

**ARCS**  
**An Augmented Reality Consumption Reducing App**

By  
Jingpo Li

A thesis exhibition presented to OCAD University  
in partial fulfillment of the requirements for the degree of  
Master of Design in Digital Futures

Toronto, Ontario, Canada, 2020

## Abstract

Climate change is a “wicked” problem resulting from overconsumption. This thesis illustrates the importance of addressing sustainable consumption and aims toward helping consumers change their shopping patterns and live a sustainable life in the long run. AR may help in increasing environmental awareness of consumption, providing available information on sustainable consumption, and ways to reduce the Value-Action Gap through the design of AR Consumption Reducing System. By employing the mixed methodology of Research Through Design and Speculative Design, a prototype AR tool with an engagement system for sustainable consumption decision making named ARCS (AR Consumption Reducing App )was developed. Two personas were developed following the speculative design methodology in order to show how the prototype could lead from a probable and plausible to a preferred future.

**Keywords:** Augmented Reality, Reducing, Sustainable Consumption, Sustainable Consumption Awareness, Consumption Behavior Awareness, Value-Action Gap, Engagement System, Speculative Design, Research Through Design.

## Acknowledgements

I would like to express my sincere thanks to my advisors, Alexis Morris and Adam Tindale. Thank you for your kind, patience, guidance, encouragement and continuous guidance. I appreciate both of you have great but very different ways of thinking, and gave me inspirations on my thesis from different angles. If possible, I sincerely want to put this page in the most prominent position of my thesis, because without your patient help and guidance, I would not have this thesis with my own effort. Although the time of each meeting was limited, my thesis was inspired by your thoughts and, most importantly, I learned something that could not be found anywhere else. In the process of talking with you, what I feel and learn is your logical thinking, learning method, and the ways how you solved the problems. As a result, I have developed a lot of good study and research habits. I will look up the meaning of each proper noun that I don't understand to determine whether I have a correct interpretation of an idea; I will use mind maps, diagrams, or models to summarize and clarify my thoughts; I know how to research and identify valuable literature, and so on. In my future study and work, I will not forget your help trying to cultivate my own systematic logical thinking and summarize my own methodology.

# Table of Contents

Abstract.....	2
Acknowledgements.....	3
Table of Contents.....	4
List of Figures.....	8
Chapter 1: Introduction.....	9
1.1 Motivation.....	9
1.2 Augmented Reality as a possible aid to sustainability.....	12
1.3 Research Summary .....	13
1.4 Chapter Overview .....	15
Chapter 2: Literature review .....	16
2.1 Augmented Reality .....	18
2.1.1 What is Augmented Reality? .....	18
2.1.2 History of Augmented Reality.....	18
2.1.3 Current Trend of Augmented Reality .....	19
2.2 Reducing .....	21
2.2.1 The Concept of Reducing .....	21

2.2.2 Environmental Impact on Household Consumption.....	21
2.2.3 Product's Environmental Cost .....	22
2.2.4 Reducing and Economic Sustainability .....	24
2.2.5 AR in sustainability: Immersive Experience and Empathy .....	25
2.3 Sustainable Consumption.....	27
2.3.1 The Concept of Sustainable Consumption.....	27
2.3.2 Consumers' Awareness on Consumption Behavior .....	27
2.3.3 Consumers' Knowledge on Sustainable Consumption.....	29
2.3.4 The role of education in increasing sustainable consumption awareness.....	30
2.3.5 AR in Education: Knowledge and Awareness.....	31
2.4 Value-action gap .....	32
2.4.1 The Concept of Value-Action Gap .....	32
2.4.2 The Value-Action Gap for Sustainable Consumption .....	32
2.4.3 Why do people have the Value-Action Gap? .....	33
2.4.4 How to reduce the Value-Action Gap using AR technology? .....	34
2.4.5 AR in gaming: Engagement and Motivation .....	35
2.5 Summary .....	37
Chapter 3: Research Methodology.....	38
3.1 Research Through Design.....	39
3.2 Speculative Design.....	41

3.3 Persona.....	43
3.4 Research Methods Flowchart.....	44
Chapter 4: Early Development of AR Prototypes.....	46
4.1 Prototype 1: A Recycling AR Game.....	47
4.2 Prototype 2: An AR Consumption Reducing App.....	58
Chapter 5: Final Prototype and Evaluation.....	68
5.1 Final Prototype.....	68
5.1.1 Final Prototype Design .....	68
5.1.2 Final Prototype Making .....	75
5.2 Evaluating Speculations.....	82
5.2.1 Future Scenarios and Personas Building .....	82
5.2.2 Testing and Evaluation .....	88
5.2.3 Reflection.....	92
Chapter 6: Concluding Remarks.....	95
6.1 Thesis Goal .....	95
6.2 Contributions and Limitation.....	95
6.3 Future Work .....	96
6.4 Final Thoughts .....	98
Works Cited .....	100
Appendices.....	110

	7	
Appendix A. 12 possible future scenarios.....		110
Appendix B. Four Personas.....		114

# List of Figures

Figure 1 Research Methods Flowchart .....	44
Figure 2 5 environmental protection apps. ....	48
Figure 3 10 popular AR games. ....	50
Figure 4 Scan this water bottle. ....	52
Figure 5 Learn how to recycle this water bottle. ....	52
Figure 6 Get reward from recycling right. ....	53
Figure 7 Digital prototype built with TORCH_2D objects and video. ....	54
Figure 8 Digital prototype built with TORCH_3D objects and 3D scenarios .....	55
Figure 9 Paper prototype testing. ....	57
Figure 10 AR Consumption Reducing System .....	59
Figure 11 User Journey Map. ....	61
Figure 12 Challenges and possible solutions from user journey map. ....	62
Figure 13 User Flow Chart. ....	63
Figure 14 Wireframe Design. ....	64
Figure 15 Digital prototype building in Unity. ....	65
Figure 16 Digital prototype testing. ....	66
Figure 17 Design Goal. ....	69
Figure 18 Design Requirements. ....	70
Figure 19 Information Architecture. ....	70
Figure 20 The corresponding system of each function. ....	71
Figure 21 Wireframe Design. ....	74
Figure 22 Final Prototype. ....	77
Figure 23 Step 1_Knowledge sharing system. ....	78
Figure 24 Step 2_Environmental cost calculation system. ....	78
Figure 25 Step 3_Engagement system. ....	79
Figure 26 Testing in the grocery shopping scenario. ....	80
Figure 27 12 possible future scenarios. ....	83
Figure 28 12 possible future scenarios. ....	85
Figure 29 Persona_Emily. ....	86
Figure 30 Persona_Josh. ....	87
Figure 31 Evaluation_Emily. ....	93
Figure 32 Evaluation_Josh. ....	93



# Chapter 1: Introduction

## 1.1 Motivation

Many of the global issues we are facing today are the result of these two challenges:

Environmental problems and resource problems. Most people do not realize that excessive consumption is the main reason for those two problems. If we change our consumption habits, this would have a drastic effect on our environmental footprint. Several promising approaches have been developed in the past few years, one of them is the “3 R’s” system in waste management. “3 R’s” (Reduce, Reuse, and Recycle) is one of the most common and popular rules of waste management. “3 R’s” system “were proposed with priority on source minimization, intermediate treatment then final disposal and enlighten the waste generators to practice “3 R’s” s as a substantial measure to reduce, reuse and recycle the generated solid waste there all day” (Jibril, Jibril Dan Azimi, et al., 626). However, the facts show that we are not doing very well and that the amount of garbage is still growing at an alarming rate. “In 2016, the world generated 242 million tonnes of plastic waste”(Kaza, Silpa, et al., 13)

At the beginning, my thesis was focusing on recycling. Recycling is an approach to change or transform waste into raw materials that can be reused to create new objects. Recycling systems are different throughout countries and states. Then, I realized that reducing might be preferable to either reusing or recycling. Ivanova, Diana, et al. states that the emissions of carbon dioxide and other greenhouse gases are good indications of a country's consumption, because products cause environmental impacts along its whole life cycle(38-40). In addition, the process of reusing and recycling has an additional monetary and environmental cost. Not everything can

be recycled because of equipment technological difficulties and material physical limitations (Laustsen, 1-4).

**First problem with reducing:** People might not have enough awareness of the environmental impact on their consumption behavior. In other words, some people do not understand why we have to reduce. Some people often choose to believe messages led by marketing and advertising that make them feel guilt-free. For example, Starbucks advertises itself as using eco-friendly paper cups, so some people may feel free to drink Starbucks and ignore the environmental facts behind those paper cups, plastic straws, plastic caps. “Starbucks’ cups can be recycled under the right circumstances, they usually are not. Most facilities don’t recycle paper cups because to do so, they would have to separate the cups’ plastic lining from the paper. Many recyclers find that process to be more trouble than it’s worth.”(CNN.com, February 27, 2019) Paper cups need a plastic lining to be waterproof, and that lining is polyethylene. However, “PLA recycling depends on the development of plastic sorting systems, which are not currently available. ” Recyclable cups are hard to be composted or recycled if the rest of the system doesn’t change (Lee, 4).

**Second problem with reducing:** With the continuous upgrading of consumption level, some people don't have enough awareness of their unconscious consumption behavior, and they also do not have enough knowledge, available information, or advice on sustainable consumption. In other words, some people do not know how to reduce. Let's take Starbucks coffee as an example. Most people cannot answer the following questions: “How many cups of coffee I am consuming last week?”, “How do I compare my consumption of coffee to the average level?”, “Did I drink

up all of the coffee I bought?”. The statistics are staggering. From investopedia news on Mar 9, 2020, “Starbucks operates in 78 markets with almost 30,000 locations”(Farley). According to the Telegraph, around 7 million paper coffee cups are sold each day and 2.5 billion every year in Great Britain (Turner).

**Third problem with reducing:** People need triggers or incentives to transform attitudes to behavior, actively reducing their own consumption in practices. “When people decide to change their behavior, it is related to very complex processes such as stimulus, perception, memorization, recognition, motivation, action and so on.” (Lee, 10). In occasions when people are in great need of a cup of coffee to refresh themselves in the mornings, when they are very thirsty walking on the street, or when they smell the aroma of coffee beans and are very eager to get a bite, what stop them drinking or switching from paper cups to their own coffee cups? They need an incentive to finally turn their attitude into action when purchasing, and they also need positive feedback to encourage them to stick with it in the long run and thus develop new good habits.

## 1.2 Augmented Reality as a possible aid to sustainability

AR “refers to display systems where computer generated images are either analogically or digitally overlaid onto live or stored video images.” (Milgram, et al., 284).

It could be understood as a scenario that real surroundings are augmented by virtual objects (Milgram, et al.): the superposition of 3D content and information such as text, pictures and videos are put into the real world by computing devices. Successful AR application, like Ikea Place app, avoids the situation where people want to purchase furniture but discover it does not work in the place once it was delivered.<sup>1</sup> The Gatwick airport passenger app helps passengers navigate through the airport by using the AR maps from their mobile phone.<sup>2</sup>

There are a lot of application software that are designed for promoting environmental protection. AR technology, as an empathy tool, can positively influence people by creating an immersive experience, which has great potential in sustainability. Besides, everyone heavily depends on smartphones. From the point of view of portability and mobility, mobile phones now are light, portable and easy to operate. AR glasses, smart watches, and other wearables won't replace cell phones within a short period of time. Today's technology ensures AR runs quickly on smartphones. Therefore, one of the solutions could be an Augmented Reality (AR) mobile application addressing the reducing strategy.

---

<sup>1</sup> Pardes, Arielle. “Ikea's New App Shows the Practical Promise of Augmented Reality.” Wired, Conde Nast, 20 Sept. 2017, [www.wired.com/story/ikea-place-ar-kit-augmented-reality/](http://www.wired.com/story/ikea-place-ar-kit-augmented-reality/).

<sup>2</sup> Koolonovich, Nikolai. “Gatwick's Augmented Reality Passenger App Wins Awards.” VRFocus, [www.vrfocus.com/2018/05/gatwick-airportsaugmented-reality-passenger-app-wins-awards/](http://www.vrfocus.com/2018/05/gatwick-airportsaugmented-reality-passenger-app-wins-awards/).

## 1.3 Research Summary

### **Problem Statement**

We don't have a good solution for effectively increasing public environmental awareness, promoting sustainable behavior, and changing consumers' habits when facing the increasingly serious environmental problems.

### **Hypothesis**

AR, as an emerging technology, has the possibility of increasing public awareness of environmental impact on unconscious consumption, spreading knowledge and providing support on sustainable consumption behavior, transforming consumer' incentive into behavior in practices, and possibly involving consumption patterns and lifestyle change in the future.

### **Research Questions**

- Main research question:

How can AR technology help to increase people's awareness of their consumption behavior and sustainable consumption practices, and how AR (with an engagement system) can provide options and incentives to help to reduce the Value-Action Gap in practices?

- Sub research questions:

1. How to design an environmental cost calculation system which can be used to increase people's awareness of their consumption impact?
2. How to design a knowledge sharing system that increases people's awareness of their consumption behavior and to acquire knowledge on sustainable consumption?

3. How to design an AR engagement system based on the knowledge sharing system and cost calculation system, which can be used to transform attitude to action making better consumption decisions?

### **Research Goal**

To build an example AR Consumption Reducing System(ACRS) to explore the possibility of AR technology in increasing people's awareness of their consumption impact on environment protection, and using AR engagement systems to help users to make better consumption decisions.

### **Research Objectives**

- Objective 1:

To design an environmental cost calculation system and make use of the system in an AR application.

- Objective 2:

To design a knowledge sharing system about product consumption that uses AR technology.

- Objective 3:

To design an AR engagement and reward system based on the knowledge sharing system and cost calculation system.

## 1.4 Chapter Overview

This chapter introduced the AR consumption reducing project, including the inspiration behind it as well as the research questions, research goals, and research objectives.

Chapter 2 begins with a literature review that addresses several important points. It introduces AR technology by defining its concept and discussing this technology in chronological order. The concept of reducing will be introduced. From the perspective of the consumer, this chapter then talks about awareness on consumption behavior and sustainable consumption and phenomenon of value-action-gap.

Chapter 3 discusses the adopted methodology to create the AR Consumption Reducing App. The use of a mixed methodology of Research Through Design and Speculative Design will be used in designing AR Consumption Reducing App. A research method flow chart will be presented at the end.

Chapter 4 documents the whole process of my prototype iteration in chronological order from prototype 1, the Recycling AR Game, to prototype 2, the AR Consumption Reducing App, and how each of them contributes to the final project.

Chapter 5 presents the designing and making process of my final project. After presenting the final output that was generated from the literature review and previous prototypes, I evaluate my speculative work by building scenarios of possible futures and personas.

Chapter 6 concludes this thesis by revisiting its goals and contributions, discussing potential futuristic technological advancement, and highlighting the future work and possibilities of the AR Consumption Reducing Application in possible futures.

## Chapter 2: Literature review

My thesis begins with the literature review that addresses several important points.

It introduces AR technology by defining its concept within the Mixed Reality framework and discussing this technology in chronological order. In chapter 2.2, I present the concept of reducing as a general overview, and illustrate that most people do not realize that reducing occupies a very important role in environmental protection: Household consumption has a huge impact on the environment. By examining each stage of products' life cycle and giving an example of environmental cost calculation of plastic water bottles, I suggest that products cause environmental impacts along its whole life cycle, and the best solution for that is to reduce the amount we use to reduce the amount to be reused or recycled in the first place. There are two ways of reducing: to use fewer inputs of raw materials and energy to achieve established production goals, and to reduce total consumption. However, in the context of economic sustainability, reducing doesn't mean reducing consumption level but promoting sustainable consumption from the perspective of consumers: one way is to redefine people's demand and reduce their unnecessary consumption without changing lifestyle. Another way is to choose alternatives (goods or services) with lower energy consumption and lower waste emissions to live a more sustainable life. To illustrate the capability of AR as an empathy tool with the use of immersive technology, I introduce current AR applications in sustainability.

Then, this chapter discusses that people do not have enough awareness of unconscious consumption behavior and are lack of knowledge on sustainable consumption. The way of helping people in redefining demand and reducing unnecessary consumption is to increase awareness of consumers' consumption behavior by 1) letting consumers be aware of their own



consumption behavior, 2) and telling them how much resource is actually needed to live a sustainable life. The way of helping people in choosing environmentally friendly alternatives is to inform environmental knowledge and to provide available information on choosing products and companies. This chapter also highlights education's role in environmental protection. To explore the possibility of AR technology in increasing public awareness, this chapter includes a case study of AR technology used in education.

Though positive environmental attitudes and available information on sustainable consumption are positively correlated with environmental behavior, there is a Value-Action Gap where people act in a manner that is inconsistent with their personal attitude on the environment. In Stewart Barr's model, both situational variables and psychological variables are influencing the transformation between values and action (50). *Assuming that people already have a good understanding of their consumption behavior and have enough awareness, knowledge and information on sustainable consumption (for example, lack of information and intrinsic motivation are not factors), I argue that people need triggers (from Fogg Behavior Model) to transform awareness into action, followed by a case study of AR game with an engagement and reward system, Pokémon Go.*

## 2.1 Augmented Reality

### 2.1.1 What is Augmented Reality?

Augmented reality technology links the real world and virtual world "seamlessly". Physical and digital objects can coexist and interact in real time in a new visual environment. *“An AR system supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world. While many researchers broaden the definition of AR beyond this vision, we define an AR system to have the following properties: 1) combines real and virtual objects in a real environment; 2) runs interactively, and in real time; and 3) registers (aligns) real and virtual objects with each other”* (R. Azuma, et al., 34). The real world and the augmented environment can interact simultaneously, allowing users to perform different digital operations. Milgram, et al. talk about augmented reality in the framework of mixed reality, which includes both augmented reality and augmented virtuality. Mixed reality includes augmented reality and augmented virtuality (4).

### 2.1.2 History of Augmented Reality

In 1966, Ivan Sutherland, the father of computer graphics and augmented reality, developed the first augmented reality system. In 1992, the term “augmented reality” was officially born. Tom Caudell, a researcher at Boeing, and his colleagues developed the head-mounted display. In 1994, AR technology was first put to artistic use (Isberto). *“For the next few decades much research was done on getting computers to generate graphical information, and the emerging field of interactive computer graphics began to flourish. Photorealistic computer-generated*

*images became an area of research in the late 1970s, and progress in tracking technology furthered the hopes to create the ultimate simulation machine. The field of VR began to emerge.”*

(Craig, 2) In 2000, Hirokazu Kato from the Nara Institute of Science and Technology in Japan developed the first AR open source framework: the ARToolKit. In 2009, Esquire magazine used augmented reality in their print media and ARToolKit made augmented reality available to Internet browsers (Isberto). In April 2012, Google announced the company's glass augmented reality eyewear project (Trefis).

### 2.1.3 Current Trend of Augmented Reality

In order to find a suitable development platform for an AR project, I analyzed the existing AR technology and its development trends trying to find technology I can refer to in my prototyping.

**AR Mobile Display Device.** As mentioned by Craig et al, AR has multiple methods of augmenting the visual sense: “these can be head-worn displays, mobile hand-held displays, or displays integrated into the physical world. Other senses (hearing, touch, or smell) can also be potentially augmented.” (Craig, 4) In recent years, smart mobile devices have developed rapidly. Most existing smart handheld devices are equipped with cameras, global positioning system (GPS), gyroscopes, accelerometers and other sensors, as well as large high-resolution display screens. This provides a good development platform for mobile augmented reality (Daniel and Dieter, 221).

**Touch based interaction technology.** Touch-based interactive technology is a human-oriented input technology, which is more user-friendly than traditional keyboard and mouse input. The popularity of smart mobile devices has led to the rapid development of touch-based interactive technology, which is more easily recognized and used (Juny, et al., 17). In recent years, touch-based interaction technology has been developed from single touch to multi-touch, realizing the transformation from single finger click to multi-point or multi-user interaction (Hardy, Robert, and Enrico Rukzio, 2).

## 2.2 Reducing

### 2.2.1 The Concept of Reducing

The principle of reducing material consumption(reducing) requires the use of fewer inputs of raw materials and energy to achieve established production or consumption objectives. Hence, people need to pay attention to resource conservation and pollution reduction at the first place among all economic activities (Sakai, et al., 87; Jibril, Jibril Dan Azimi, et al., 628-630). The principle of reducing has two aspects:

From the side of production, the principle of reducing is expressed as to use fewer inputs of raw materials and energy to achieve established production or consumption goals. Reducing resource consumption through technological advances, improvements in production processes, or environmentally friendly designs. It may increase economic growth but it depends on the emergence of environmentally friendly technologies. From the side of the customer, the principle of reducing is to reduce total household consumption, but the reduction of total consumption may reduce the economic growth rate. (Kalmykova, Yuliya, et al., 70-80; Xu, 2)

### 2.2.2 Environmental Impact on Household Consumption

Climate change is the result of household overconsumption, but most people do not realize that reducing occupies a very important role in environmental protection. Ivanova, Diana, et al. analyze the environmental impact of household consumption in terms of the raw material, land,

freshwater, and greenhouse gas (GHG) emissions. In their research, they indicate that footprint is related to the amount of household expenditure and write,

a comprehensive insight into the global environmental impacts by households. It highlights the significance of environmental pressure arising from households, with their consumption giving rise to more than 60% of global GHG emissions and between 50% and 80% of total resource use. A significant portion of the emissions and resource use are embodied in internationally traded commodities.”(532)

The global material footprint of households amounts to 48% of the total raw materials that were extracted and used that year; Around 70% of the global land use was because of household purchases; Household consumption amounts to 81% of the total use of freshwater (528-532).

Household consumption is highly related to environmental resource problems and environmental pollution.

### 2.2.3 Product's Environmental Cost

To understand why consumption behavior is more responsible for environmental problems among all human activities, I read literature on product life cycles assessment.

