiences with the same target group, our two research questions were formed to guide our research efforts:

8.1 1) Can a serious game promote awareness towards best practices on avoiding food waste among children?

Educational games have shown to be a positive experience in stimulating learning in children [18]. This pilot test with children from our target age group was extremely helpful in answering our research questions, even though the game only offered a portion of the final experience.

Children improved their knowledge of how to be more responsible with handling the food in order to waste less food while having a fun experience. The fun factor of the game was concluded from the user's interactions, observation notes out of which they seemed very enthusiastic in regards to the experience. The questionnaire results resultied in 21 questionnaire users (95,5 %) who answered they liked the game from the 22 users tested.

The users were able to acquire more knowledge and were active participants in their learning process [30]. This knowledge was evaluated with the pre and post-tests performed during the pilot test study with our target age group. The game's effectiveness as an educative experience was proved with the comparisons of the results from the pretest to the post-test. Additionally, 21 of the 22 users tested (95,5%) answered that they learned something from the game in the questionnaire.

8.2 2) What game mechanics can effectively teach about avoiding food waste while maintaining high levels of enjoyment?

The customization was a very welcome addition as Titiu [49] did in the "Feed the movement" application, users from both the pilot and usability test were engaged with this component of the game.

While the characters inside our game were not so much the focus as the learning about food waste, they followed the Hugon et al [24] stories which had memorable characters. The use of characters who are determined to achieve a goal and have unique features, such as the monkey's creativity of using different food scraps, that influence the user, as proposed by [50, 51].

The use of rewards from experience, customization options, trophies, and star scores at the end of the level was appreciated by users from the three studies conducted. As Hanus et al [35] referred gamification elements benefit the game's educational goals, pursuing the user to improve to receive more and better rewards.

Users from the pilot test noted that certain game elements were confusing or were not explained properly, but users mentioned and agreed that Chef Olivia was useful to help them understand more about the game. Additionally, the characters left some resemblance in the users who remembered their names, since their names came up in name suggestions and various open-ended questions. As the pilot test was only a demonstration with the most features that had the most impact on the game, users left wanting a more complete experience and suggested possible additions. The realization that the pilot test's user's suggestions of things to add or improve in the game were in line with our short-term goals was very reassuring in continuing the development for the next phase. For the usability study, the game was a more complete experience, however, users noted that the game could make use of even more features, but more refinements could be done to existing features in order for them to be more intuitive and exciting.

Having a beta version of our game testing usability and being presented in a focus group to our client simultaneously, helped us identify the most critical issues of our current version of the game. Having both of these elements identify the same problems and provide possible solutions for the usability issues and ways to improve the experience of the game is always very welcoming. Users already enjoyed the experience, but with the improvement of these elements, we believe the game can become a useful artifact in the education of this topic.

In summary, our research appears to be aligned with our goals, we were able to test the main components of the game with our target age group and the results were very positive for our research questions, the users found the game fun and learned with the experience. The testing made with our target age group happened in two instances, in the first prototype built with Figma, which validated our concept for the game. Later in the pilot test build, which was a smaller, but more significant, portion of the final game. Even though the game did not offer everything already implemented, users were responsible for suggesting changes and additions as Druin [44] mentioned helping the experience to be more suitable for other children of the game's age group. Given all these results our project appears to be headed in the correct direction with the potential for a successful final study with our target age group.

9 Limitations and Future Work

The final version of the game, with the extra features and levels, could not be tested with our target group due to the time the game needed to be finished and the children were on their summer break, so one of our priorities in the future work is to conduct an evaluation in the school context with the intended target group and sample size larger than the previous pilot test.

Regarding the game design, adding more game mechanics that focus on reinforcing how to avoid food waste would be beneficial to increase the awareness effect, further refining the experience to

be a more cohesive restaurant experience, some of these mechanics could also target other age groups. A opportune test for the future would be to maintain interest in the game for a longer period. This would also be useful in understanding the long-term impact of this experience at the household level.