**Product Life Cycle Assessment.** “Over the past few decades, life cycle assessment (LCA) has been established as a critical tool for the evaluation of the environmental burdens of chemical processes and materials cycles.” (Antelava Plastics, et al., 230) The research started with the article, *Politics and the plastic crisis: A review throughout the plastic life cycle*, which surveyed more than 180 scientific articles in the field of environmental science and environmental

problems. Product causes environmental impacts throughout its whole life cycle. They investigated the material flows as well as the environmental impacts of the various stages of the plastic life cycle(5). Issa, Isabela, and Tim McAloone also talk about products' life cycle stages and environmental aspects related to each stage. Each stage (pre-manufacturing, manufacturing and design, distribution and packaging, use and maintenance, and end-of-life) implies the input of resources (materials and energy) and generation of waste(solid waste, waste water, gaseous emissions, and energy loss)(30-40). In their research, the product related indicators are chosen from 250 environmental performance indicators (EPIs). They selected product-related EPIs distinguished into input and output indicators. The input indicators are material and energy. The output indicators are solid waste, waste water, gaseous emissions, and energy loss.

**Environmental Cost Analysis on One Single Plastic Water Bottle.** Research shows that the production of plastics is related to fossil feedstock. Throughout the plastic life cycle, approximately 400 million tons of CO<sub>2</sub> rises every year (Nielsen, Tobias D, et al., 3-6), so I choose to take one plastic water bottle as the analysis object and calculate its environmental cost as an example. The environmental calculation system based on the product's life cycle assessment can be applied to more products in the future.

Gironi, et al. analyze the life cycle environmental performance of polylactic acid(PLA) and polyethylene terephthalate bottles(PET) drinking water bottles by covering all relevant process stages from raw material used(crude oil) to the final waste management or recycling of the used packaging. Both PLA and PET are most frequently used renewable materials for recyclable bottles. They compared environmental impact for production, transportations and final destination(with four scenarios) of PLA and PET bottles(463-465).

*The Life Cycle of a Plastic Water Bottle*, written by Angel Water, Inc., walks through the lifecycle of one plastic bottle. Environmental cost calculation for a bottle starts with crude oil. One fourth bottle of crude oil is used to produce each bottle, and one plastic bottle takes triple the amount of water to produce it (Angel).

## 2.2.4 Reducing and Economic Sustainability

In previous sections, we can see through statistics that environmental problems are mostly resulting from overconsumption from the perspective of consumers. Most people do not realize that reducing occupies a very important role in environmental protection. By analyzing products' environmental cost using the LCA model, we can further confirm the important role of reducing environmental protection. The best solution for that is to reduce the amount we use and thus to reduce the amount to be reused or recycled. However, reducing is not simply reducing their consumption level in the context of economic sustainability.

The Office of Sustainability of University of Mary Washington at their home page interprets economic sustainability as “practices that support long-term economic growth without negatively impacting social, environmental, and cultural aspects of the community.” Directly cutting off the consumption will change customers' consumption patterns, which will eventually result in reducing economic growth rate. Decreasing consumption level and the total consumption will have some negative impacts on the economy, which is controversial to the concept of economic sustainability.

In the context of economic sustainability, briefly there are three recommendations for changing household consumption practices that correspond to three types of changes in



consumption level. The first one is to simply replace traditional ones with environmentally friendly products without financial support or changes in lifestyle and consumption patterns. The second one needs to redefine consumer demand and consumer activity. And the third one is consumption reduction, which requires a radical change in lifestyle and a reorganization of consumption activities. In fact, the first two are to reduce material consumption under the condition of keeping the total consumption unchanged or even increasing, which have a positive effect on economic growth (Spangenberg, et al., 127–140; Princen, et al., 33–50).

To summarize, reducing for consumers is to 1) choose alternatives (goods or services) with lower energy consumption and lower waste emissions, and 2) redefine their needs, reduce unnecessary consumption, and form a sustainable consumption pattern without reducing consumption level and changing lifestyle. This will additionally lead consumers to have brand loyalty on environmentally friendly products and companies, which would in turn encourage companies to invest money and resource on environmental issues.

### 2.2.5 AR in sustainability: Immersive Experience and Empathy

Jeremy Bailenson, professor at the Stanford Virtual Human-Computer Interaction Lab, discussed how VR can help create empathy around climate change in the 2016 TED and explained why VR changes human behavior. By setting up control experiments and tracking the results, professor Bailenson has proved that VR has the ability to increase people's awareness and thus influence their behavior (It was found that the group using VR was the group most affected by the study and reduced the paper consumption by 20% after the experiment). Both VR

and AR are empathy tools with the use of immersive technology, so that AR may also help people relate to each other better than words, papers or films.<sup>3</sup>

Adidas has partnered with eyecandylab and MONOCHROME to develop an app called "For The Oceans" that allows customers to experience the immersive AR marine world in the adidas store. When opening "For The Oceans" and placing the phone in front of the big screen, a huge whale will appear on the screen with a lot of plastic garbage floating in the surrounding water. Customers can then experience the entire process of Adidas environmentally-friendly shoemaking.<sup>4</sup>

Other interesting uses of immersive technology include White Noise, an AR installation that was built from passion about an environmental issue, climate change. They really wanted to tell an impact story through the lens of AR and data.<sup>5</sup> There is also an app that supports iOS and Android devices that have launched a new AR experience, called "Inside the Amazon: The Dying Forest" promising to take users deep into the disappearing rainforest. *Time Magazine* sent two producers and journalists, Matt Sandy, to the Amazon to explore remote areas threatened by deforestation while using a drone to scan the environment in 3D (Time.com, September 12, 2019).<sup>6</sup>

---

<sup>3</sup> TED Archive. "Can VR help create empathy around climate change? Jeremy Bailenson." YouTube, 22 Dec. 2016, <https://www.youtube.com/watch?v=zJCD3R3LISs&t=8s>.

<sup>4</sup> eyecandylab. "eyecandylab x adidas | For The Oceans." YouTube, 19 Nov. 2019, <https://www.youtube.com/watch?v=ObeW9VOdW4o>.

<sup>5</sup> Paper Triangles. "White Noise AR Installation." YouTube, 11 Oct. 2017, [https://www.youtube.com/watch?v=GWlfp8\\_iulc&t=22s](https://www.youtube.com/watch?v=GWlfp8_iulc&t=22s).

<sup>6</sup> Person. "Go Inside the Amazon Rain Forest With TIME's AR Experience." Time, Time, 12 Sept. 2019, [time.com/longform/inside-amazon-rain-forest-vr-app/](https://time.com/longform/inside-amazon-rain-forest-vr-app/).

## 2.3 Sustainable Consumption

### 2.3.1 The Concept of Sustainable Consumption

From Wikipedia, sustainable consumption is “the use of material products, energy and immaterial services in such a way that it minimizes the impact on the environment, so that human needs can be met not only in the present but also for future generations”(“Sustainable consumption”) Sustainable consumption is often related to sustainable lifestyle and sustainable production. There are two approaches to achieve the goal of sustainable consumption: First is to increase efficiency of consumption and the second is to change the consumption levels, shopping patterns and lifestyle of people who share a large ecological footprint(Lange, et al., 81-100).

### 2.3.2 Consumers’ Awareness on Consumption Behavior

In the context of sustainability, simply reducing consumption level and changing in consumption patterns will not work. As I mentioned in previous section, there are two ways for consumers to reduce consumption under the condition of keeping the total consumption unchanged or even increasing, which have a positive effect on economic growth: One of them is to redefine their demand and reduce unnecessary consumption to form sustainable consumption patterns without reducing consumption level and changing lifestyle.

I think the criteria of “redefine demand” is 1) to be aware of one’s own unconscious consumption behavior, 2) and to learn how much resource is needed to live a sustainable life.

For a long time, economists and psychologists have regarded consumers as conscious decision makers that “Each option in a choice set is assumed to have a utility, or subjective value, that depends only on the option” (Bettman, et al., 187). In addition to conscious thought, however, humans also have a lot of unconscious thought. Unconscious thought is defined as “cognitive and/or affective task-relevant processes that take place outside conscious awareness” (Dijksterhuis, Ap, and Zeger Van Olden, 586). Unconscious consumption behavior mainly refers to consumer's consumption behavior happens when consumers are exposed to a large amount of information about available goods, so their attention is given by unrecognized desires, secret thoughts, primitive impulses or instincts(Felix, 292-303). “Only a limited number of choices are based on conscious information processing strategies. The rest of the variance left to explain is caused by unconscious effects of all kinds of subtle cues in the environment”(Felix, 302). In real life, the unconscious consumption behavior mainly appears in the occasions where consumers purchase more frequently, such as supermarkets and convenience stores.

In addition, sometimes people don't even realize that they consume more than they actually need, particularly those in developed countries. “12 percent of the world's population lives in North America and Western Europe and accounts for 60 percent of private consumption spending” (WorldWatch Institute, 2012). The researchers found that the footprints are unevenly distributed across regions, with wealthier countries generating the most impacts per household(Ivanova, Diana, et al., 530-536). According to estimates by the World Wildlife Fund (WWF), high-income countries are responsible for much more footprint than middle-income countries and low-income countries. “Footprint by national average per person income. High-income countries' average per capita footprint more than doubled between 1961 and 2003” (Loh, Jonathan & Goldfinger, Stephen, 18). In reality, most consumers do not have enough awareness

on their consumption behavior, and they also do not know how much they need for a sustainable life.

### 2.3.3 Consumers' Knowledge on Sustainable Consumption

Another way for consumers to reduce material consumption in the context of economic sustainability (under the condition of keeping the total consumption unchanged or even increasing) is to choose alternatives (goods or services) with lower energy consumption and lower waste emissions to live a more sustainable life.

Now, we are not only consuming more than we need unconsciously but also consuming at levels that are not sustainable. This requires consumers to have enough knowledge on sustainable consumption. The problem with that is consumers are not being able to read product labels, to understand the product's environmental profile, to have access to the company's environmental performance, or to have attractive sustainable consumption options offered by the market. That is to say, available information and knowledge about sustainability are the premise of making the right decision. In reality, problems we often encounter is information asymmetry among consumers and retailers: products and companies' information are not open to the public, not transparent, or there is no way to access. "A sufficient implementation of consumer rights, especially of the right to choose and the right to be informed, is a prerequisite for consumers to act responsibly in line with knowledge about sustainability"(Thøgersen, et al., 2). Meanwhile, the information and knowledge cannot be simply spread through text. We need to choose the right media and select useful information to provide services and help at the right time under the right circumstances. "The adequateness of facts to satisfy information needs and to transfer

existing knowledge about sustainable consumption is not only a question of the right content but also of the right way to communicate it with regard to format, timing, and context”(Thøgersen, et al., 2). In brief, knowledge is needed to foster sustainable consumption with a positive impact on sustainability.

### 2.3.4 The role of education in increasing sustainable consumption awareness

Increasing awareness of sustainable consumption through public education could be an effective way of solving the environmental problems. Zhiying in his paper, *reducing material consumption: a literature review on sustainable consumption*, states that Chinese scholars proposed the five factors influencing the realization of sustainable consumption: government, non-governmental organizations, companies, consumers and education. The government is responsible for legislating, enforcing regulations, informing and encouraging innovation. Non-governmental organizations release relevant information to members and the public to put pressure on the government and society. To create and meet consumer needs, the companies produce sustainable products and advertise products to enhance demand. Consumers change their values and attitude towards consumption patterns. Among all these factors, education's role is to transform consumers' values, spread the basic knowledge of sustainable consumption, and explore new possibilities. Education is a prerequisite for consumers to transform attitude and gain knowledge about sustainable consumption, so they can responsibly play their role in environmental protection(3).

### 2.3.5 AR in Education: Knowledge and Awareness

AR applied in education can help learners to gain a deeper understanding of content in the visual world, and to explore content driven by their current environment.

In the journal, *Mobile Augmented Reality for Learning: A Case Study*, Specht, et al. discuss augmented reality educational patterns for supporting certain learning objectives with AR. The purpose for “Dynamic 3D Objects” is to illustrate learning content in 3D, so that learning content can be explored from different perspectives. The purpose of “Augmented Books” and “Real-World Object Scanners” is to give users additional perspectives by extending the user senses range. Educational objectives of “Sensor-Based Layers” are exploration support and immersion support.

**Case study: Magic Book.** One of the first examples of augmented reality in education was “Magic Book”. It creates 3D scenes and animations based on book content, and uses special glasses to allow children to see a combination of virtual and reality (Billinghurst, Mark, et al., 2005). Dünser, et al. used the fable story as learning content to observe and analyze children's learning behavior. Children think that the AR environment is new and interesting, which significantly increases their interest in knowledge. Then, based on the data feedback. They mainly analyze how children build meaningful connections between knowledge and skills in the real world and the AR environment. The research shows that AR interactions are basically the same as those in the real world, and the display effect makes them more interested in reading, and learning content stays longer after reading (305–315).

## 2.4 Value-action gap

### 2.4.1 The Concept of Value-Action Gap

The Value-Action Gap is a psychological phenomenon where people act in a manner that is inconsistent with their personal values. This phenomenon is associated with the environmental protection field, relating to attitude/awareness/intention and behavior surrounding environmental issues (Blake, 256). In that sense, the Value-Action Gap in the context of consumption happens when consumers who say they are concerned about environmental issues but do not necessarily express them in their market behavior. One of the most common phenomena of Value-Action Gap is recycling in the environmental context. There is a gap between how much people say they care about recycling, and how much they are willing to change their behavior and recycle in practice.

### 2.4.2 The Value-Action Gap for Sustainable Consumption

In recent years, the relationship between environmental awareness/attitude/intention and environmental behavior has become a popular research field. A lot of research related to attitude and behavior had been done. Howley, et al. analyzed the survey data of 100 residents in the United States and Hungary, and concluded that environmental attitudes are positively correlated with environmental behavior (248-256). Lopez-mosquera, et al. studied the factors influencing recycling, green buying behavior and car use, and found that environmental attitude was an important factor influencing these behaviors (29-39). However, The success of sustainable



consumption relies on people turning their positive consumption intention into actual sustainable consumption behavior, but this conversion rate is relatively low in reality. The Value-Action-Gap in sustainable consumption is when people's awareness of sustainable consumption increases, but sustainable consumerism has not had the desired results. “A McKinsey survey of consumers in Brazil, Canada, China, France, Germany, India, UK and the US found that 53% were concerned about environmental and social issues, but not willing to take action at the shops; a further 13% were willing to pay more, but currently did not do so”(Roy,17)

### 2.4.3 Why do people have the Value-Action Gap?

Logically, positive environmental values would be expected to lead to an intention to action. Environmental value established from rich environmental knowledge and the strong awareness of sustainable consumption. In that case, consumers have a relatively high intention of sustainable consumption. However, from Conceptual Framework of environmental behavior map by Stewart Barr, there is a gap between the “Environmental values” and “behavior”. From value to action there are two categories of variables: situational variables and psychological variables. Both categories of variables influence behavioral intention and also modify the intention-behavior relationship. Situational variables include enablers and disables, while psychological variables include motivators and barriers.

Young, William, et al. used the depth interview method in investigating sustainable consumption behavior of consumers when purchasing energy-efficient appliances. They found that high price, time pressure, lack of information and environmental awareness are the main

obstacles for consumers to transform positive attitudes into actual behavior. (21-30) Padel, et al. used a focus group interview method in investigating sustainable consumption behavior of consumers when purchasing organic food. They found that high price, product competition, lack of product knowledge and brand certification are the main obstacles for consumers not to buy organic food (611). Newton, et al. conducted a research on 1250 subjects in Australia, and the results showed that there is a gap between consumers' sustainable consumption attitude and behavior, and lack of information, higher prices, lack of time and consumption habits are the reasons for this gap (1229). These case studies show that the value-action gap phenomenon is especially prevalent when acting in accordance with one's beliefs incurs some cost, such as lack of information and money.

#### 2.4.4 How to reduce the Value-Action Gap using AR technology?

In Stewart Barr's model in section 2.4.3, there are two types of variables, situational variables and psychological variables influencing the process of transforming positive attitudes into actual behavior. Since my research is from the perspective of consumers. In other words, regardless of the factors of company, government, and non-profit organization, the main factors, such as price and policy, are not in the research scope. Assuming that people already have a good understanding of their consumption behavior and have enough awareness and knowledge on sustainable consumption, what do people might need to transform awareness into action?

**Trigger.** In 2009, B J Fogg at Stanford university published a model discussing behavior design, called the Fogg's Behavior Model, which helps “turn behavior change from a mass of

psychological theories into something organized and systematic.”(1) This model can be simply a formula:  $B=MAT$ . B(behavior) represents the user's behavior. M(otivation) represents intent and motivation of doing something. (A)bility represents the ease of doing something. T(rigger) is the defining moment. Motivation, ability, and trigger are positively relative to actual behavior. There is a lot of overlap between these two models, Fogg Behavior Model and Stewart Barr Model. M(otivation) to some extent represents psychological variables, and (A)bility represents Situational variables.

People's behavior does not entirely depend on motivation, attitude, or awareness ,but is also affected under the dual effect of social situation and personal factors. If you start people out doing something easy and if they feel a sense of accomplishment of doing that thing, they're much more likely to do it. (Fogg, 1) Briefly, strong motivation and rich knowledge and resources are not the only reasons that lead to actual behavior. To break through the activation threshold, people need triggers, an incentive to transform awareness into actual action.

### 2.4.5 AR in gaming: Engagement and Motivation

**Gamification.** User incentive system is one of approaches to gamification design, and the product incentive system design is often referred to as "gamification design". Gamification is not a new idea which can be seen as a way of designing systems triggering people to transform the intention into action. Achievement badges, for example, have a long history. “The Boy Scouts of America began handing out merit badges in 1911. They understood the motivational power of goals, mastery seeking, reputation, and identity signaling with valued accomplishments.” (Antin, 3) Humans are susceptible to reward, and they show these neurological responses to many types of rewards, including gold points, digital currency, coupons, etc.

**Pokémon Go.** This is a virtual reality game: while the map is real, the Pokémon are virtual. Finding and capturing Pokémon is the player's main task. Pokémon will appear on your map wherever you are. As long as you find a Pokémon, you turn on your phone's camera and swipe the ball under your pet to hit the Pokémon. “Most health apps that promote physical activity tend to get users who want to be healthy. Pokémon Go isn’t marketed as a health app, but players still end up doing a lot of walking”(McCartney, 2) Pokémon Go’s reward and feedback mechanism make people so obsessed with the game. Finding and catching a Pokémon is purely probabilistic. Users never know how far they need to wander before they will find a new Pokémon. The possibility and uncertainty of the game is the trigger that gets players who never move at home to start walking for the day.

## 2.5 Summary

Both environmental problems and resource problems are resulting from overconsumption, since household consumption especially has a huge impact on the environment. Although there are many factors affecting sustainable consumption, including government, enterprises and factories, we not only play a role as consumers but also active voters who have the responsibility and obligation to make changes and contribute to the cause of sustainable development. The literature review provides theoretical basis and inspiration for my prototype design, an AR consumption reducing mobile application aims to help in providing support and solving problems from the perspective of consumers.

From literature review, reducing plays a very important role in sustainability, and sustainable consumption requires us to take environmental protection, energy sustainability, economic sustainability, and food security into account when designing the tool. Literature reviews helped me understand the internal and external problems people are facing related to sustainable consumption behavior from a cognitive and psychological perspective. In the process of raising awareness on environmental impact on consumption, providing available information and knowledge on sustainable consumption, transforming positive attitude to sustainable behavior, and possibly involving lifestyle and consumption pattern change in the future, consumers are facing many barriers. However, the application of AR technology in education, gamified design, immersive experience, and engagement system brings opportunities to my design in solving those consumers' problems.

## **Chapter 3: Research Methodology**

In order to help people to live a more sustainable life and help to solve the environmental problems, I use mixed methodology of Research Through Design and Speculative Design in my project, aiming to explore the possibility of AR technology on raising people's awareness, promoting behavior, and possibly involving habit and lifestyle change in the possible futures. These two methodologies will be implemented in the designing and prototyping process. In this chapter, the concepts of the thesis methodologies, Research Through Design and Speculative Design, and the design method, including personas, will be introduced.

## 3.1 Research Through Design

Research Through Design is a research methodology where the design process itself becomes a way to acquire new knowledge. In other words, design is a form of research and research is a part of design, which indicates that both design and research are essentially the same in resulting in new knowledge. There are a number of ways to introduce research through design.

Zimmerman, et al. indicates that Research Through Design is a “research approach that employs methods and processes from design practice as a legitimate method of inquiry” (310). “Research through design has been used for over 20 years within the design community as a distinct term to describe practice-based inquiry that generates transferable knowledge.” (Durrant, et al., 3)

Frayling’s “Research in Art and Design” is a foundational paper for Research Through Design.

In his paper, he attempts to explain what research is in the context of arts and design. He discusses the difference between research into art and design, research for art and design, and research through art and design. The meaning of using the Research Through Design methodology for both design researchers and artifacts is to do the right thing and focus on transforming the world from now to a preferred future, (Frayling, 5). Research Through Design has been used in many diverse fields of design. For example, in human-computer interaction (HCI), Research Through Design “is not a formal methodological approach with a particular epistemological basis. Instead, it is a foundational concept for approaching inquiry through the practice of design” (Durrant, et al., 3)

This project employs Research Through Design by iteratively developing prototypes. I struggled with opportunities and constraints of AR technology and wanted to know what AR technology can do in the field of environmental protection. Research through design is seen as an

attempt to re-value practice. I think the cycle of learning, thinking and improving is a good practice for me to constantly improve my prototype's functions and usability. At present, AR technology is in its "infancy" stage, and there are many technical bottlenecks. However, there is no doubt that AR technology may significantly exceed our current expectations in the future. So, I also hope to take the process of iteratively developing prototypes as an opportunity to discuss the current constraints of AR technology and explore more possibilities of this technology by later taking my prototype into possible future scenarios using Speculative Design methodology. The process of creating prototypes aims to answer the research question involves further changes and iterations, hopefully the process of design and research continues till the design of prototype can itself be used to offer a potential solution to the initial research questions.



## 3.2 Speculative Design

From James, Speculative Design is “a design speculation requires a bridge to exist between the audience’s perception of their world and the fictional element of the concept.” (12) We have a long history of creating imaginary scenarios, such as science fiction. However, when Speculative Design is used in the so-called “real world”, “designers need to consider scenarios for future trends and research into the adoption of emerging technologies” (Kunjo). Speculative Design usually takes the form of scenarios starting with what-if questions. In addition, Speculative Design should “open up all sorts of possibilities that can be discussed, debated, and used to collectively define a preferable future for a given group of people: from companies, to cities, to society.” (Dunne and Raby, 6) When using Speculative Design, designers also need to think about the question of “for whom?” and “who decides?”.

**Cones of Possibility.** In 2009, Stuart Candy used a model, Cone of possibilities, to illustrate different kinds of potential futures. The cone of possibility is a great tool for future forecasting that can give us a solid basis for analysis, planning and designing. It consisted of several cones fanning out from the present into the future. The largest cone is possible, which is the link between now and future. “Possible” is based on some future knowledge we don’t have yet but we might someday. “In the scenarios we develop, we believe, first, they should be scientifically possible, and second, there should be a path from where we are today to where we are in the scenario.” (4) The next cone is probable. “It describes what is likely to happen unless there is some extreme upheaval such as financial crash, eco disaster, or war.(3)” The third cone is

plausible futures. “This is the space of scenario planning and foresight, the space of what could happen.” Preferably intersect the probable and plausible. (4)

**Reason for Choice.** “Speculative design, sometimes called critical design or design fiction, asks us to zoom out beyond user-centered design and ask what the effects of our designs could be on future societies.” (Peace) I decided to use Speculative Design methodology rather than use User Centered Design methodology mainly for two reasons below:

Firstly, Speculative Design questions the practice of design and its modernist definition. Since my research topic is environmental protection oriented, I want to move away from the constraints of commercial practice, and use storytelling and visions of possible scenarios as approaches evaluating how my prototype and designed systems work, thus reflectively exploring the role and impact of the new technology, AR, on today, and more importantly, tomorrow. I consider my design over a set of possible scenarios, ask how the design may help or hinder my attempt to build a preferable future, and initiate dialogue between new technology and users. future trends and research into the adoption of emerging technologies.

Secondly, the reason why I do not use user-centered Design methodology is not that I think User experience or User usability is not important. I spent time on user experience design in the process of iterating prototypes. However, at my current stage, with limited resources and time, I have two limitations on usability tests: 1) The product is aimed at a relatively wide range of users, from students to housewives. Currently, I don't have enough samples and resources. 2) The process from raising awareness to promoting behavior, and finally involving consumption habit formation and lifestyle change takes time. What I am more concerned about is the usability

of my design in the long run, but currently I don't have enough time to conduct a long-term research study.

### 3.3 Persona

Personas can be used in User experience design, known as user profiles. *The Inmates Are Running the Asylum* (1998), written by Alan Cooper, introduced the use of personas as a practical interaction design tool. The original purpose of user portrait is to help us find the target users and identify their likes and dislikes, so as to optimize the product functions and services we can provide, and finally create more commercial and social value. These personas need to be based on user research and secondary research, and can also be described in narrative form in specific scenarios. The role of personas is to build empathy. Creating personas has become synonymous with creating persona profiles, a document of a virtual user model abstracted from real information such as user basic attributes, social attributes, behavioral attributes and psychological attributes. (Goodwin,2; Goodwin,1-4 )

### 3.4 Research Methods Flowchart

I employ Research Through Design (RTD) throughout the project by iteratively developing prototypes of the AR Consumption Reducing Application. Then, I employ Speculative Design by testing my prototype in several future scenarios that are possible for the world of today and more importantly, the world of tomorrow. I use the flowchart below to describe my project goal, timeline, and process. In this chapter, I used a flowchart to describe the development of this project.

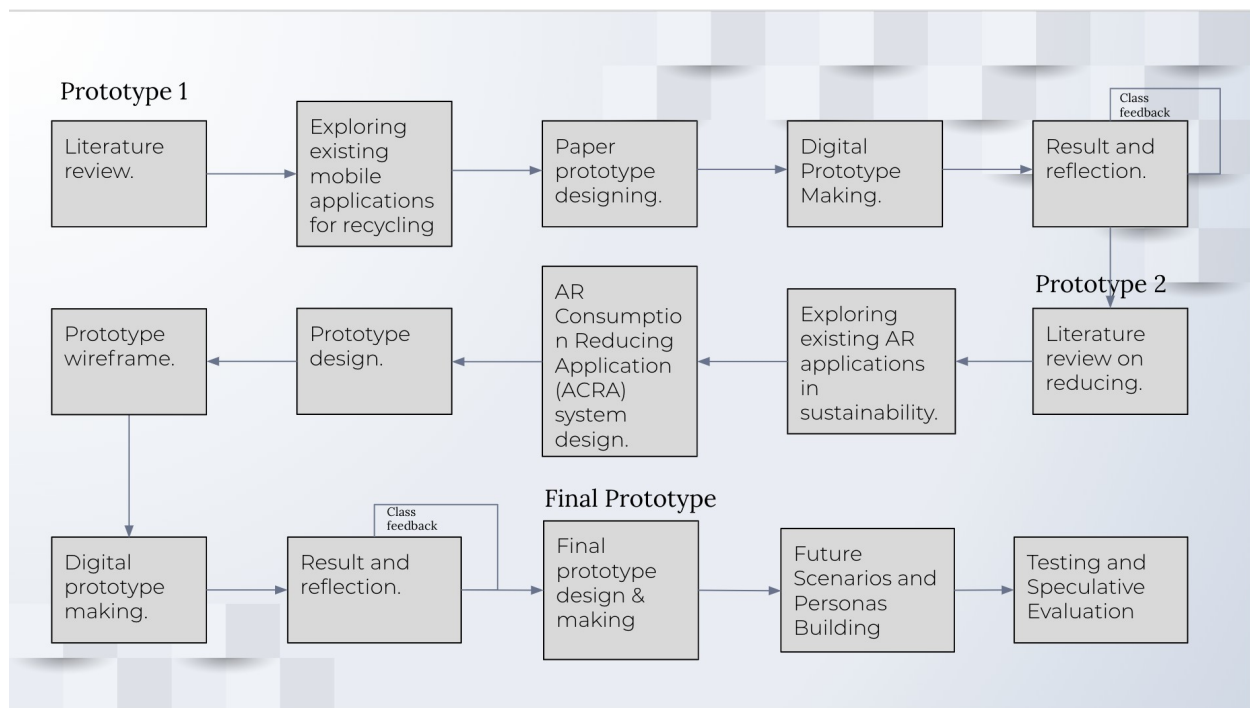


Figure 1 Research Methods Flowchart

When designing and making prototype 1, I did a literature review on economic sustainability, environmental protection, and global recycling problems. I explored existing AR

applications for recycling. In the process of paper prototype designing, I designed the paper prototype based on what I have learnt from literature and existing works. Before I used Unity to build my prototype, I built web AR apps with Torch AR and shared on my phone to test the 3D object and interfaces. Based on the feedback on my first prototype I got in class, I read more literature on reducing, sustainable consumption, and AR technology. I also investigated a mobile phone application identifying garbage by using AR technology. In order to answer my research question and achieve my research goal, I designed the AR Consumption Reducing System(ACRS). Then, I had the wireframe design with fundamental functions and made a prototype using Unity and Vuforia. By testing my second prototype in class, I got more useful feedback. Derived from the early prototype, I used the ACRS system as my design guideline. Then, I had my wireframe design and made the final prototype in Unity. To have a sense of what may happen in the future, I built possible scenarios and personas. Lastly, I demonstrated and tested personas' use flow in future scenarios.

## **Chapter 4: Early Development of AR Prototypes**

I try to answer the main research question and achieve the research goal by creating an AR tool, an AR Consumption Reducing Application. This chapter introduces the design process and iterative prototypes following the timeline of the research methods flowchart in chapter 3. With the use of mixed methodology of Research Through Design and Speculative Design, the design of these prototypes is based on literature review, secondary research, consumer's insights, observation, and class reflections.

## 4.1 Prototype 1: A Recycling AR Game

My first prototype is a recycling AR game. To contribute to long-term environmental protection, the app's design needs to focus on increasing the app's stickiness and retaining users. It is quite difficult and boring to constantly save and conserve energy, reduce consumption and recycle solid waste from the aspect of life for a long time. Enriching the emotional experience and increasing the participation of users are challenges to app's designers. Then, I decided to make the environmental protection mobile application into a nurture-type game with the help of AR technology.

**Literature review.** At this stage, I mainly focused on recycling, and the original idea was to design an educational application that tells you exactly how to recycle the garbage. I looked through statistics on recycling rates by countries and found out that the recycling rate of generated packaging and containers is still very low. Then, I was inspired by Heinz ketchup augmented reality advertising: Customers scan to read product information and swipe the screen to check the ketchup food menu(Macleod). So, I wanted to try to design an AR tool where customers can use their phone to scan and interact with the label.

- **Exploring existing mobile applications for recycling.** I downloaded and tested 10 popular AR games and 5 environmental protection apps. From the market of these environmental mobile phone software, we can see that people have from different aspects of life (such as saving food, travel, recycling, footprint etc.), to reduce energy consumption. However, I found the capability of current AR technology and its usage

scenarios are limited. I think gamification design makes energy saving and environmental protection more interesting, which can be used in sustainable application design.

<i>Oroeco</i> <sup>7</sup>	A carbon footprint calculator that calculates your carbon footprint and compares your number to community average.	Carbon footprint calculator
<i>Refresh Go Green</i> <sup>8</sup>	An app gives you tips for a greener life. Users can also share their thoughts on living a sustainable life.	Green life tips
<i>Love food hate waste</i> <sup>9</sup>	An app that optimizes your food consumption. Users can help users to avoid food waste at home.	Food waste
<i>Garbage is coming</i> <sup>10</sup>	A creative environmental game related to household garbage sorting that the users drag the garbage to the trash bin users think is appropriate.	Garbage sorting
<i>HK AQHI</i> <sup>11</sup>	Display air quality health index recorded at air quality monitoring stations	Air quality

Figure 2 5 environmental protection apps.

<sup>7</sup>“Oroeco.” Home, [www.oroeco.com](http://www.oroeco.com). Accessed 11 May 2020.

<sup>8</sup> Belinda. “The Refresh & Go Green App Is Here!!” The Refresh Project, 13 May 2015, [www.therefreshproject.com.au/refresh-go-green-app](http://www.therefreshproject.com.au/refresh-go-green-app).

<sup>9</sup>“Love Food Hate Waste - Google Zoeken.” Love Food Hate Waste, [www.google.com/search?q=Love+food+hate+waste&oq=Love+food+hate+waste&aqs=chrome..69i57.273j0j7&sourceid=chrome&ie=UTF-8](http://www.google.com/search?q=Love+food+hate+waste&oq=Love+food+hate+waste&aqs=chrome..69i57.273j0j7&sourceid=chrome&ie=UTF-8). Accessed 11 May 2020.

<sup>10</sup> Garbage is coming. 2019. Game on garbage classification from diyiyou, 2019. <https://m.diyiyou.com/xiazai/103079.html>

<sup>11</sup> “HongKong Air Pollution: Real-Time Air Quality Index.” Aqicn.Org, [aqicn.org/city/hongkong](http://aqicn.org/city/hongkong). Accessed 11 May 2020.



AR Application	Description	Experience & Comments
<i>AR Dragon</i> <sup>12</sup>	An augmented reality virtual pet simulator where players take care for their dragon.	The experience was beyond my expectations, and the dragons were designed to be cute and interactive beyond your imagination It feels like a single-player simulation game.
<i>IKEA Place</i> <sup>13</sup>	Consumers can select furniture from the IKEA Place database and display AR furniture on their phone.	All the furniture in AR are the same size, users can adjust the Angle, and simulate the real effect. Besides, I can modify dimension, material, and color of the furniture.
<i>Home Android Measure</i> <sup>14</sup>	<i>Measure</i> is an ARCore-based ruler app released by Google that measures the length of an object using a smart phone.	For measurement, it is very convenient to have a tool for temporary use. But the overall usage makes me feel that the measurement data is not accurate.
<i>GIPHY World</i> <sup>15</sup>	Users can put various GIF images into the surrounding scene (choose AR stickers, or draw with their fingers).	I recorded the videos and posted them on social media. Personally, I don't like it very much, but I can imagine that some people would like it.
<i>HOLO</i> <sup>16</sup>	Support for adding holographic 3D images or photos to the camera, including movie characters, celebrities.	I added some interesting original characters who can speak. I can turn the character in 360 degrees, as if you're seeing a real person, but there's no other interaction.
<i>Paint Space AR</i> <sup>17</sup>	It is a creative graffiti application. The canvas is no longer a simple pure color picture. Pictures, videos, real scenes, etc.,	The operation is not as smooth as expected, and many beautiful brushes need to be paid extra. I

<sup>12</sup> “AR Dragon - Augmented Reality Virtual Pet Simulator.” Playside, [www.playsidestudios.com/ar-dragon](http://www.playsidestudios.com/ar-dragon). Accessed 11 May 2020.

<sup>13</sup> Pardes, Arielle. “The Ikea Place App Shows the Practical Promise of AR Kit.” *Wired*, 20 Sept. 2017, [www.wired.com/story/ikea-place-ar-kit-augmented-reality](http://www.wired.com/story/ikea-place-ar-kit-augmented-reality).

<sup>14</sup> “Google AR ‘Measure’ App Turns Android Phones into Virtual Measuring Tapes | Inquirer Technology.” *Measure*, 25 June 2018, [technology.inquirer.net/76830/google-ar-measure-app-turns-android-phones-into-virtual-measuring-tapes](http://technology.inquirer.net/76830/google-ar-measure-app-turns-android-phones-into-virtual-measuring-tapes).

<sup>15</sup> Giphy. “GIPHY World.” GIPHY, [giphy.com/apps/giphyworld](http://giphy.com/apps/giphyworld). Accessed 11 May 2020.

<sup>16</sup> 8i. “This Is Holo | Now With ARKit.” YouTube, 19 Sept. 2017, [www.youtube.com/watch?v=vsECVPUCYt8](http://www.youtube.com/watch?v=vsECVPUCYt8).

<sup>17</sup> Paint Space. “Paint Space - AR Painting For Your Phone.” YouTube, 24 July 2017, [www.youtube.com/watch?v=uVCCvPcN5Ew](http://www.youtube.com/watch?v=uVCCvPcN5Ew).

	can become a place for you to display your talent and wave your brush.	think collective creation should be fun.
<i>Ink Hunter</i> <sup>18</sup>	Users can "try out" tattoos with augmented reality.	The app is able to project any tattoo design to any part of the body, helping me see the effect of the tattoo from different positions and angles.
<i>Star Chart</i> <sup>19</sup>	With the help of the GPS technology, three-dimensional modeling of the universe and AR technology, Star Chart can calculate the current position of each planet and planets in real time.	Instead of touching the screen, turning the phone to display a real-time view of the sky in the current direction. This is the most interesting AR application for me.
<i>Google Translate</i> <sup>20</sup>	Translate any of the more than 30 languages currently supported (text translated into more than 100 languages) by pointing the camera of your phone or tablet at Google.	It will translate the words immediately, eliminating the complicated process of typing. It was quite useful.
<i>Civilizations AR</i> <sup>21</sup>	Users can view three-dimensional artworks in a three-dimensional space without leaving their homes.	The software seems to be a must for students and historians alike.

Figure 3 10 popular AR games.

**Paper prototype design.** With the use of AR technology, I designed an AR mobile tool with an engagement system where customers can use their phone to scan and interact with the product's label to enrich the emotional experience for users, to help them to gain a deeper understanding of content, and to increase the participation of environmental protection. In the prototype design, I faced a challenge on recycling. It is difficult to design a unified recycling application for users in different regions because of inconsistent environmental protection policies and in different areas,

<sup>18</sup> INKHUNTER. "INKHUNTER - the Best Mobile App for Trying on Virtual Tattoos Using Augmented Reality." YouTube, 5 Oct. 2016, [www.youtube.com/watch?v=p\\_Q7eA-C6X0](http://www.youtube.com/watch?v=p_Q7eA-C6X0).

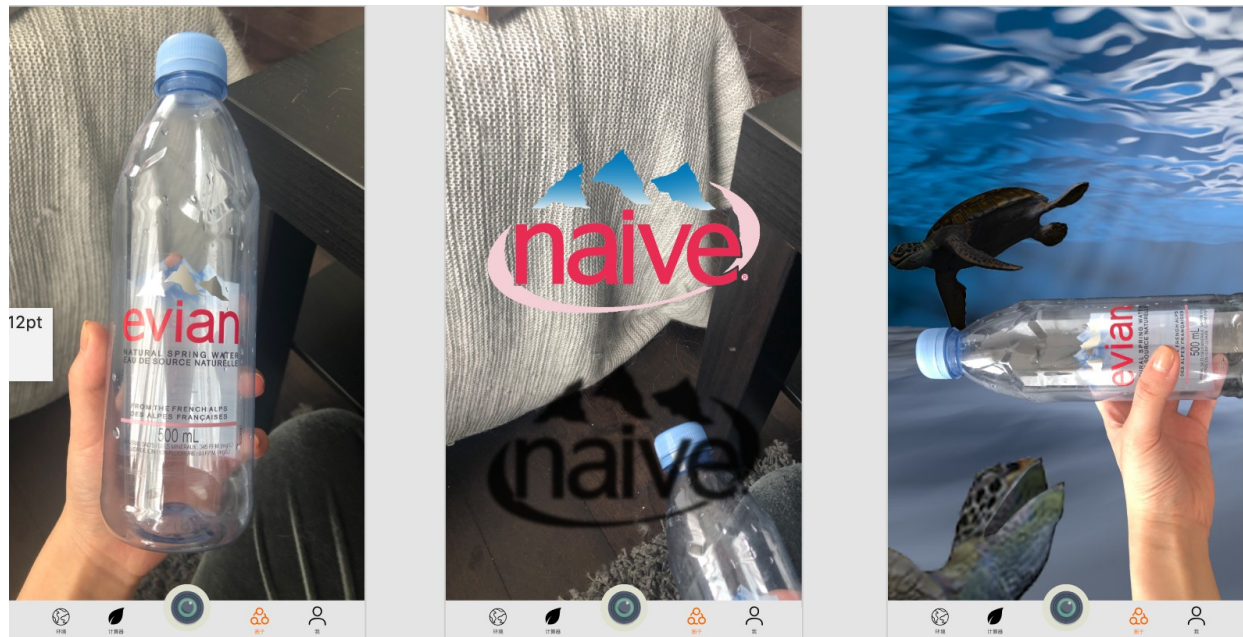
<sup>19</sup> Chris' Tutorials. "Introduction to Star Chart Astronomy Mobile App." YouTube, 19 June 2016, [www.youtube.com/watch?v=ob5XPLWUxAE](http://www.youtube.com/watch?v=ob5XPLWUxAE).

<sup>20</sup> Rich DeMuro. "Google Translate App Works Like Magic." YouTube, 11 Feb. 2015, [www.youtube.com/watch?v=Ro-HfETpzhc](http://www.youtube.com/watch?v=Ro-HfETpzhc).

<sup>21</sup> Mark Anderson. "BBC Civilisations AR App." YouTube, 20 Apr. 2018, [www.youtube.com/watch?v=0c3-Za57dYc](http://www.youtube.com/watch?v=0c3-Za57dYc).

so I took Ontario as an example. When designing the prototype, I divide household waste into two categories: daily supply and durable goods. For different types of garbage, the prototype will give users different suggestions and solutions. The prototype has two usage scenarios, the first one is where the user prepares to consume in the mall(Before), and the second one is where the user prepares to recycle at home(After).

Step 1: Scan the garbage and learn the environmental facts of plastic pollution by experiencing AR simulated ocean. ( Plastic water bottle as an example in my paper prototype design. )



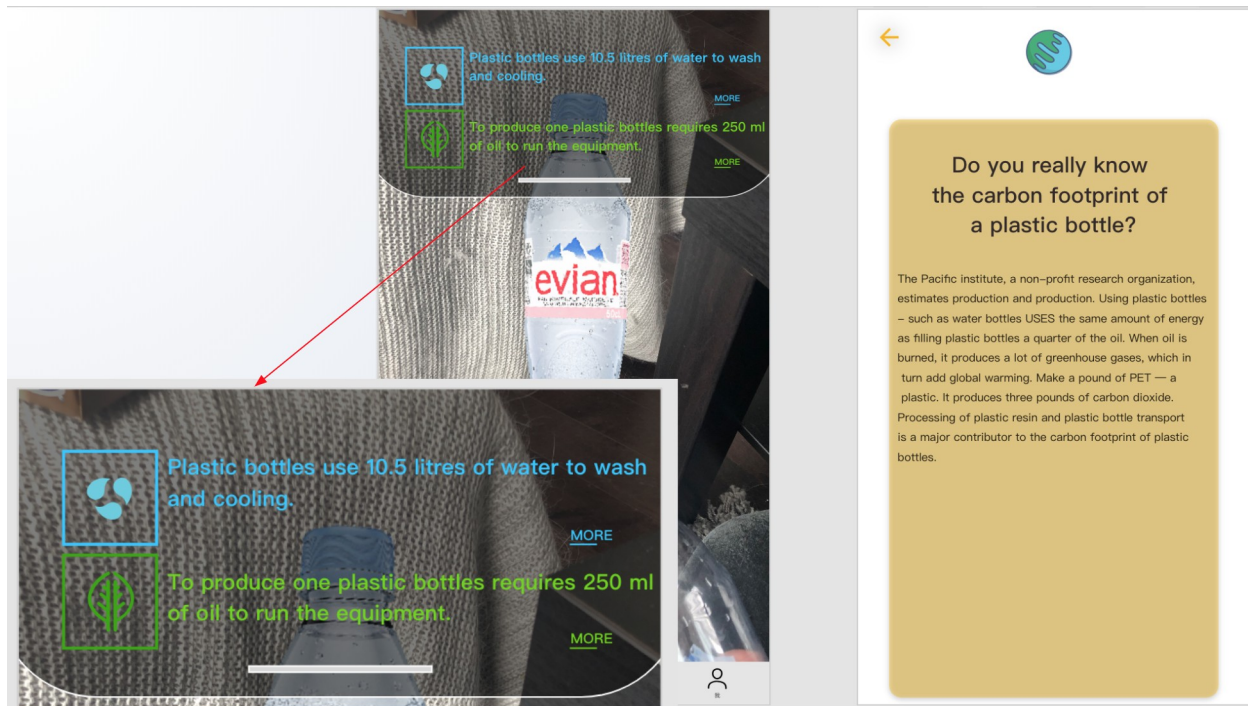


Figure 4 Scan this water bottle.