The game still has problems with different aspect ratios and screen layouts, we plan to further refine this part of the experience so that all the users, meeting the system requirements, can run the game seamlessly on their smartphones.

Currently, the game is only available for Android but has not been released in the Google Play store, in the future we plan to build an iOS version of the game and distribute it in each of the distributor's marketplace.

10 Conclusion

This project presents an enriching experience in the area of sustainability, the artifact produced is sure to be useful for sharing the theme of food waste for children. *Banco Alimentar da Madeira* , our client, was very excited with what was presented and eager to share this experience in their activities with our target age group.

This serious game is a positive addition to the educational area and will hopefully be used by many different institutions to share this topic in a successful manner. Furthermore, the use of $UnrealEngine5$ demonstrates that it is a very powerful tool that can be used in different situations, even in a mobile game with this small type of scope.

Concluding we achieved the goals we set out at the start of this project. We evaluated the potential of this experience, in the target age group study, which demonstrates that children can learn with our game. The engagement, and enjoyment from our game were also positive from all three studies' results, especially the customization and slicing in the game.

10.1 Contributions

This project looks to be a useful tool in teaching children about food waste, as well as a promising entertaining product. Our client was excited about the potential of the game and is anxiously waiting for the delivery of the final product to be used to share this information.

The process followed for the development, and management of milestone goals and versions deployed for testing should be useful for similar works, they should prove useful for being efficient with their management of time. The studies from this work provide, should be of use to other projects in the sustainability area, working with a client and developing digital experiences for children. The studies for the game demonstrate a positive experience with the majority of users.

References

[1] T. A. Smith and C. E. Landry, "Household Food Waste and Inefficiencies in Food Production," *American Journal of Agricultural Economics*, vol. 103, no. 1, pp. 4–21, Jan. 2021. [Online]. Available: https://onlinelibrary.wiley.com/doi/10.1111/ajae.12145

[2] F. Girotto, L. Alibardi, and R. Cossu, "Food waste generation and industrial uses: A review," *Waste Management*, vol. 45, pp. 32–41, 2015. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0956053X15004201

[3] L. Vieira. (2017, 5) Combate ao desperdício alimentar começa entre os alunos das escolas - xxi governo - república portuguesa. Accessed on: 2022-09-03. [Online]. Available: https://www.portugal.gov.pt/pt/gc21/comunicacao/noticia?i=20170519-seaa-desperdicio-alimentar

[4] U. Nations. (2015) Objetivos de desenvolvimento sustentável - onu portugal. Accessed on: 2022-12-27. [Online]. Available: https://unric.org/pt/objetivos-de-desenvolvimento-sustentavel/

[5] P. B. Issock Issock, M. Roberts-Lombard, and M. Mpinganjira, "Understanding household waste separation in South Africa: An empirical study based on an extended theory of interpersonal behaviour," *Management of Environmental Quality: An International Journal*, vol. 31, no. 3, pp. 530–547, Feb. 2020. [Online]. Available: https://www.emerald.com/insight/content/doi/10.1108/MEQ-08-2019-0181/full/html

[6] A. Dhir, S. Talwar, P. Kaur, and A. Malibari, "Food waste in hospitality and food services: A systematic literature review and framework development approach," *Journal of Cleaner Production*, vol. 270, p. 122861, 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0959652620329061

[7] Edubirdie. (2021, 5) Digging through school waste composition - edubirdie.com. Accessed on: 2022-09-02. [Online]. Available: https://edubirdie.com/blog/school-waste-statistics

[8] M. Hebrok and N. Heidenstrøm, "Contextualising food waste prevention - Decisive moments within everyday practices," *Journal of Cleaner Production*, vol. 210, pp. 1435–1448, 2019. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0959652618335443

[9] C. Cicatiello, S. Franco, B. Pancino, and E. Blasi, "The value of food waste: An exploratory study on retailing," *Journal of Retailing and Consumer Services*, vol. 30, pp. 96–104, 2016. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0969698916300078