Step 2: Learn how to recycle this water bottle.

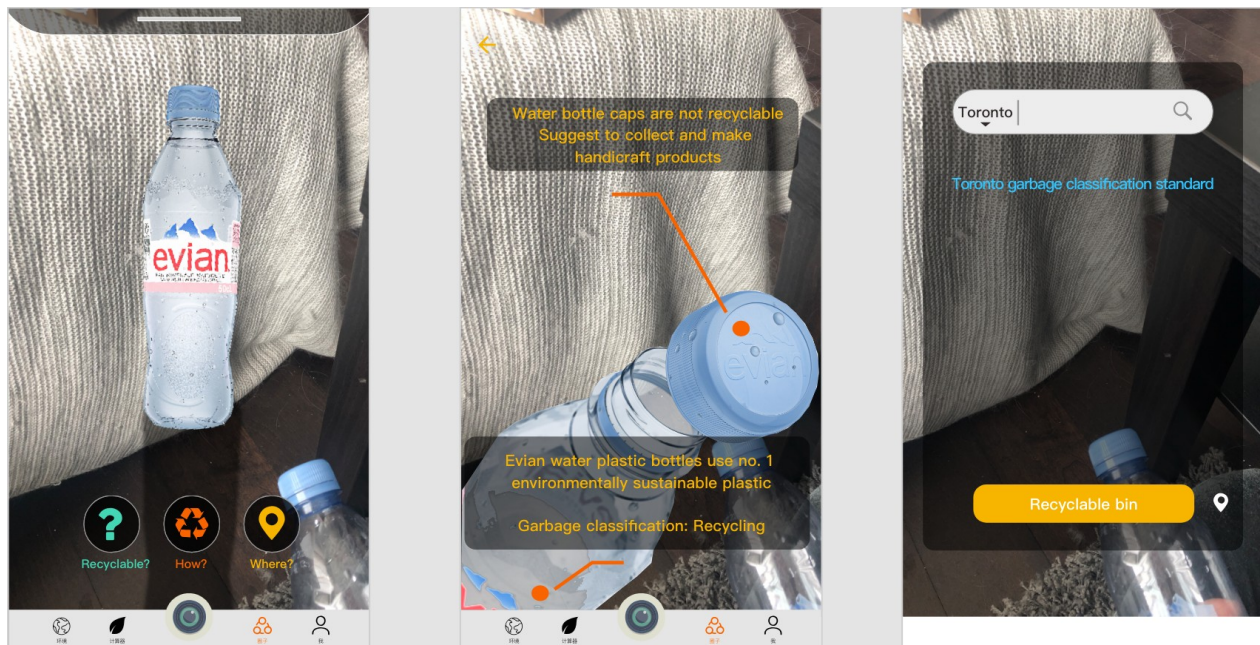
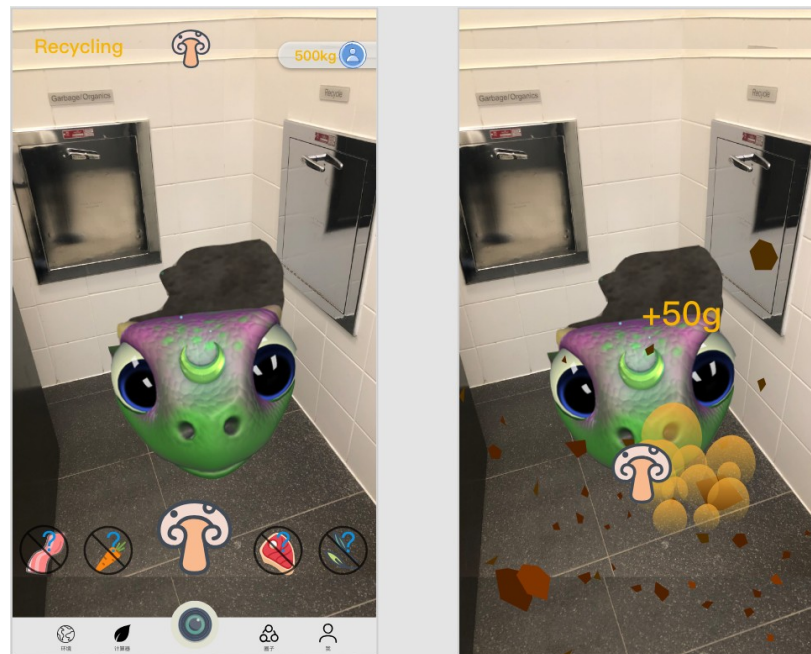


Figure 5 Learn how to recycle this water bottle.



Step 3: I got inspiration from an AR game called AR Dragon(Felicia), which is a nurturing game raising a cute little dinosaur. All sustainable behavior should be rewarded, so when users do reducing and recycling, the little dinosaur gets food and grows.



*Figure 6 Get reward from recycling right.*

**Digital prototype making.** I watched the Unity ARkit tutorial about tracking. I also did research on face recognition and tracking CV and libraries, such as AR.js and AFrame.js. ARKit is the AR development platform is launched by apple. The tool lets developers create augmented reality apps for the iPhone and iPad (McGarry). Computer Vision(CV) helps in tracking, processing and understanding digital images, which is defined as “a field of study that seeks to develop techniques to help computers “see” and understand the content of digital images such as photographs and videos”(Brownlee). That is to say, CV enables mobile phones to accurately perceive and judge the world, while AR presents the digital world to us through CV perception. Compared to CV, AR technology is the best tool and form for data visualization. Before I used

Unity to build my prototype, I built a web AR app with Torch AR and shared it on my phone to test the 3D object and the interfaces. The first image below is testing 2D objects and video in AR. The second picture is testing 3D objects and 3D scenarios.



*Figure 7 Digital prototype built with TORCH\_2D objects and video.*

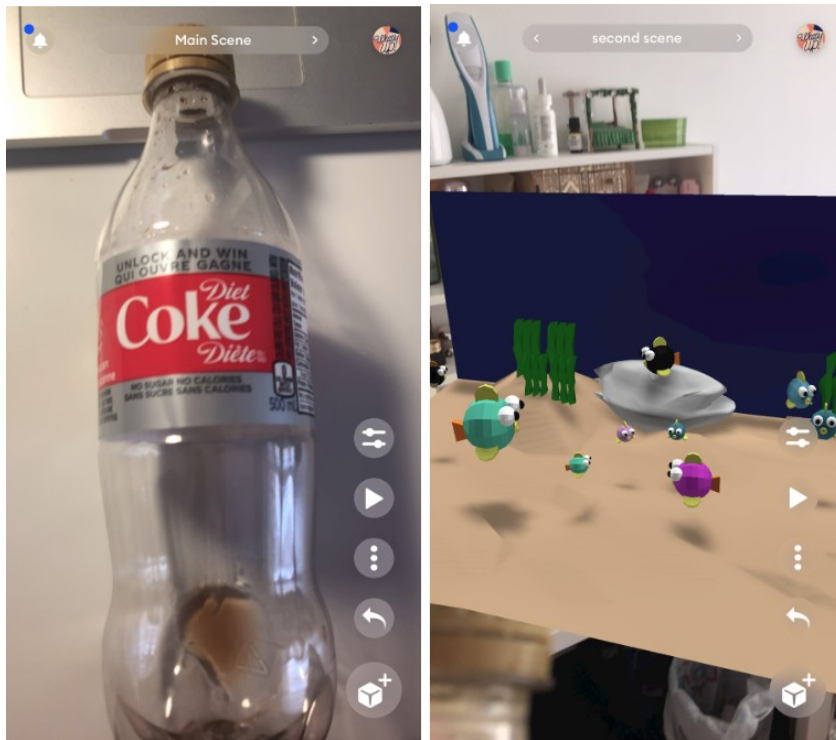


Figure 8 Digital prototype built with TORCH\_3D objects and 3D scenarios

**Result and Reflection.** I had a prototype made with Sketch and a digital prototype made with TORCH. Paper prototype was tested by my classmates in class. The following are the feedback, insights and the on-site observation I got from class.

1. “Think of the steps Reduce, Reuse, Recycle.”
2. “Gamifying is great to reach a wider audience.”
3. “Are you satisfied with just letting people know that their plastic still exists?”
4. “Think of how in restaurants or shops the calories count on everything dissuades you from buying things.”
5. “Think of how much plastic is used to wrap fruits and vegetables.”
6. “What about visual cues in the grocery store that are AR activated if you are at the point of purchase?”

7. “You think you know how to recycle but you don’t.”
8. “A tool for complacency? We use recycling to make ourselves feel better.”
9. “Think of the emotional component and how that relates to recycling.”
10. “What is actually good vs. What makes me feel good.”

From my classmates’ feedback, they are more interested in reducing strategy, which reminds me of the importance of reducing reflecting on my research question. I made a prototype with two usage scenarios: not only help people recycle after consumption but also help people reduce before consumption. People suggested me to just keep focus on reducing. They also mentioned how much they wanted to see where the abandoned water bottles end up, as well as whether their efforts have a positive effect on the environment. I also got an interesting feedback that I can learn how restaurants or shops count calories on everything when I calculate the environmental cost of certain products. Overall, people like the interaction with the AR interface, 3D environment, which are significantly new and interesting.





## 4.2 Prototype 2: An AR Consumption Reducing App

Learned from my first prototype, the second prototype is an AR Consumption Reducing App. Although the usage scenarios and functions of the application have changed, the second prototype still retains the previous concept of gamified design. Previously, I was concerned about the process of reuse and recycling after the purchase of users. Now I focus on the consumption scenarios and barriers and stimulates and decision-making process in the user consumption journey. To answer my research questions and achieve the thesis objectives, I design the AR Consumption Reducing System, including Knowledge Sharing System, Environmental Cost Calculation System, and AR Engagement System.

**Literature review on reducing.** My focus of literature review gradually shifts from recycling towards reducing. I began to pay attention to psychological analysis of consumer behavior trying to understand people's consumption habits and user journey, and explored the factors affecting people's consumption behavior. People must acquire the necessary knowledge to form appropriate values, and to translate attitude into action.

**Exploring existing AR applications in sustainability.** To identify garbage, *Alipay* announced that it officially launched the function of AR garbage scanning and sorting on July, 2019(Chen). AR recognition is characterized by continuous self-learning: the richer the items being scanning, the higher the accuracy of the application.

**AR Consumption Reducing Application(ACRA) system design.** In order to answer my research question and achieve my research goal. I designed the AR Consumption Reducing Application(ACRA).

This system includes Knowledge Sharing System, Environmental Cost Calculation System and Engagement System. The Knowledge Sharing System in this paper means knowledge dissemination, which refers to the process of sharing and transmitting specific knowledge information to users through the application. It is not a social activity within social environments, expecting to receive the expected communication effect. The Environmental Cost Calculation System shows the environmental performance through its life cycle of one single product you are scanning. AR Engagement System includes interface design, reward system design, and decision support design. The diagram below shows the flow of the ACRA system.

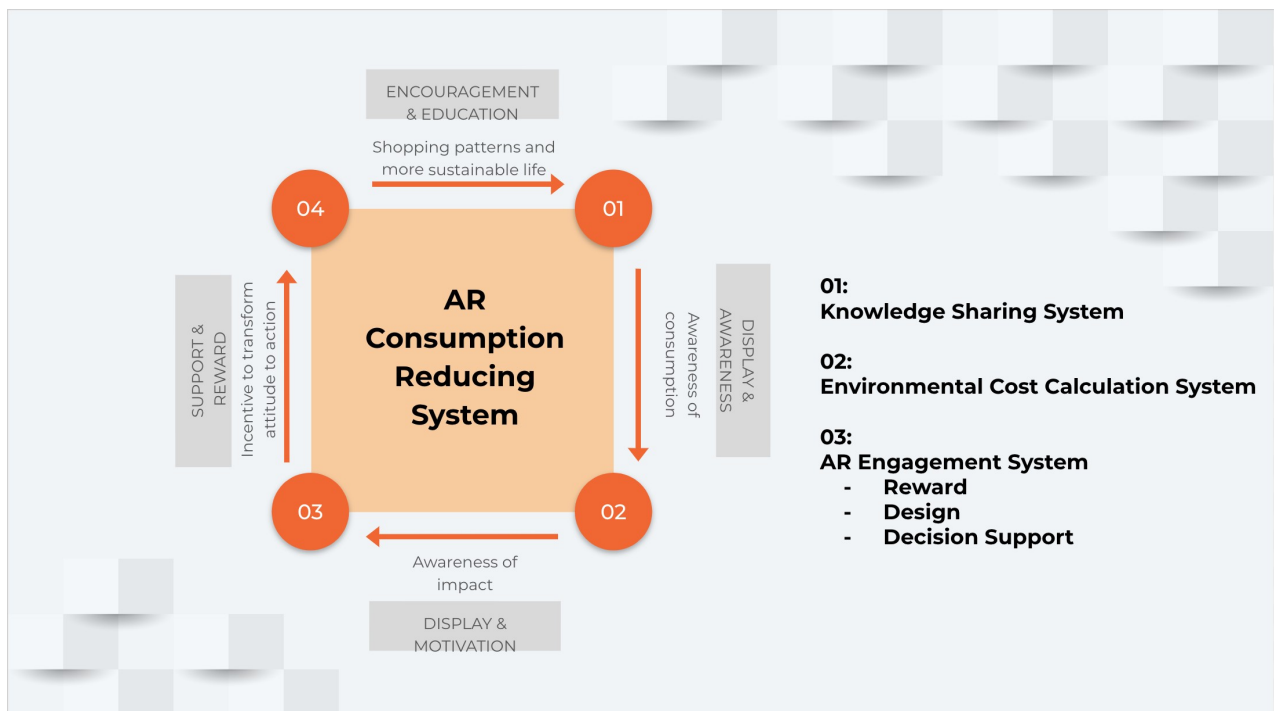


Figure 10 AR Consumption Reducing System

**Prototype design.** Based on the framework of ACRA system design, I chose to use a plastic milk bottle as the object of my example prototype and made the user journey map below.

The scenario is in grocery store shopping. The main character, Emily, wants to buy milk. She needs to buy milk almost every day for her kid. But she doesn't have enough awareness of the environmental impact on plastic milk bottles. Emily cares about environmental protection, feeling a little helpless on sustainable consumption. Maybe there is a prototype that can help.

- Understanding users: collect and evaluate all existing literature on target consumers.
- Create a persona: a customer model which fully describes the customer's goals and behavior in using the prototype.
- Draw customer journey: a map including steps, emotion and thoughts, actions and opportunities of using this prototype.

Through this map, I tried to interpret and describe the details of the customer's experience, subjective reaction and feelings when using the prototype. I focus on the whole process from the user's initial visit to the achievement of the goal. From this chart, I got the pain points of each stage of the user, Emily. This user journey map helps me with the speculative future scenarios descriptions and personas building.

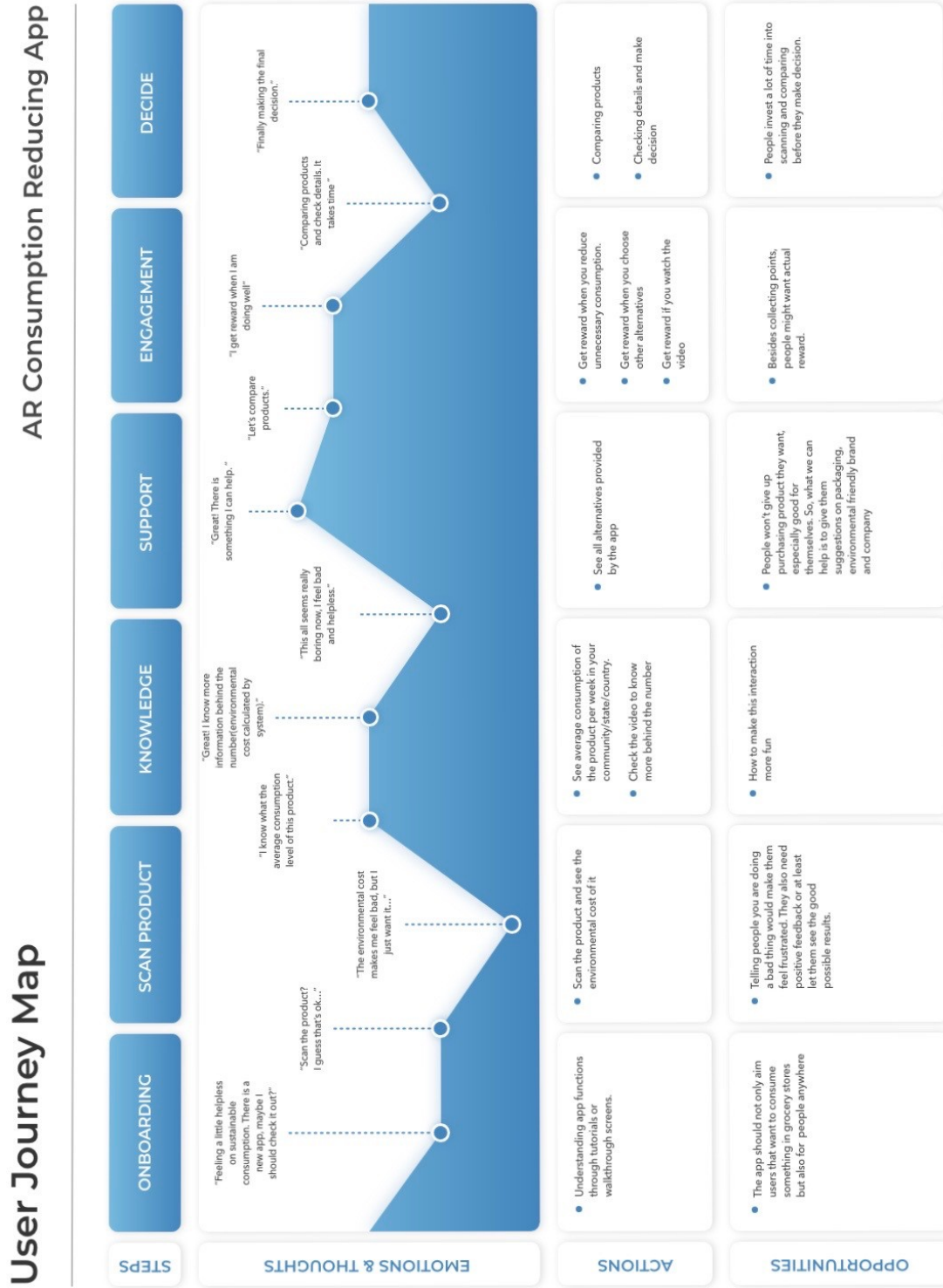


Figure 11 User Journey Map.

After I did this user journey map, there were some highlights helping me think about my design. To illustrate the functionality of my prototype and its challenges and possible solutions, I made this table below:

Function	Descriptions	Challenges	Possible Solutions
Environmental Calculation	Environmental cost of this plastic milk bottle calculated by the environmental cost calculation system based on its life cycle assessment.	Telling people, the environmental cost of the product they want to buy would make them feel bad.	They need positive feedback or at least let them see the good possible results.
Educational Video	Explaining the calculation of the environmental cost of the product.	People don't have the patience to start and finish the video.	Design and content of the video
Your Consumption Level V.S. Average	Average consumption of milk by community/state/country	Telling people that they are consuming more than they need even might make them angry.	To transform anger into motivation.
Provide Sustainable alternatives	Encourage people to buy milk in glass. Provide a list of environmentally friendly milk brands.	People won't give up purchasing products they want, especially good for themselves.	What we can help is to give them suggestions on packaging, environmentally friendly brands and products.
Reward and Engagement	Get reward when you reduce unnecessary consumption. Get rewarded when you choose other alternatives. Get a reward after you watch the video.	People would feel bored over time. How to make them continuously interested in this game?	People need actual rewards, such as coupons.

*Figure 12 Challenges and possible solutions from user journey map.*

**Prototype wireframe.** This is the first digital prototype built in Unity. By having the basic functionality that users need, I want it to achieve the research objectives: 1) to increase awareness of environmental impact on consumption behavior; 2) to reduce unconscious consumption behavior; 3) to reduce the Value-Action-Gap.

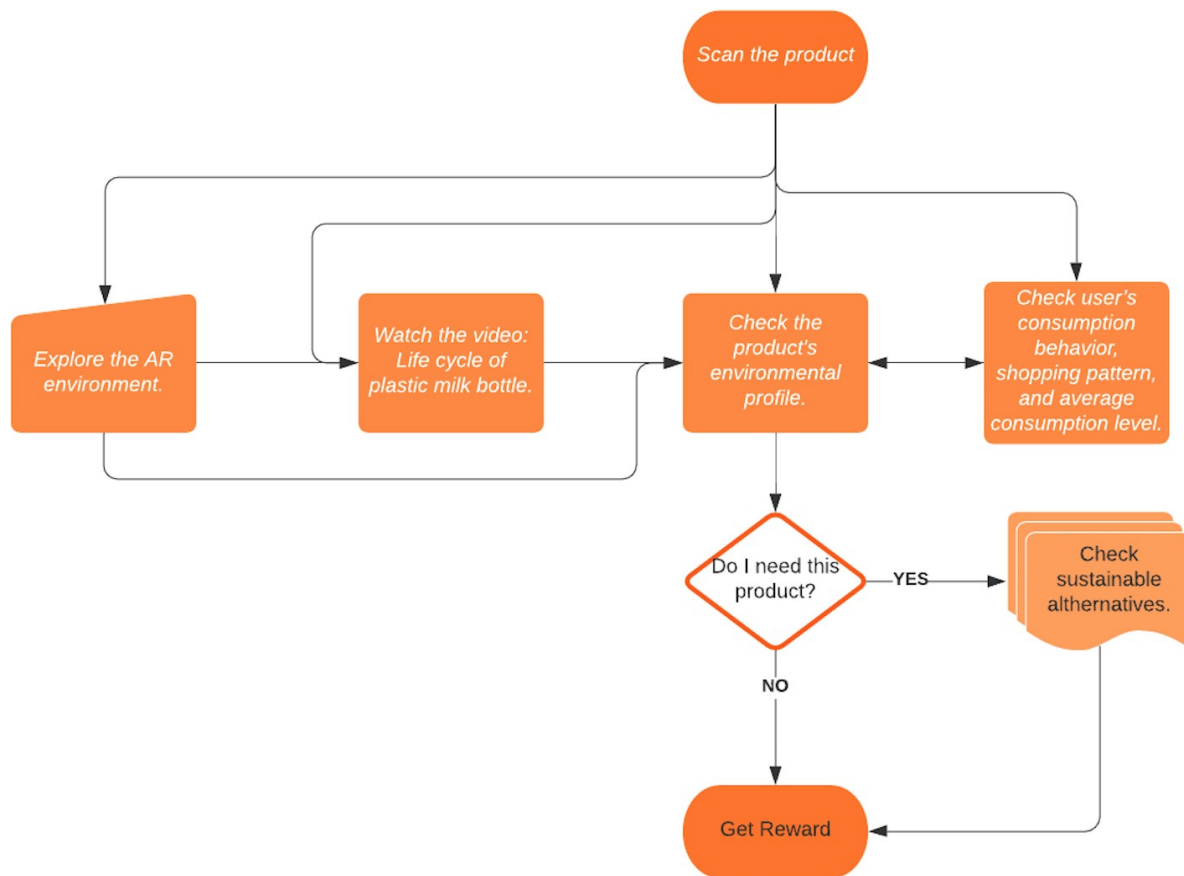


Figure 13 User Flow Chart.



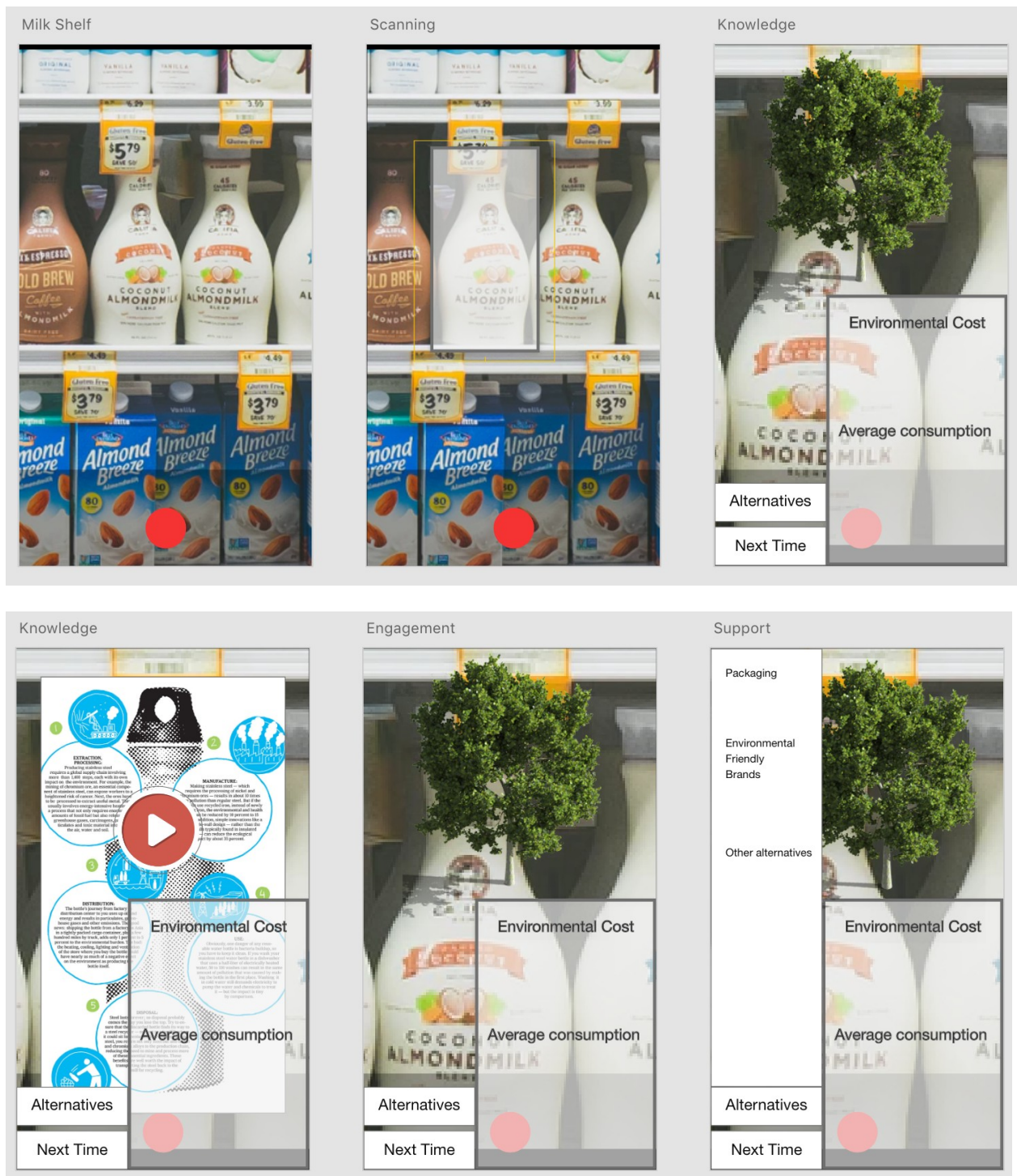


Figure 14 Wireframe Design.



*Design choice:* instead of a cute dinosaur in my first prototype, I chose the tree as the game object. In people's thinking, trees represent clean air, a natural living environment, and a comfortable space. Trees also symbolize green consumption. I want people to see that their environmental behavior can make a difference to the environment. If they can make the tree grow, they can change the ecology of the earth.

**Digital prototype making.** I used one of the mainstream AR SDK, Vuforia. I made this prototype in Unity3D and Vuforia.

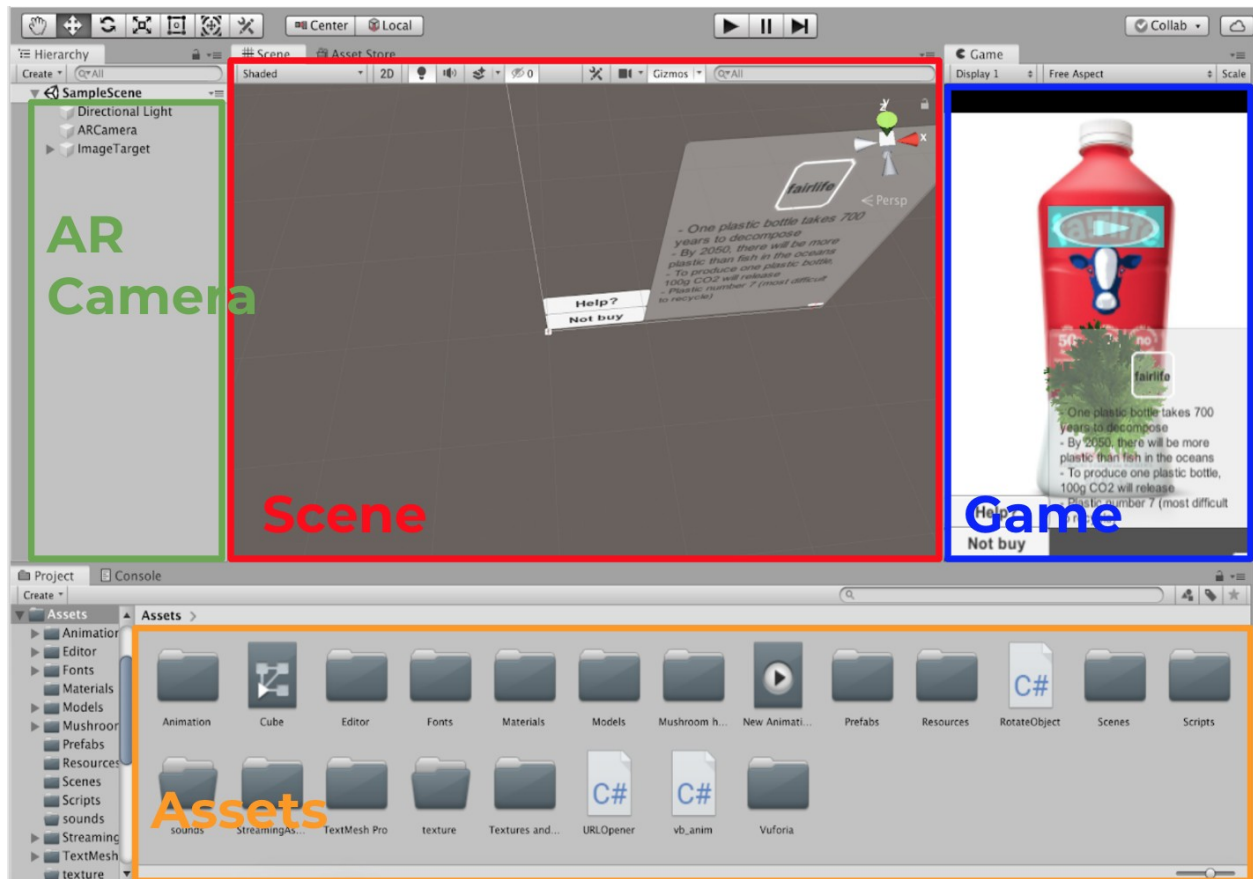


Figure 15 Digital prototype building in Unity.

Each element or function in the interface corresponds to a system(knowledge sharing system, environmental cost calculation system, and engagement systems). The following figure shows each element and indicates its corresponding system. For example, the tree corresponds to the AR engagement system. At this stage, the digital prototype's final look is slightly different from the design in the wireframe. I changed the button's name to “Help?” and “Not buy”.

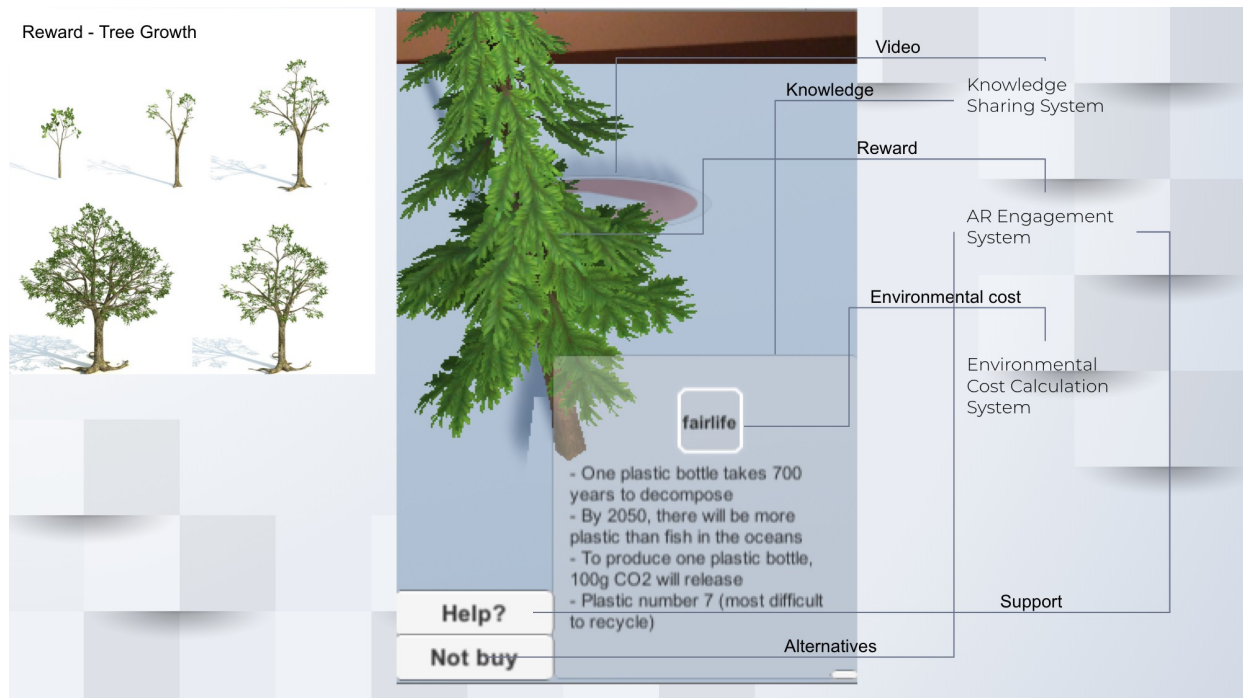


Figure 16 Digital prototype testing.

## Result and Reflection

I received feedback of my second prototype from class:

1. Consider more about the user reward system.
2. People need positive feedback when they are doing something.

3. Do more research on solid waste to build an environmental cost calculation system based on some existing models.
4. Answer questions like why a boxed milk bottle is better than a plastic one.
5. Consider more about user experience.
6. Why I choose AR as the technology.

Speaking to the feedback that I received, it is important to know people's needs in each specific scenario. When people scan the product, some people want to quickly check the "Product Environmental Profile" with environmental cost calculated by system, because those numbers will be their helpful "shopping instructions". To save time, some people would skip others and jump to alternatives. One interesting feedback I got in class is that people not only want to know the environmental cost as a number, but also want to know the meaning behind those costs and how these costs relate to them. Moreover, I realize the engagement system doesn't work the way I expected. A game is an experience created by rules. The important thing is that the rules themselves are not the game, but the resulting interactions are the game itself. In this case, I think I should improve users' experience which leads to a better interactive experience including three parts, "watching", "thinking", and "doing".

Based on the real offline scenarios of users, the product functions are designed based on the consumption reducing system. Because the product is not a pure online product, nor a product combining online and offline (such as Uber Eat). The product needs perfectly integrate with the shopping scenes in life, so if I have more time, I will pay more attention to the user experience and the product use process, so as to ensure the users' experience and efficiency in using the product.

## **Chapter 5: Final Prototype and Evaluation**

### **5.1 Final Prototype**

This chapter introduces the final prototype, the AR Consumption Reducing App. By identifying the challenges and opportunities in my previous prototypes. The final output is a mobile application that helps to increase people's awareness of environmental impact on their consumption behavior, to reduce unconscious consumption, and to promote sustainable consumption practices. This chapter then discusses possibly involving lifestyle change in the future. The main mechanic of this app is providing meaningful contents, including texts, images, videos, and AR interaction experience with the image target. The modified prototype was improved with a new design user interface.

#### **5.1.1 Final Prototype Design**

##### **Design Goal**

Design goal is derived from the research goal. Each sub system in the AR Consumption Reducing System answers sub research questions and achieves research objectives separately. The design of the system also conforms to the Fogg Behavior Model.

ACRS (AR Consumption Reducing System)			
<b>Knowledge Sharing System</b>		<ol style="list-style-type: none"> <li>1. Letting consumers be aware of their own consumption behavior to avoid unconscious shopping.</li> <li>2. Telling them how much resource they actually needed to live a sustainable life.</li> </ol>	Awareness
<b>Environmental Cost Calculation System</b>	To increase people's awareness on environmental impact on their consumption behavior.	<ol style="list-style-type: none"> <li>1. Providing available information on environmental performance on companies.</li> <li>2. Informing environmental knowledge on product based on LCA</li> </ol>	Ability
<b>AR Engagement System</b>	To reduce the Value-Action Gap	<ol style="list-style-type: none"> <li>1. Providing sustainable alternatives.</li> <li>2. Engagement and reward on good behaviors.</li> </ol>	Trigger

Figure 17 Design Goal.

### Design Requirements

Who	This age group are opinion leaders, families and major consumers in society who are also sensitive to new technology.
When	<ol style="list-style-type: none"> <li>1. When users choose between products</li> <li>2. When users need advice on alternatives</li> <li>3. When users do well on sustainable consumption</li> </ol>
How	<ol style="list-style-type: none"> <li>1. 3D model</li> <li>2. Video</li> </ol>

	3. Text information 4. Images 5. Labels
Where	Scenarios where consumers purchase more frequently, such as supermarkets and convenience stores.

Figure 18 Design Requirements.

## Usage scenarios

Food and drink have the highest levels of ecological impact per dollar spent, according to WWF.

So, in designing the final prototype, I decided to use grocery shopping as the usage scenario.

## Information Architecture

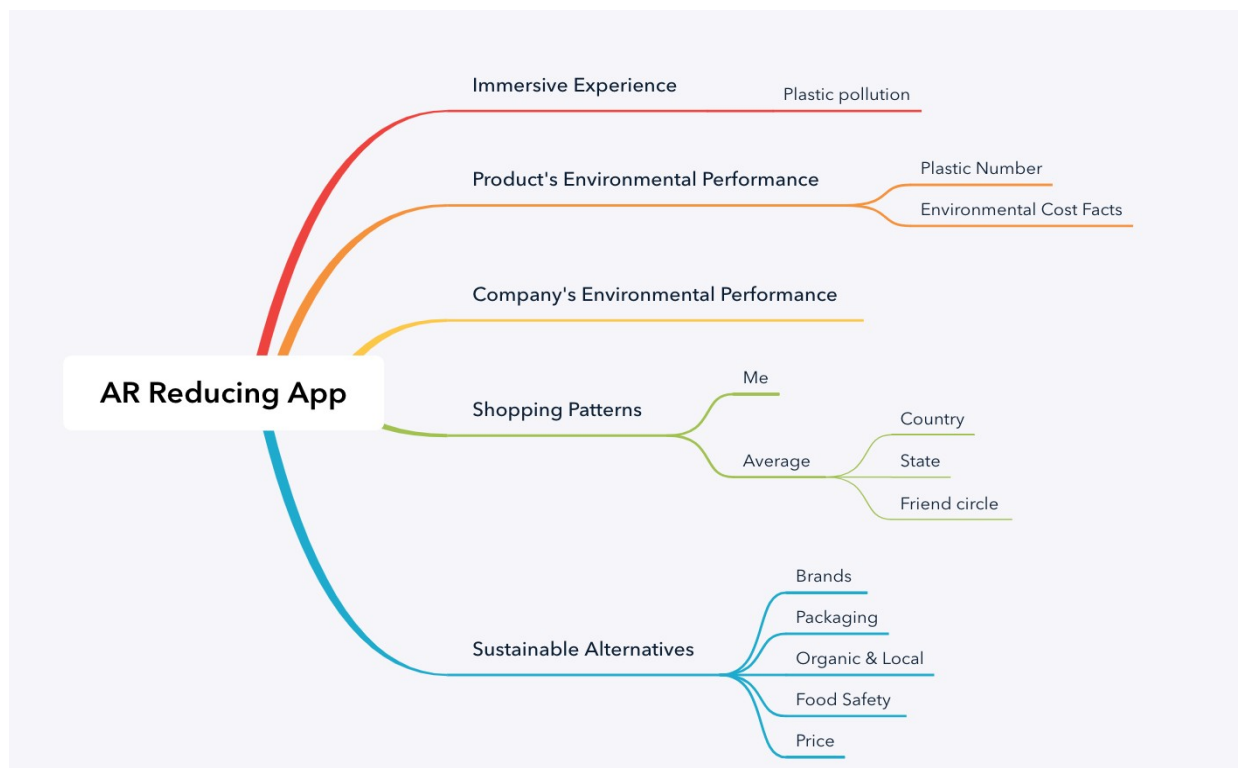



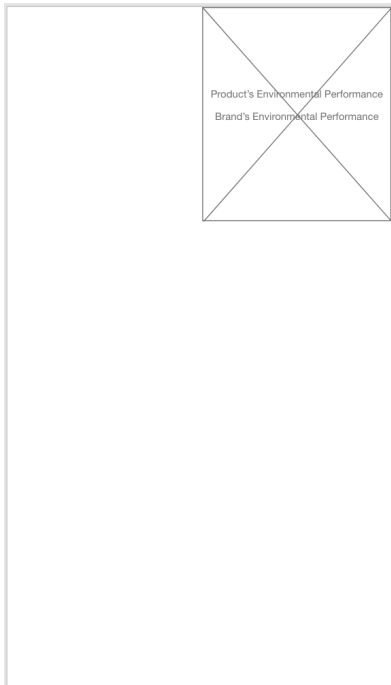
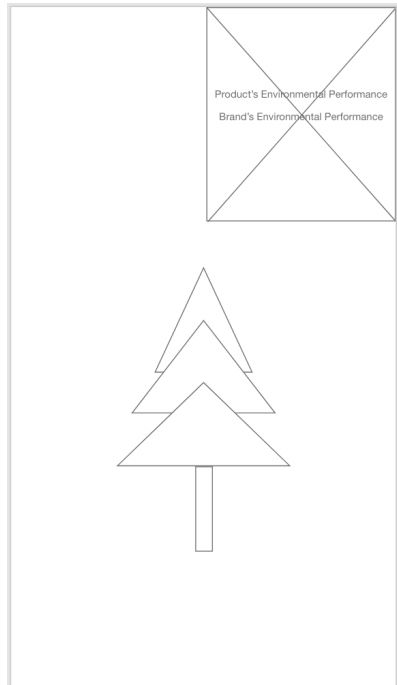
Figure 19 Information Architecture.