[10] M. Boulet, A. C. Hoek, and R. Raven, "Towards a multi-level framework of household food waste and consumer behaviour: Untangling spaghetti soup," *Appetite*, vol. 156, p. 104856, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0195666320301537

[11] V. Filimonau, J. Matute, M. Kubal-Czerwińska, K. Krzesiwo, and M. Mika, "The determinants of consumer engagement in restaurant food waste mitigation in Poland: An exploratory study," *Journal of Cleaner Production*, vol. 247, p. 119105, 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0959652619339757

[12] A. Heidari, F. Mirzaii, M. Rahnama, and F. Alidoost, "A theoretical framework for explaining the determinants of food waste reduction in residential households: a case study of Mashhad, Iran," *Environmental Science and Pollution Research*, vol. 27, no. 7, pp. 6774–6784, Mar. 2020. [Online]. Available: http://link.springer.com/10.1007/s11356-019-06518-8

[13] K. Schanes, K. Dobernig, and B. Gözet, "Food waste matters - A systematic review of household food waste practices and their policy implications," *Journal of Cleaner Production*, vol. 182, pp. 978–991, May 2018. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0959652618303366

[14] S. Attiq, M. Danish Habib, P. Kaur, M. Junaid Shahid Hasni, and A. Dhir, "Drivers of food waste reduction behaviour in the household context," *Food Quality and Preference*, vol. 94, p. 104300, Dec. 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S095032932100183X

[15] W. Leal Filho, A. Lange Salvia, B. Davis, M. Will, and S. Moggi, "Higher education and food waste: assessing current trends," *International Journal of Sustainable Development & World Ecology*, vol. 28, no. 5, pp. 440–450, 2021.

[16] C. Fisher, *DESIGNING GAMES FOR CHILDREN*. TAYLOR & FRANCIS LTD, 2015, accessed on: 2023-01-20.

[17] P. Lacasa, *Learning in Real and Virtual Worlds*. Palgrave Macmillan US, 2013, accessed on: 2023-01-21. [Online]. Available: http://link.springer.com/10.1057/9781137312051

[18] M. Hosťovecký, I. Salgovic, and R. Viragh, "Serious game in science education: How we can develop mathematical education," in *Serious Game in Science Education: How we can Develop Mathematical Education*, 11 2018, pp. 191–196, accessed on: 2023-01-24.

[19] E. Fraj-Andrés, C. Herrando, L. Lucia, and R. Perez, "Informative initiatives as a useful tool to raise awareness of food waste. an application to higher education," *Informative initiatives as a useful tool to raise awareness of food waste. An application to higher education*, vol. 24, pp. 840–858, 02 2023.

[20] E. Graham-Rowe, D. C. Jessop, and P. Sparks, "Identifying motivations and barriers to minimising household food waste," *Resources, conservation and recycling*, vol. 84, pp. 15–23, 2014.

[21] R. Portuguesa. (2018) Plano de ação - Índice de medidas. Accessed on: 2022-12-28.

[22] G. de Portugal, "Prevenir desperdÍcio alimentar um compromisso de todos!" *PREVENIR DESPERDÍCIO ALIMENTAR UM COMPROMISSO DE TODOS!*, 10 2014, accessed on: 2022-09-02.

[23] (2019) Annual food service compliance of policy 6700. Accessed on: 2022-12-29.

[24] M. Hugon, A. Gonçalves, I. Zambujal, R. G. de Sousa, J. Peixoto, C. Bakker, A. M. Magalhães, I. Alçada, and C. Nazareth. (2015, 5) Livros infantis de combate ao desperdício alimentar. Accessed on: 2022-09-16. [Online]. Available: https://zerodesperdicio.pt/livros-infantis-combateaodesperdicioalimentar/

[25] B. Trindade, *Desperdício Zero à Mesa com o Pingo Doce*, 1st ed., M. Costa, Ed. Pingo Doce, 9 2020, accessed on: 2022-09-04.