Knowledge Sharing System	User's shopping pattern
	Product's environmental performance
	Company's environmental performance
	Sustainable alternatives
Environmental Cost Calculation System	Immersive experience of plastic pollution
	Environmental cost calculation
AR Engagement System	User interaction with AR

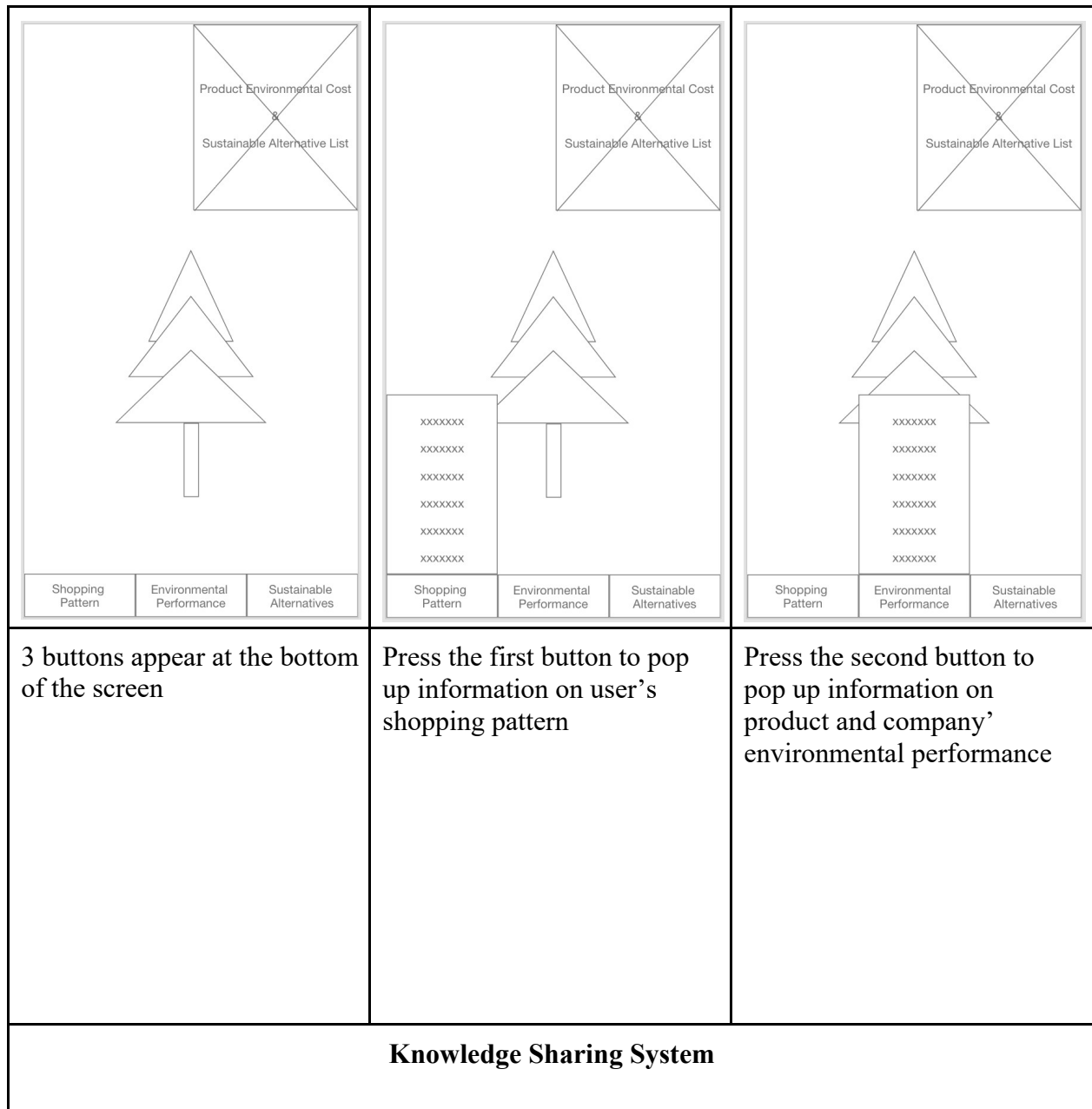
*Figure 20 The corresponding system of each function.*

## Wireframe Design

The wireframe design shows the low-fidelity user interface, the user usage process, the app's function, as well as the programming process of my app. It is designed under the guidance of ACRS principles.

		
<p>After scanning the product, look down and press the play button to watch the video.</p>	<p>Product's environmental cost calculation with sustainable alternatives is displayed at the top right of the screen</p>	<p>The 3d game object appears in the middle next to the product.</p>
<p><b>Environmental Cost Calculation System</b></p>		<p><b>AR Engagement System</b></p>





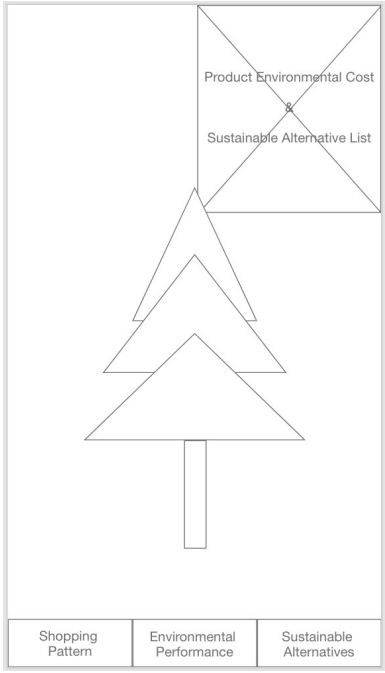
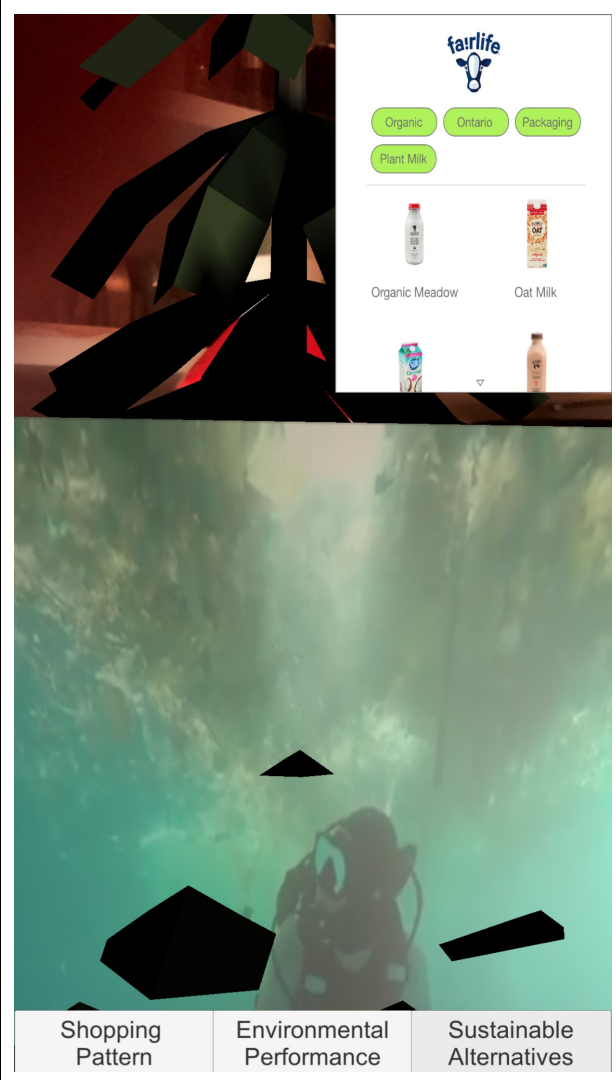
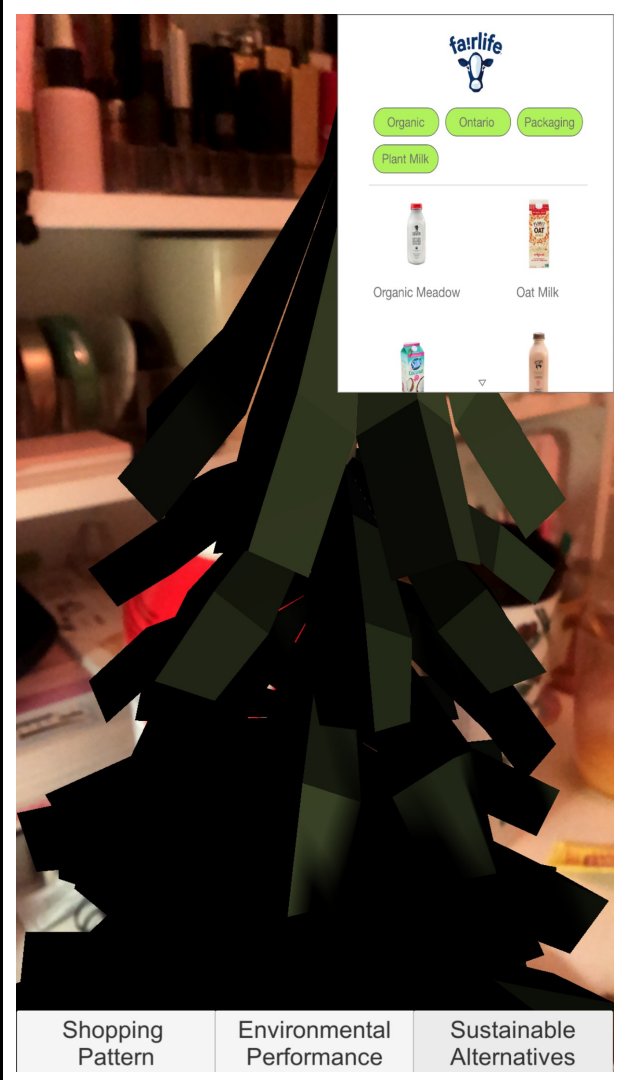
	
<p>Choose sustainable alternatives and get points. Tree grows up.</p>	
<p><b>AR Engagement System</b></p>	

Figure 21 Wireframe Design.

### 5.1.2 Final Prototype Making

The final prototype making completely follows wireframe design in the above section and implements all the functions of the app.

 The image shows the Unity logo, which consists of a white cube icon and the word "unity" in a white sans-serif font, preceded by the text "Made with". The entire logo is centered on a solid dark gray background.	 The image shows a red and white Fairlife milk bottle. The bottle is labeled "fairlife" in a stylized font, with a cow's face logo below it. It also features nutritional information: "LESS 50% sugar than regular milk", "HIGH QUALITY 13g protein per serving", and "NATURAL COWS NO HORMONES". The bottom of the bottle is white and labeled "WHOLE ultra-filtered milk", "LACTOSE FREE", "CONTAINS 9 ESSENTIAL NUTRIENTS", and "52 FL OZ (1.5L)".
<p>Welcome page of unity apps.</p>	<p>Scan the milk bottle.</p>

	
<p>Look down and press the play button to watch the video.</p>	<p>Read a list of sustainable alternatives on the top right corner.</p> <p>Choose sustainable alternatives and get points. Tree grows up.</p>

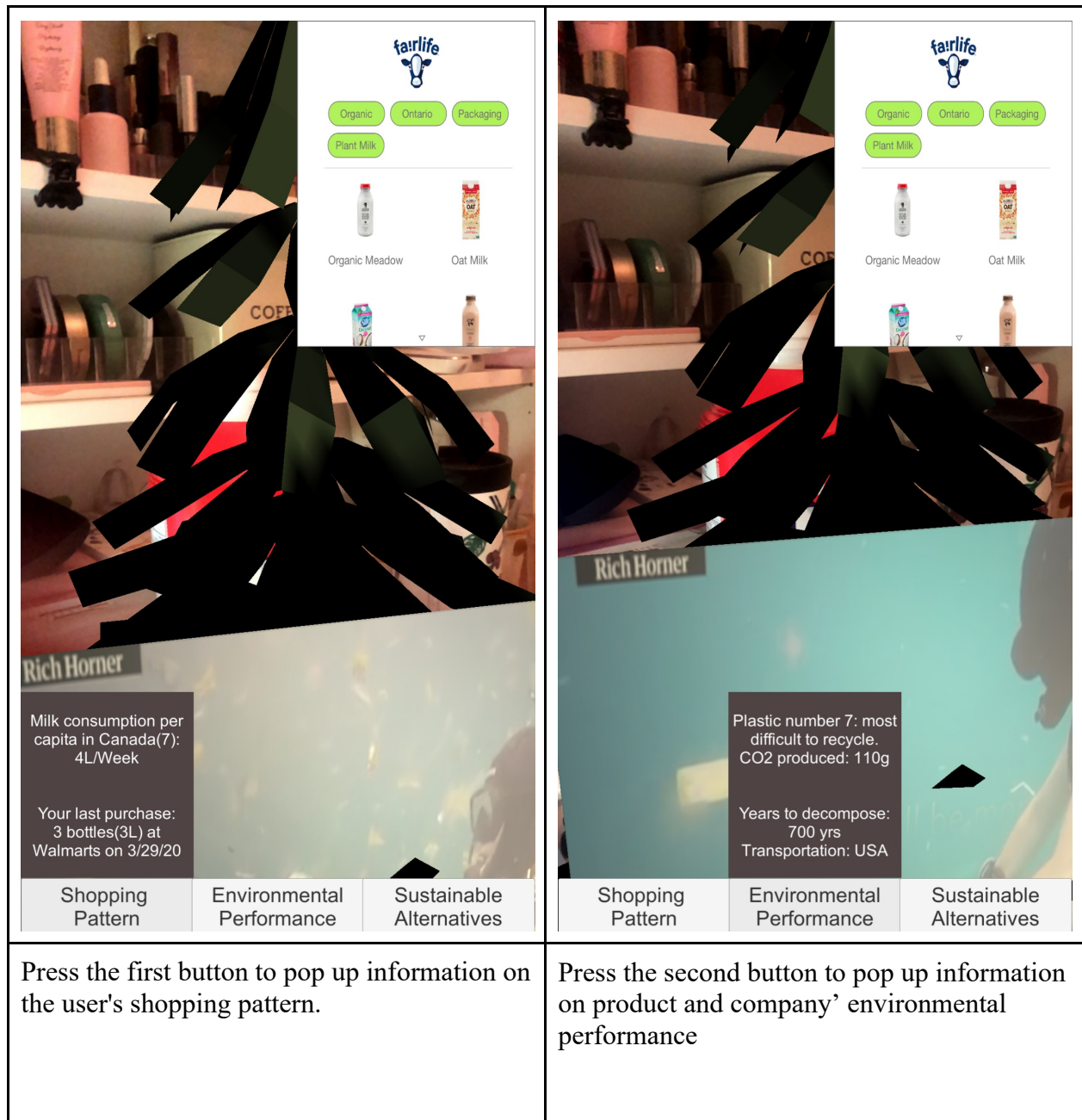


Figure 22 Final Prototype.

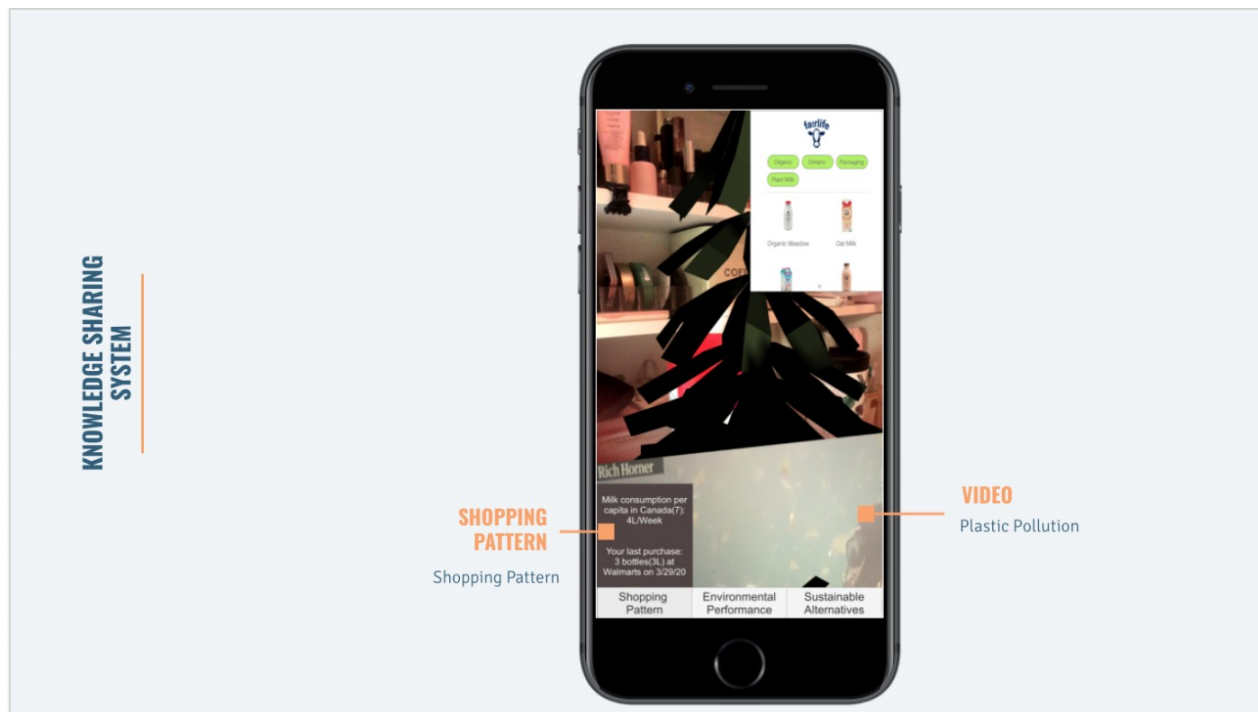


Figure 23 Step 1\_Knowledge sharing system.

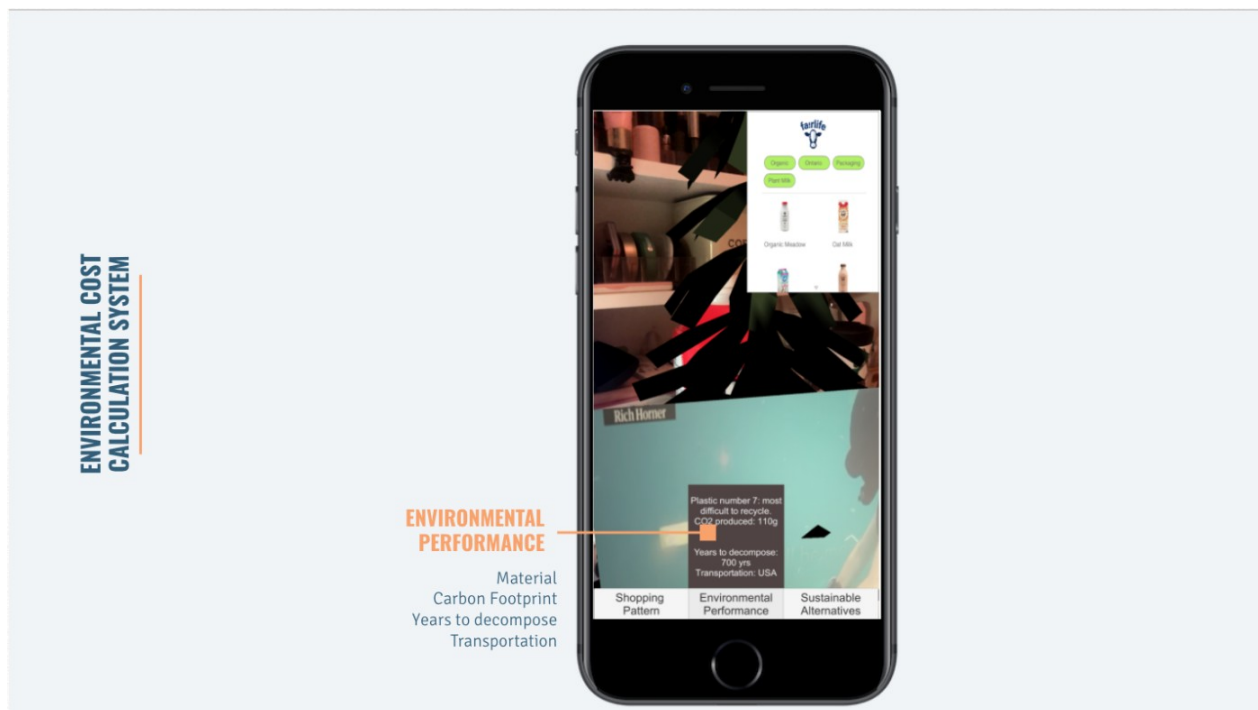


Figure 24 Step 2\_Environmental cost calculation system.

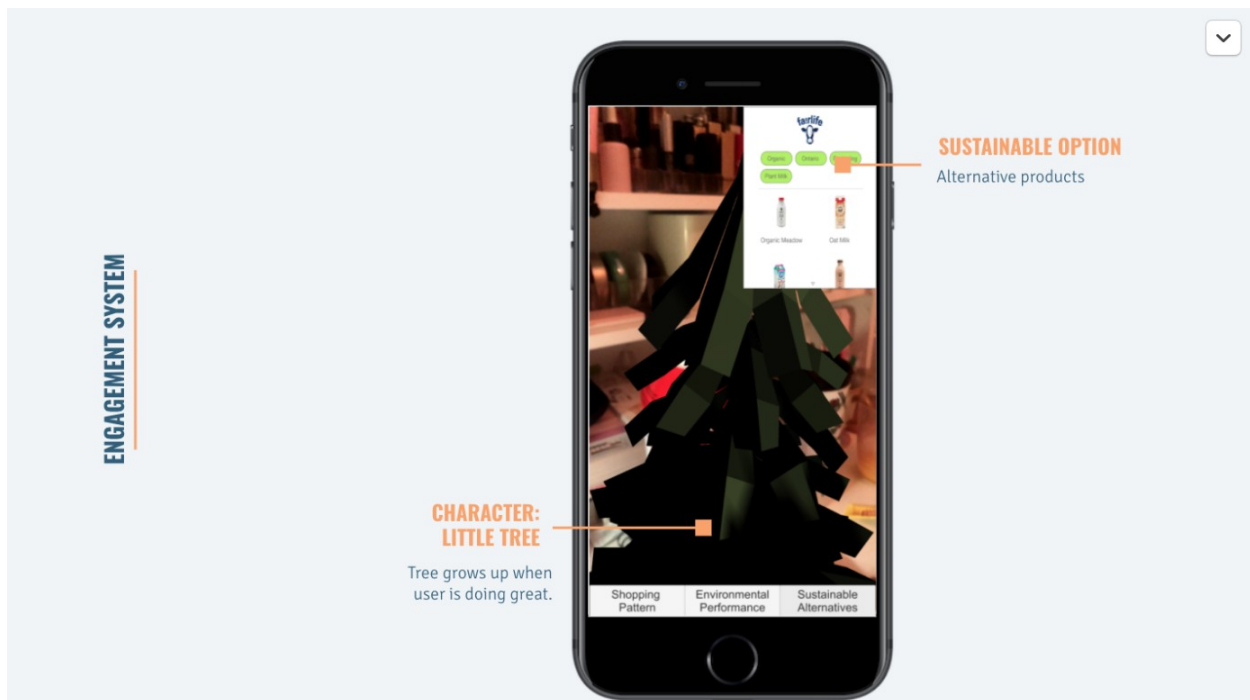


Figure 25 Step 3 \_Engagement system.