[26] U. C. o Desperdício. (2020) Livro contra o desperdicio - receitas & dicas sustentáveis. Accessed on: 2022-09-03. [Online]. Available: https://livrocontraodesperdicio.pt/

[27] M. Sofia and M. Correia, "Sensibilizar para o desperdício alimentar: impacto de um jogo online em alunos do 1.º ceb," 2017, accessed on: 2022-09-05.

[28] E. Linhares and M. Correia, "Reduzir o desperdício alimentar: aprender e sensibilizar através de um jogo online reduce food waste: learn and raise awareness through an online game," *Reduzir o desperdício alimentar: aprender e sensibilizar através de um jogo online Reduce food waste: learn and raise awareness through an online game*, vol. 11, 2019, accessed on: 2022-09-05. [Online]. Available: http://www.eduser.ipb.pt

[29] K. S. Fjællingsdal and C. A. Klöckner, "Gaming green: The educational potential of eco – a digital simulated ecosystem," *Frontiers in Psychology*, vol. 10, p. 2846, 12 2019, accessed on: 2023-01-26.

[30] F. M. M. Lucas, "The game as an early childhood learning resource for intercultural education," *Procedia - Social and Behavioral Sciences*, vol. 237, pp. 908–913, 2 2017, accessed on: 2023-01-24.

[31] B. Sawyer. (2002) Improving public policy through game-based learning and simulation. Accessed on: 2023-01-26. [Online]. Available: https://www.wilsoncenter.org/publication/executive-summary-serious-games-improving-public-policy-through-game-based-learning-and

[32] I. Dwipayana and I. Sukajaya, "Delta's adventure: A constructivism-based serious game for the 1 st grade of elementary school students on inequality concept," in *2020 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM)*. IEEE, 2020, pp. 127–131.

[33] A. Calvo-Morata, C. Alonso-Fernández, M. Freire, I. Martínez-Ortiz, and B. Fernández-Manjón, "Serious games to prevent and detect bullying and cyberbullying: A systematic serious games and literature review," *Computers & Education*, vol. 157, p. 103958, 2020.

[34] L. Panagiotopoulou, N. Cía Gayarre, G. W. Scurati, R. Etzi, G. Massetti, A. Gallace, and F. Ferrise, "Design of a serious game for children to raise awareness on plastic pollution and promoting pro-environmental behaviors," *Journal of Computing and Information Science in Engineering*, vol. 21, no. 6, 2021.

[35] M. D. Hanus and J. Fox, "Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance," *Computers and Education*, vol. 80, pp. 152–161, 2015, accessed on: 2023-01-24.

[36] J. R. Tudge and P. A. Winterhoff, "Vygotsky, Piaget, and Bandura: Perspectives on the Relations between the Social World and Cognitive Development," *Human Development*, vol. 36, no. 2, pp. 61–81, Jan. 2010. [Online]. Available: https://doi.org/10.1159/000277297

[37] C. Obikwelu and J. C. Read, "The serious game constructivist framework for children's learning," *Procedia Computer Science*, vol. 15, pp. 32–37, 1 2012, accessed on: 2023-01-24.

[38] B. Barry, "Sustainability and intergenerational justice," *Theoria*, vol. 44, no. 89, pp. 43–64, 1997, accessed on: 2023-01-24.

[39] A. Cutter-Mackenzie and D. Rousell, "Education for what? shaping the field of climate change education with children and young people as co-researchers," *Children's Geographies*, vol. 17, no. 1, pp. 90–104, 2019, accessed on: 2023-01-24. [Online]. Available: https://doi.org/10.1080/14733285.2018.1467556

[40] F. F. Loss, "Waste and the right to adequate food: Making the connection," *FAO: Rome, Italy*, vol. 1, 2018.