This app allows you to scan products and make right sustainable consumption decisions by experiencing an immersive environment that combines both reality and virtuality and choosing sustainable alternatives. After I made the final prototype in Unity, I imported the application into the ISO phone through XCode and took it to the real world for testing.



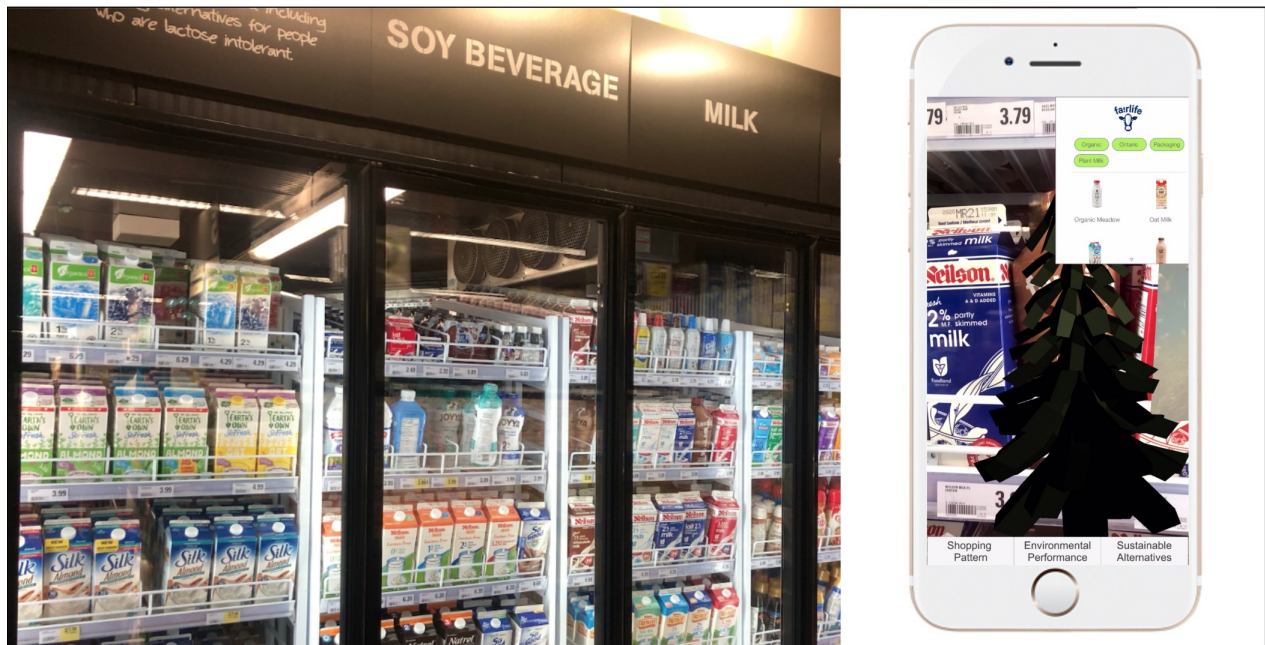


Figure 26 Testing in the grocery shopping scenario.

## Result and Reflection

The reason for doing this in-store test in a real shopping environment is because I want to experience and simulate the user's use process, and do self-reflection on the design. There was plenty of milk on the shelves. When the Fairlife's milk was scanned, the app quickly identified the bottle through the glass of the freezer. Overall, the reward mechanism and interaction of this app applied by the user is basically the same as I expected.

However, I think the three systems are relatively independent that do not give users a smooth and perfect experience. Ideally, the application should follow the user's natural, cognitive and behavioral usage habits: First, to increase environmental awareness through the environmental cost system; Second, notice their consumption behavior and obtain environmental knowledge from the knowledge sharing system; Then, make the right consumption decision by accessing available information and positive solutions; Lastly, users get positive action feedback



and incentives from the AR engagement system. Nevertheless, from the perspective of the user experience, the hierarchical structure of the user interface is scattered, which cannot guide users to complete the designed user journey. For example, users are very likely to skip the first two systems and jump directly to the engagement system, and I lose the chance of users' environmental education.

## 5.2 Evaluating Speculations

I have been inspired by the previous in-store scenario test, but I know that the test is not enough. First, the test did not reach the actual key users of the app; Second, the test did not extend to the broader possible future scenarios. The mission of this project is to explore the possibilities and opportunities in possible future usage scenarios based on the difficulties encountered in current environmental protection and sustainable consumption development.

To have a sense of what may happen in the future, tools that facilitate building and exploring future scenarios I use for Speculative Design are:

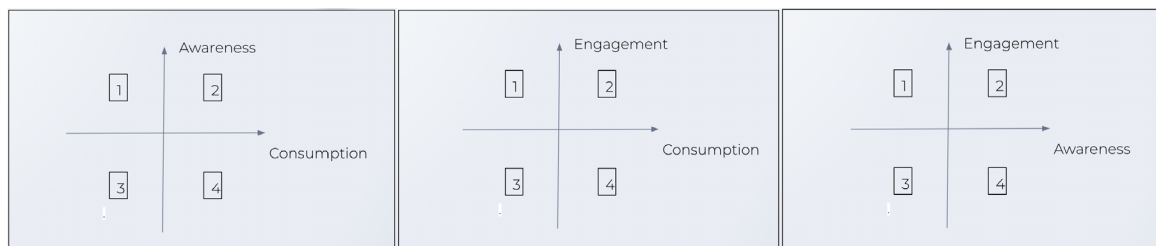
- Providing lists of future predictions of scenarios.
- Thinking about different groups of people and creating personas.
- Testing the final prototype which can be used to quickly demonstrate or simulate the use flow in future scenarios.

### 5.2.1 Future Scenarios and Personas Building

**Future Scenarios.** Providing lists of future predictions of scenarios. Speculative Design is not only about the possibilities but also probabilities of the future. So, I'll list all the possible scenarios based on factors of consumption, awareness, and engagement first, and then categorize the results by probability using the Future Cone model introduced in chapter 3.

When predicting possible future scenarios, I selected three variables, consumption, awareness, and engagement. Consumption means average consumption level; Awareness means awareness on unconscious consumption behavior and its impact on the environment;

Engagement means, with the use of emerging technologies, activity or strategy of promoting sustainable consumption are provided by the government, companies or non-profit organizations. People are actively participating in sustainability. For every 2 variables in a group, it will generate 4 scenarios. For example, scenario 1 is “low consumption & low awareness”. There are 3 variables, so there will be 12 scenarios in total. In Appendix A. 12 possible future scenarios, I have detailed descriptions for each scenario.



*Figure 27 12 possible future scenarios.*

In the Future Cone, there are 4 Ps: possible, plausible, probable, and preferred. According to this model, each scenario (out of the 12 scenarios) corresponds to one specific future: either possible future, plausible future, probable future, or preferred future. I won't take the preferred future (perfect world) as a testing scenario. Since preferred future is the intersection of plausible and probable futures, I am more interested in exploring these plausible and probable futures (runoff world), testing the prototype, and doing self-reflection on it to see how AR technology can help in increasing awareness, improving engagement, reducing the Value-Action Gap, and possibly changing consumption pattern and lifestyle. Therefore, there are three scenarios for testing generated:

1. Scenario one (Plausible Future): In this scenario, people have low awareness and engagement, but high consumption.

This future isn't very likely to happen to developed countries, but it is still possible for developing countries. Some developing countries at the beginning will adopt relatively aggressive policies to stimulate consumption for their own economic development.

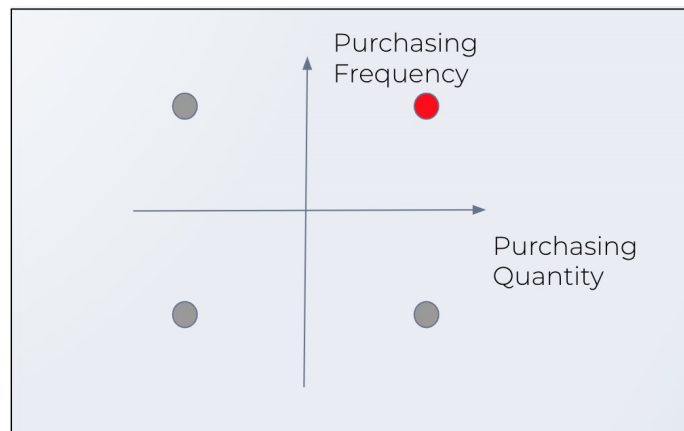
2. Scenario two (Probable Future): In this scenario, people have high awareness and engagement and high consumption.

People don't redefine their consumption level. With the awareness and knowledge of sustainable consumption, they are actively engaged in consuming environmentally friendly products. People in this world consume without remorse.

3. Scenario three (Probable Future): In this scenario, people have high awareness but low engagement with high consumption.

People in this world already have environmental awareness on their consumption. They have a reason for living a sustainable life, they just don't have enough motivation to transform attitude into actions. So, the consumption level is still high.

**Personas.** Thinking about different groups of people and creating personas. The production of user portraits needs the preliminary investigation on demographic and interviews as the data support. Because of the limited resources, I built a persona based on secondary research, observation and my personal understanding. Target users are the real decision-maker in the purchasing process, so I look at two key factors, purchasing frequency and purchasing quantity, to determine a user's profile. Purchasing frequency represents the frequency of shopping. Purchasing quantity represents the quantity of goods consumers purchase.



*Figure 28 12 possible future scenarios.*

My target audience are decision-makers, which means they decide what to buy, what not to buy, where to buy, and how much to buy. In addition, my design not only aims to help users solve their problems in life and to help them live a more sustainable life, but also hopes to solve environmental problems on a larger scale, so my target users should also be people who have a large amount of consumption. The mechanism for generating personas is the same as the one for generating scenarios, because there are only two factors this time, so there will only be four personas. By considering those four consumer personas from both household and company perspectives, I further divided the 8 categories of consumers into 8 based on family decision making and corporate decision making. So, I have 8 types of consumers in total. In Appendix B. 8 consumer personas, I have detailed descriptions for each consumer.

The app's target users are people with "high frequency & high quantity", so there are two personas for testing. By considering the factors including customer demographics, behavior patterns, barriers, and goals, I have a list of pain points for each user persona.

## Persona 1: Emily, the stay at home mom.

Emily's purchasing profile represents consumers with "High frequency vs High Quantity".

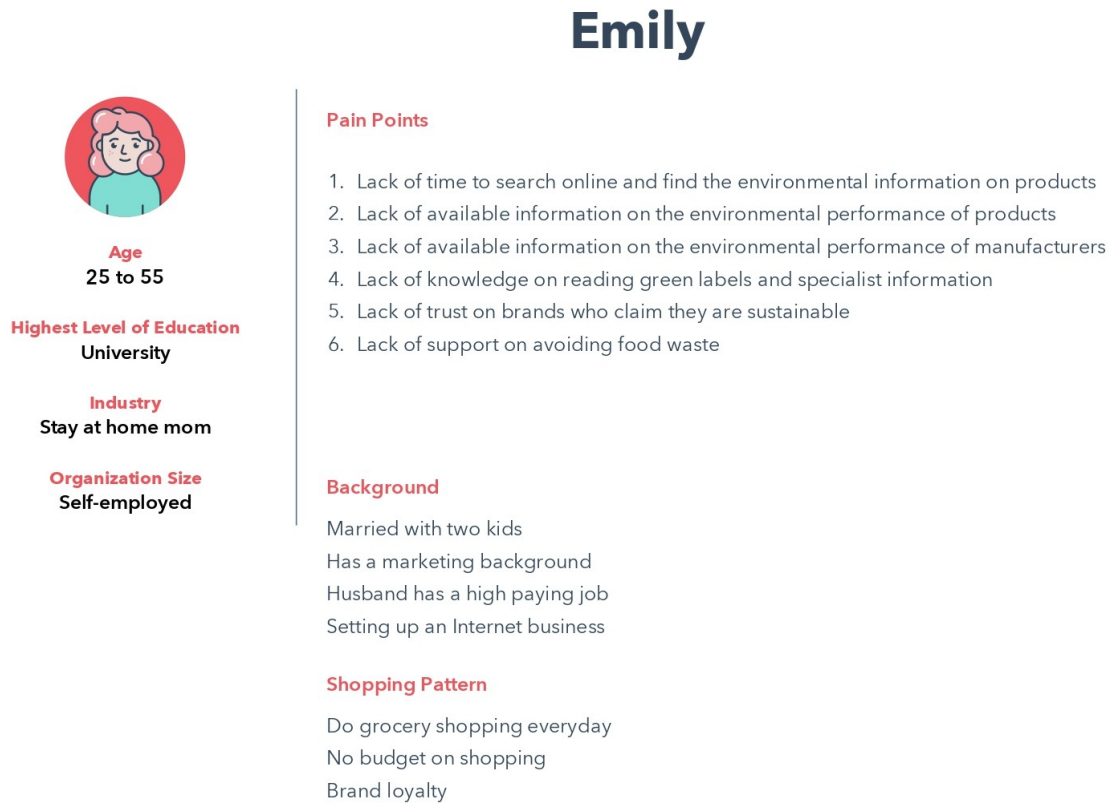


Figure 29 Persona\_Emily.

## Person 2: Josh, the restaurant owner.

Josh's purchasing profile represents small business owners with "High frequency vs High Quantity".

# Josh



### Age

Under 45 years

### Highest Level of Education

Less than a Bachelor Diploma

### Industry

Restaurant

### Organization Size

15 employees

### Pain Points

1. Lack of resource in cost reducing
2. Lack of time in dealing with suppliers
3. Lack of resource in sustainable products availability
4. Lack of trust on brands who claim they are sustainable
5. Lack of resource in protecting environment with limited budget.

### Background

Single

Running the restaurant

Dealing with suppliers and staff

Thinking about marketing

Need new ways to increase revenue.

### Problems

1. Lack of awareness on environmental impact on product and its packaging

Figure 30 Persona\_Josh.

## 5.2.2 Testing and Evaluation

Testing the final prototype which can be used to quickly demonstrate or simulate the use flow in future scenarios.

First, put two personas created for testing and self-reflection into three future scenarios:

S1 (where people have low awareness and engagement, but high consumption); S2 (where people have high awareness and engagement and high consumption); and S3 (where people have high awareness but low engagement with high consumption).

### **Scenario 1: A↓ E↓ C↑**

This is the last world we want to see in the future, where human activities place an unprecedented burden on the environment, and they do not control their consumption level as a result. Consumerism is spreading, people are not aware enough of their consumption behavior and its negative effect may bring to the environment. They are not so actively involved in environmental protection either.

### **Emily**

Emily goes to the supermarket today to buy the daily necessities and food for her family for the next week. Emily has an oversized refrigerator and freezer. She likes to fill them up so she doesn't waste storage space and her children can eat whatever they want. Faced with the dazzling array of goods, she pushed the shopping cart directly into the supermarket. Emily does her best to do garbage sorting and to avoid food waste as much as possible because it makes her feel less guilty. Emily now is encouraged to use a mobile app. In addition to showing the price of the



product, the mobile phone application also shows the environmental cost of the product. A simple plastic bottle will take hundreds of years to degrade, which will also cause a lot of carbon dioxide during manufacturing and transportation. Emily was very surprised after seeing the number. Emily decided not to buy milk in a plastic bottle but in a paper box. When Emily realized she could get digital points which can be traded for store credit, she was happy.

### **Josh**

Customers all like his restaurant very much. He is very busy running between restaurants and dealing with suppliers and staff. He hardly has any leisure time of his own. In order to save cost, on the premise of ensuring taste, he is most concerned about the price of food materials. He would not know whether the food materials are organic or environmentally friendly. Sometimes restaurants have some food waste. Now Josh was using an eco-friendly mobile app. He realized that the waste of food in his restaurant was huge. At the same time, a large number of meal boxes and food packaging cause irreversible damage to the environment. plastic pollution has seeped into every aspect of life. He decided to encourage customers to take their own containers to get free meals at lunch hour.

### **Scenario 2: A↑ E↑ C↑**

In this future world, people are aware of the importance of sustainable economic and environmental development. They recognize the inseparable relationship between the two. Meanwhile, the garbage recycling industry chain is relatively complete, and the developed

technology makes providing sufficient supply of environmentally friendly products on the market possible. People also have a high level of awareness and participation. In shopping malls, environmental standards, certificates, and labels are a very important reference for their purchasing. Because of this, people no longer feel guilty when consuming, resulting in a high level of consumption.

### **Emily**

Emily was just like them. In a crowded supermarket at the weekend, she had no time to really read the product labels or search product's environmental profile online. Though a lot of goods will also promote their performance on environmental protection, it is not a guide for her to purchase goods. She is now picking out milk in the freezer, and there are a lot of brands and flavors. Now, there is a mobile app that might help her situation. When Emily opens the mobile app, the app displays her consumption record of nearly a month or a year: information including the product category she consumed, and times and frequency of her consumption on a certain product. And there is a table that compares her consumption level with the average of her region or country. She had never realized how many drinks she consumed in a week, including coffee, milk, coke, etc. This app also saves a lot of time for her by providing information on environmental performance of products and companies, and a list of sustainable alternatives, etc. Emily is happy with this app.

### **Josh**

Everyone takes environmental protection very seriously, so people choose green restaurants they trust. Coffee shops will completely ban plastic straws and plastic cup lids, and the restaurant will

not provide meal boxes. In order to compete with other restaurants, Josh also tried his best to make his restaurant green at all costs. An app is now available for Josh. There will be environmental protection scores for all restaurants on this app. He can see if his restaurant is performing well. There are many detailed evaluation indicators in the evaluation system of this app. Josh can use this as a reference to improve the selection of suppliers, business models, and services of his restaurant.

### **Scenario 3: A↑ E↓ C↑**

The third situation is that people's consumption levels remain high, but the good news is that people already have a strong sense of environmental protection. Government and society attach importance on the popularization, promotion and education of environmental protection knowledge. However, people's participation is still not high. Because of personal and environmental factors, the conversion rate of consciousness into environmental protection actions is very low. Many people say that they care about environmental issues, many of them are generally unwilling to take actions that will solve those issues, especially when the necessary actions will inconvenience them even slightly.

### **Emily**

Emily needs coffee to wake her up in the morning. She knows the plastic straw and the paper cup itself have a negative effect on the environment. Citizens are encouraged to use their own coffee cup for coffee. The problem is that she always forgets to bring her coffee cups. Her friend introduced her to a mobile app. Users can check their consumption records and see whether their

consumption activities meet environmental protection requirements through the app. All environmental protection behavior and effort will be shown to users in the form of points. If Emily takes her coffee cup to the store today, she will get points. This is the engagement and reward system designed for the app. Each time you earn points, the character of your game, the little tree, will grow taller.

### **Josh**

Everyone takes environmental protection very seriously, but some people would still choose restaurants that taste good. Many of them were wasting food by ordering a bunch of dishes they cannot finish. Coffee shops encourage people to bring their own coffee cups, but people still forget. People have a high awareness of environmental protection, but they lack a little motivation to really turn their consciousness into action, and they feel very guilty about it. In order to create more revenue, Josh decided to cooperate with an environmental protection application to make users of the app more involved in environmental protection activities, and any environmental protection behavior will be rewarded in reality. Users can use the points in their app to redeem free meal vouchers in restaurants.

### **5.2.3 Reflection**

Then, I imagine and think how Emily and Josh would reflect on the functionalities and usability of my prototype in those three futures, and give the experiences a score based on their current pain points from 1 to 10.

<b>Emily</b>			
Pain Points	S1 A↓ E↓ C↑	S2 A↑ E↑ C↑	S3 A↑ E↓ C↑
Lack of time to search online and find the environmental information on products.	7	9	9
Lack of available information on environmental performance of products.	7	9	9
Lack of knowledge on reading green labels and specialist information.	7	9	9
Lack of trust on brands who claim they are sustainable.	8	9	9
Lack of support on avoiding excessive consumption and food waste.	6	6	6
Comments: Emily represents people with higher education who to some extent have some awareness and knowledge on sustainability. This app does not help a lot in preventing food waste by simply listing consumption activities and patterns.			

Figure 31 Evaluation\_Emily.

<b>Josh</b>			
Pain Points	S1 A↓ E↓ C↑	S2 A↑ E↑ C↑	S3 A↑ E↓ C↑
Lack of resources in sustainable products availability	9	9	9
Lack of time in dealing with suppliers	7	7	7
Lack of resource in cost reducing	6	6	6
Lack of trust on brands who claim they are sustainable	9	9	9
Lack of resources in protecting the environment with a limited budget.	6	6	6
Comment: Josh is a businessman who needs to consider costs and revenue. Currently this app is more likely to be designed for household consumers rather than business owners.			

Figure 32 Evaluation\_Josh.

## Result and Reflection

I will try this app as Emily and Josh in different possible scenarios in the future. To summarize, in possible future scenarios, this app has the possibility of involving lifestyle change in the future which may help in positively influencing people's consumption attitude, improving environmental awareness, spreading environmental knowledge and solving users' difficulties. I think this app can help me in different life scenarios. There are some future improvements of this application if I had more time:

1. Improve the design. Games and gamified gameplay activities naturally have strong “user viscosity”. I feel that the value of this app is more reflected as an environmental fact search engine, for example, I open the application and scan only when I need to know more detailed environmental information about this product in my hand. The core of the gameplay is to convert the core functions of the App into "tasks", so people log in every day to obtain the points.
2. Improve database. At present, the model can only identify one product, so as to improve image recognition accuracy, enrich database, this prototype would identify more types of products. This would help in improving overall user efficiency.
3. Improve user experience. Use high fidelity prototypes for user testing to optimize visual presentation. Summarize the collected data and user test results to optimize the design. Consumption reducing system includes 3 systems. The three systems must work together, conform to the user's cognitive process, and give the user a smooth experience.