[41] R. S. Pinto, R. M. D. S. Pinto, F. F. S. Melo, S. S. Campos, and C. M.-d.-S. Cordovil, "A simple awareness campaign to promote food waste reduction in a University canteen," *Waste Management*, vol. 76, pp. 28–38, Jun. 2018. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0956053X18301107

[42] M. Cardenas, S. Joshi, and A. Vergara. (2010) Stopfoodwaste blog. Accessed on: 2022-09-03. [Online]. Available: https://stopfoodwaste.org/

[43] S. V. Russell, C. W. Young, K. L. Unsworth, and C. Robinson, "Bringing habits and emotions into food waste behaviour," *Resources, Conservation and Recycling*, vol. 125, pp. 107–114, Oct. 2017. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S092134491730160X

[44] A. Druin, "Children as codesigners of new technologies: valuing the imagination to transform what is possible." *New directions for youth development*, vol. 2010, pp. 35–43, 2010, accessed on: 2022-10-29.

[45] M. da Educação. (2019) Recursos educativos digitais e abertos (reda) | apoio às escolas. Accessed on: 2022-09-27. [Online]. Available: https://apoioescolas.dge.mec.pt/recursos/recursos-educativos-digitais-e-abertos-reda

[46] D.-G. da Educação. (2022) Ilha periscópio. Accessed on: 2022-09-26. [Online]. Available: https://redge.dge.mec.pt/ilha/

[47] A. Ferreira and D. Brandão, "Tony waste: A serious game to fight food waste museum of ransom view project," 2019, accessed on: 2022-09-28. [Online]. Available: https://www.researchgate.net/publication/351736759

[48] J. Kanonik and Z. Boudreau. (2022) Upcycle: A game about food waste | 2022 d&ad new blood winner | ustwo & play4theplanet | d&ad. Accessed on: 2022-10-27. [Online]. Available: https://www.dandad.org/awards/new-blood/2022/ustwo-play4theplanet/4055/upcycle-a-game-about-food-waste/

[49] A. D. Titiu, "Designing a gamified application to promote food waste awareness in household and further educate consumers on their food waste behavior," 7 2019, accessed on: 2022-09-06.

[50] P. Markopoulos, J. C. Read, S. MacFarlane, and J. Höysniemi, "Chapter 12 - the wizard of oz method," in *Evaluating Children's Interactive Products*, ser. Interactive Technologies, P. Markopoulos, J. C. Read, S. MacFarlane, and J. Höysniemi, Eds. Burlington: Morgan Kaufmann, 2008, pp. 218–233. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780123741110000128

[51] J. F. J. Kelley, "Wizard of oz (woz): A yellow brick journey," *J. Usability Studies*, vol. 13, no. 3, p. 119–124, may 2018.

[52] A. Druin, "Copyright page," in *Mobile Technology for Children*, A. Druin, Ed. Boston: Morgan Kaufmann, 2009, p. iv, accessed on: 2023-01-24. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B978012374900000017X

[53] J.-E. Lee, "Prospective elementary teachers' perceptions of real-life connections reflected in posing and evaluating story problems," *Journal of Mathematics Teacher Education*, vol. 15, pp. 429–452, 2012.

[54] A. Kano, M. Horton, and J. C. Read, "Thumbs-up scale and frequency of use scale for use in self reporting of children's computer experience," in *Proceedings of the 6th Nordic Conference on Human-Computer Interaction Extending Boundaries - NordiCHI '10*. Reykjavik, Iceland: ACM Press, 2010, p. 699, accessed on: 2022-12-31. [Online]. Available: http://portal.acm.org/citation.cfm?doid=1868914.1869008

[55] M. Naftis, G. Tsatiris, and K. Karpouzis, "How Camera Placement Affects Gameplay in Video Games," Sep. 2021, arXiv:2109.03750 [cs]. [Online]. Available: http://arxiv.org/abs/2109.03750

[56] "Blueprints Visual Scripting." [Online]. Available: https://docs.unrealengine.com/5.1/en-US/blueprints-visual-scripting-in-unreal-engine/