## Chapter 6: Concluding Remarks

### 6.1 Thesis Goal

Currently, we don't have a good solution for effectively solving the serious environmental problems we are facing. The research goal of the thesis is exploring the opportunities and possibilities of AR technology in sustainability and build an example AR Consumption Reducing System(ACRS), including Knowledge Sharing System, Environmental Cost Calculation System, and AR Engagement System, exploring the possibility of AR technology in the process of increasing public environmental awareness of their consumption impact, promoting sustainable consumption by providing support and incentives, reducing the Value-Action-Gap, and possibly playing a central role in customer decision making processes in possible futures and thus forming consumers' sustainable consumption habit on a larger scale.

### 6.2 Contributions and Limitation

**Contributions.** This work makes several contributions to the research field of sustainability and the future use of emerging AR technology in sustainable consumption from the perspective of consumers. A thorough literature review on reducing, sustainable consumption and the Value-Action-Gap which provide fundamental theoretical basis for the design, creation and evaluation of projects like the AR Consumption Reducing App. A creative design of the AR tool in the framework of AR Consumption Reducing System is developed which may help in increasing

awareness, providing sustainable consumption decision support, and reducing the Value-Action-Gap, and possibly involving lifestyle and consumption pattern changes in possible futures.

**Limitation.** The thesis is mainly focusing on citizen consumers, which means factors, such as government, companies, and non-profit organization, would be ignored in the research. I did a literature rereview on reducing and sustainable consumption from the perspective of consumers. This project challenges my ability in terms of programming and design tools to achieve the research objectives. The design of the prototype is targeting general citizens, including household consumers and small business owners. The usage scenario I designed is limited to the grocery shopping, and the targeted product I selected is plastic milk bottles.

## 6.3 Future Work

This work has given rise to several future directions for the research community divided into 3 stages: First stage is to focus on the design and development of the AR Consumption Reducing Application; Second stage will work on consumption habits study; Third stage is to apply the work for future users on a larger scale.

**First Stage.** At present, my prototype can only identify milk bottles in a limited way. I hope the first stage of the involvement will improve the prototype's design so that it can identify a variety of products. The goal of this stage is beyond my personal ability because other techniques, such as Artificial Intelligence(AI), are involved in the project. AI technology has been able to recognize and classify mass images. Through data modeling, AR can continuously learn and



recognize new products by itself. The more objects it can scan, the higher the accuracy will be. If the AR mobile application encounters an unidentified item, I would like it to have the ability allowing users to enter the product name manually or by voice. In brief, the goal of the first stage is to let the AR mobile prototype become a functional product which can be used in the market.

**Second Stage.** As long as the product can be used in a certain scope in the market, I hope it can become a tool used to study people's consumption habits and consumers' journey. With the limited resources and time, a certain number of people who are selected as research samples are encouraged to use the AR application for a relatively long period. Through a long period of observation, designers and researchers were able to understand the consumers' needs and difficulties while using this product from psychological and behavioral perspectives. I believe that the meaningful conclusion generated from the observation and investigation will provide effective solutions to improve the product design in the end. This stage of investment will verify the capabilities of AR technology. Can AR change people's attitudes as an empathy tool? Whether the AR engagement system can increase user stickiness in reducing? Whether the AR Consumption Reducing System can possibly change people's consumption habits and consumption patterns? Can this mobile application addressing reducing strategy play a central role in possible future customer decision making processes and thus form consumers' sustainable consumption habit on a larger scale?

**Third Stage.** By using the mixed methodology of research through design and speculative design, the functions and design of mobile applications are continuously iterating based on the results of previous investigation and user testing. I hope it can be further developed and used by

more users all over the world in the possible future scenarios, from changing a person's consumption behavior, changing a family's consumption habits, and finally affecting the consumption and production values of the society. AR technology now, as an immensely promising technology, still has some limitations. “There is no obvious overall best solution to many of the challenging areas in the field of AR, such as tracking and display technologies.”(Craig, 5) With more technological innovations that may occur in the possible futures, the AR phone application can be used in many more scenarios in different cultures and countries helping consumers solve the problems encountered in the process of sustainable development.

## 6.4 Final Thoughts

Environmental problems and resource problems are complex issues resulting from population growth and household overconsumption. Speaking of environmental protection and reducing population growth is not the issue, but the number of consumers and the scale and nature of their consumption makes this problem serious. However, there are many factors, such as availability, affordability, and convenience, involved in the process of sustainable development. Marketing and advertising essentially catering to the nature of consumers could be another reason for overconsumption as the economy develops. Though consumers play a crucial role as consumers and voters, it is still largely determined by the government. From the World Business Council for Sustainable Development(WBCSD), “Governments and policy-makers at all levels have a vital role to play in creating the right legal, fiscal and cultural environment for sustainable businesses

to thrive”(6). In addition, companies can influence consumer behavior by providing accessible sustainable choices through product development, technological innovation, and product packaging design.

I believe that design and technology can help in raising public awareness, promoting sustainable behavior, involving consumption habits change, and thus resulting in helping people participate more actively as citizen consumers in the future. Technology is valuable, but not being seen by users. As a designer, I feel it is my responsibility to make the technology visible to the public.

## Works Cited

- Angel, Water. "The Life Cycle of a Plastic Water Bottle.", 23 Jan. 2020,  
angelwater.com/blog/life-cycle-plastic-water-bottle/.
- Antelava, A., Damilos, S., Hafeez, S. *et al.* Plastic Solid Waste (PSW) in the Context of Life Cycle Assessment (LCA) and Sustainable Management. *Environmental Management* **64**, 230–244 (2019). <https://doi.org/10.1007/s00267-019-01178-3>
- Arena, Umberto, et al. "Life Cycle Assessment of a Plastic Packaging Recycling System." SpringerLink, Ecomed, <https://link.springer.com/article/10.1007/BF02978432>.
- Auger, James. "Speculative Design: Crafting the Speculation." *Digital Creativity*, vol. 24, no. 1, 2013, pp. 11–35., doi:10.1080/14626268.2013.767276.
- Azuma, Ronald T. "A survey of augmented reality." *Presence: Teleoperators & Virtual Environments* 6.4 (1997): 355-385.
- BARR, STEWART. "Environmental Action in the Home: Investigating the 'Value-Action' Gap." *Geography*, vol. 91, no. 1, 2006, pp. 43–54. JSTOR, [www.jstor.org/stable/40574132](http://www.jstor.org/stable/40574132). Accessed 28 Feb. 2020.
- Bettman, et al. "Constructive Consumer Choice Processes." OUP Academic, Oxford University Press, 1 Dec. 1998, [academic.oup.com/jcr/article/25/3/187/1795625](http://academic.oup.com/jcr/article/25/3/187/1795625).

Billingshurst, Mark, et al. “Magic Book: transitioning between reality and virtuality” CHI 01

Extended Abstracts on Human Factors in Computing Systems - CHI 01, 2001,

doi:10.1145/634067.634087.

Blake, James. “Overcoming the ‘Value-Action Gap’ in Environmental Policy: Tensions

between National Policy and Local Experience.” *Local Environment*, vol. 4, no. 3, 1999,

pp. 257–278., doi:10.1080/13549839908725599.

Craig, Alan B. “Mobile Augmented Reality.” *Understanding Augmented Reality*, 2013, pp.

209–220., doi:10.1016/b978-0-240-82408-6.00007-2.

Dijksterhuis, Ap, and Zeger Van Olden. “On the Benefits of Thinking Unconsciously:

Unconscious Thought Can Increase Post-Choice Satisfaction.” *Journal of Experimental*

*Social Psychology*, vol. 42, no. 5, 2006, pp. 627–631., doi:10.1016/j.jesp.2005.10.008.

Dunne , Anthony, and Fiona Raby. *Speculative Everything: Design, Fiction, and Social*

*Dreaming*. MIT Press, 2014.

Dünser, Andreas, and Eva Hornecker. “An Observational Study of Children Interacting with

an Augmented Story Book.” *Technologies for E-Learning and Digital Entertainment*

*Lecture Notes in Computer Science*, pp. 305–315., doi:10.1007/978-3-540-73011-8\_31.

Durrant, Abigail C., et al. “Research Through Design: Twenty-First Century Makers and

Materialities.” *Design Issues*, vol. 33, no. 3, 2017, pp. 3–10., doi:10.1162/desi\_a\_00447.

eyecandylab. “eyecandylab x adidas | For The Oceans.” YouTube, 19 Nov. 2019,

<https://www.youtube.com/watch?v=ObeW9VOdW4o>.

- Farley, Alan. "How Starbucks Makes Money: Most Revenue Comes From Americas, Beverages." Investopedia, Investopedia, 9 Mar. 2020, [www.investopedia.com/articles/markets/021316/how-starbucks-makes-money-sbux.asp](http://www.investopedia.com/articles/markets/021316/how-starbucks-makes-money-sbux.asp).
- Felicia. "Mobile App Success Story: AR Dragon." App Samurai, 2 Apr. 1970, [appsamurai.com/mobile-app-success-story-ar-dragon/](http://appsamurai.com/mobile-app-success-story-ar-dragon/).
- Felix Acker. "New findings on unconscious versus conscious thought in decision making: additional empirical data and meta-analysis." *Judgment and Decision Making*, Vol. 3, No. 4, April 2008, pp. 292–303
- Fogg, B. J. "Fogg's Behavior Model." (2007). [http://www-personal.umich.edu/~mrother/KATA\\_Files/FBM.pdf](http://www-personal.umich.edu/~mrother/KATA_Files/FBM.pdf)
- Frayling, Christopher. "Research in art and design." *Royal College of Art, Research Papers*, vol. 1, no. 1, 1993, pp. 1-5
- Fuchs, Doris A., and Sylvia Lorek. "Sustainable Consumption Governance: A History of Promises and Failures." *Journal of Consumer Policy*, vol. 28, no. 3, 2005, pp. 261–288., doi:10.1007/s10603-005-8490-z.
- "First Augmented Reality Language App with Speech Recognition." Mondly Blog, 19 Mar. 2018, [www.mondly.com/blog/2018/03/19/introducing-first-augmented-reality-language-app-speech-recognition/](http://www.mondly.com/blog/2018/03/19/introducing-first-augmented-reality-language-app-speech-recognition/).
- "Forget Plastic Straws. Starbucks Has a Cup Problem." CNN, Cable News Network, [www.cnn.com/interactive/2019/02/business/starbucks-cup-problem/index.html](http://www.cnn.com/interactive/2019/02/business/starbucks-cup-problem/index.html).

Gironi, Fausto, and Vincenzo Piemonte. "Life Cycle Assessment of Polylactic Acid and Polyethylene Terephthalate Bottles for Drinking Water." *Environmental Progress & Sustainable Energy*, vol. 30, no. 3, Oct. 2010, pp. 459–468., doi:10.1002/ep.10490.

goodman Follow. "Speculative Design Introduction." LinkedIn SlideShare, 13 May 2014, [www.slideshare.net/egoodman/speculative-design-introduction](http://www.slideshare.net/egoodman/speculative-design-introduction).

Goodwin, Kim. "Getting from Research to Personas: Harnessing the Power of Data." Cooper, 10 Dec. 2019, [www.cooper.com/journal/2008/05/getting\\_from\\_research\\_to\\_perso/](http://www.cooper.com/journal/2008/05/getting_from_research_to_perso/).

Goodwin, Kim. "Getting from Research to Personas: Harnessing the Power of Data." Cooper, 10 Dec. 2019, [www.cooper.com/journal/2008/05/getting\\_from\\_research\\_to\\_perso/](http://www.cooper.com/journal/2008/05/getting_from_research_to_perso/).

Hardy, Robert, and Enrico Rukzio. "Touch & Interact." *Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services - MobileHCI 08*, 2008, doi:10.1145/1409240.1409267.

Howley, Peter M., et al. "Contrasting the attitudes of farmers and the general public regarding the 'multifunctional' role of the agricultural sector." *Land Use Policy* 38.38 (2014): 248-256.

Isberto, Michael. "2018 Update: A Timeline and History of Augmented Reality." Colocation America, Colocation American Staff, 13 Mar. 2019, [www.colocationamerica.com/blog/history-of-augmented-reality](http://www.colocationamerica.com/blog/history-of-augmented-reality).

Issa, Isabela, and Tim McAloone. "Selected Regional Environment-Related Indicators." *OECD Environmental Performance Reviews: Italy 2013 OECD Environmental Performance Reviews*, Aug. 2013, pp. 1–40., doi:10.1787/9789264186378-table12-en.

Ivanova, Diana, et al. "Environmental Impact Assessment of Household Consumption."

Journal of Industrial Ecology, vol. 20, no. 3, 2015, pp. 526–536., doi:10.1111/jiec.12371.

Jambeck, J. R., et al. "Plastic Waste Inputs from Land into the Ocean." Science, vol. 347, no.

6223, Dec. 2015, pp. 768–771., doi:10.1126/science.1260352.

Jibril, Jibril Dan Azimi, et al. "3R s Critical Success Factor in Solid Waste Management

System for Higher Educational Institutions." Procedia - Social and Behavioral Sciences,

vol. 65, 2012, pp. 626–631., doi:10.1016/j.sbspro.2012.11.175.

Jung, Jinki, et al. "Smartphone as an Augmented Reality Authoring Tool via Multi-Touch

Based 3D Interaction Method." Proceedings of the 11th ACM SIGGRAPH International

Conference on Virtual-Reality Continuum and Its Applications in Industry - VRCAI 12,

2012, doi:10.1145/2407516.2407520.

Kalmykova, Yuliya, et al. "Resource Consumption Drivers and Pathways to Reduction:

Economy, Policy and Lifestyle Impact on Material Flows at the National and Urban

Scale." Journal of Cleaner Production, vol. 132, 2016, pp. 70–80.,

doi:10.1016/j.jclepro.2015.02.027.

Kaza, Silpa, et al. "What a Waste 2.0: A Global Snapshot of Solid Waste Management to

2050." 2018, doi:10.1596/978-1-4648-1329-0.

Kunjo. Speculative, 12 Feb. 2017, speculative.hr/en/introduction-to-speculative-design-

practice/.

Lange, Hellmuth, and Lars Meier. "The New Middle Classes: Globalizing Lifestyles",

Consumerism and Environmental Concern. Springer, 2010.



- Laustsen, Gary. "Reduce–Recycle–Reuse: Guidelines for Promoting Perioperative Waste Management." *AORN Journal*, vol. 85, no. 4, 2007, pp. 717–728., doi:10.1016/s0001-2092(07)60146-x.
- Lee, Joongsup. "A Study for Increasing Reusable Cup Consumption in the Coffee Industry: Focused on Behavior Change with Motivation." doi:10.31274/etd-180810-4431.
- Loh, Jonathan & Goldfinger, Stephen. "Living Planet Report 2006", WWF, Living Planet Report, 2006
- Lopezmosquera, Natalia, Fernando Lara Lopez, and Mercedes Sanchez. "Key factors to explain recycling, car use and environmentally responsible purchase behavior: A comparative perspective." *Resources Conservation and Recycling*, 2015, pp. 29-39.
- Macleod, Ishbel. "Heinz Launches Augmented-Reality Trial for Ketchup with Blippar." *The Drum*, The Drum, 27 Oct. 2011, [www.thedrum.com/news/2011/10/27/heinz-launches-ketchup-augmented-reality-trial-blippar](http://www.thedrum.com/news/2011/10/27/heinz-launches-ketchup-augmented-reality-trial-blippar).
- Mccartney, Margaret. "Margaret McCartney: Game on for Pokémon Go." *Bmj*, Sept. 2016, p. i4306., doi:10.1136/bmj.i4306.
- McGarry, Caitlin. "What Is Apple's ARKit? Everything You Need to Know." *Tom's Guide*, Tom's Guide, 24 Jan. 2018, [www.tomsguide.com/us/apple-arkit-faq,review-4636.html](http://www.tomsguide.com/us/apple-arkit-faq,review-4636.html).
- Milgram, Paul, and Fumio Kishino. "A taxonomy of mixed reality visual displays." *IEICE TRANSACTIONS on Information and Systems* 77.12 (1994): 1321-1329.

- Newton, Peter, and Denny Meyer. "Exploring the Attitudes-Action Gap in Household Resource Consumption: Does 'Environmental Lifestyle' Segmentation Align with Consumer Behaviour?" *Sustainability*, vol. 5, no. 3, 2013, pp. 1211–1233., doi:10.3390/su5031211.
- Nielsen, Tobias D., et al. "Politics and the Plastic Crisis: A Review throughout the Plastic Life Cycle." *Wiley Online Library*, John Wiley & Sons, Ltd, 8 Aug. 2019, <https://onlinelibrary.wiley.com/doi/full/10.1002/wene.360>.
- Padel, Susanne, and Carolyn Foster. "Exploring the Gap between Attitudes and Behaviour." *British Food Journal*, vol. 107, no. 8, 2005, pp. 606–625., doi:10.1108/00070700510611002.
- Paper Triangles. "White Noise AR Installation." *YouTube*, 11 Oct. 2017, [https://www.youtube.com/watch?v=GWlfp8\\_iulc&t=22s](https://www.youtube.com/watch?v=GWlfp8_iulc&t=22s).
- Park, Michael. "AR Is on the Verge of Transforming the Human-Computer Relationship." *VentureBeat*, VentureBeat, 31 Oct. 2017, [venturebeat.com/2017/10/30/ar-is-on-the-verge-of-transforming-the-human-computer-relationship/](http://venturebeat.com/2017/10/30/ar-is-on-the-verge-of-transforming-the-human-computer-relationship/).
- Peace, Erin. "Speculative Design for the Real World." *Medium*, UX Collective, 25 July 2019, [uxdesign.cc/speculative-design-for-the-real-world-551130b22827](https://uxdesign.cc/speculative-design-for-the-real-world-551130b22827).
- Person. "Go Inside the Amazon Rain Forest With TIME's AR Experience." *Time*, Time, 12 Sept. 2019, [time.com/longform/inside-amazon-rain-forest-vr-app/](http://time.com/longform/inside-amazon-rain-forest-vr-app/).

- Princen, Thomas. "Principles for Sustainability: From Cooperation and Efficiency to Sufficiency." *Global Environmental Politics*, vol. 3, no. 1, 2003, pp. 33–50., doi:10.1162/152638003763336374.
- R. Azuma, et al. "Recent advances in augmented reality," in *IEEE Computer Graphics and Applications*, vol. 21, no. 6, pp. 34-47, Nov.-Dec. 2001.
- Roy, Vivek. "Sustainable Production and Consumption – Business Perspective." *Encyclopedia of Renewable and Sustainable Materials*, 2020, pp. 519–526., doi:10.1016/b978-0-12-803581-8.11510-3.
- Sakai, S., Yoshida, H., Hirai, Y. *et al.* International comparative study of 3R and waste management policy developments. *J Mater Cycles Waste Manag* **13**, 86–102 (2011). <https://doi.org/10.1007/s10163-011-0009-x>
- Spangenberg, Joachim H, and Sylvia Lorek. "Environmentally Sustainable Household Consumption: from Aggregate Environmental Pressures to Priority Fields of Action." *Ecological Economics*, vol. 43, no. 2-3, 2002, pp. 127–140., doi:10.1016/s0921-8009(02)00212-4.
- Specht, Marcus & Ternier, Stefaan & Greller, Wolfgang. Mobile Augmented Reality for Learning: A Case Study. *Journal of the Research Center for Educational Technology*. 7. ,2011.
- SpeculativeEdu, [speculativeedu.eu/approaches-methods-and-tools-for-speculative-design/](https://speculativeedu.eu/approaches-methods-and-tools-for-speculative-design/).
- "Sustainable Consumption." Wikipedia, Wikimedia Foundation, 25 Feb. 2020, en.wikipedia.org/wiki/Sustainable\_consumption.

“Sustainable Materials Management.” EPA, Environmental Protection Agency, 5 Mar. 2020, [www.epa.gov/smm](http://www.epa.gov/smm).

Team, Trefis. “Google Glasses Sound As Crazy As Smartphones And Tablets Once Did.” Forbes, Forbes Magazine, 6 Apr. 2012, [www.forbes.com/sites/greatspeculations/2012/04/05/google-glasses-sound-as-crazy-as-smartphones-and-tablets-once-did/#3b3c5d331342](http://www.forbes.com/sites/greatspeculations/2012/04/05/google-glasses-sound-as-crazy-as-smartphones-and-tablets-once-did/#3b3c5d331342).

TED Archive. “Can VR help create empathy around climate change? Jeremy Bailenson.” YouTube, 22 Dec. 2016, <https://www.youtube.com/watch?v=zJCD3R3LISs&t=8s>.

Thøgersen, John, and Ulf Schrader. “From Knowledge to Action—New Paths Towards Sustainable Consumption.” *Journal of Consumer Policy*, vol. 35, no. 1, Apr. 2012, pp. 1–5., doi:10.1007/s10603-012-9188-7.

Turner, Camilla. “Coffee Chains Accused of Making False Recycling Claims.” *The Telegraph*, Telegraph Media Group, 15 Mar. 2016, [www.telegraph.co.uk/news/shopping-and-consumer-news/12194148/Coffee-chains-accused-of-making-false-recycling-claims.html](http://www.telegraph.co.uk/news/shopping-and-consumer-news/12194148/Coffee-chains-accused-of-making-false-recycling-claims.html).

University of Mary Washington, “Home.” Office of Sustainability, 19 Sept. 2019, [sustainability.umw.edu/areas-of-sustainability/economic-sustainability/](http://sustainability.umw.edu/areas-of-sustainability/economic-sustainability/).

Wagner, Daniel & Schmalstieg, Dieter. (2006). Handheld Augmented Reality Displays. 321 - 321. 10.1109/VR.2006.67.

World Business Council for Sustainable Development(WBCSD), Sustainable Consumption Facts and Trends: from a Business Perspective. World Business Council for Sustainable Development, 2008.

Xu, Chunhui. (2017). Analysis on the Related Legislation Issues of Circular Economy.

Finance and Management. 1. 234. 10.26549/cjygl.v1i3.391.

[https://www.researchgate.net/publication/320435781\\_xunhuanjingjixiangguanlifawentiqianxi](https://www.researchgate.net/publication/320435781_xunhuanjingjixiangguanlifawentiqianxi)

Young, William, et al. “Sustainable Consumption: Green Consumer Behaviour When Purchasing Products.” Sustainable Development, 2009, doi:10.1002/sd.394.

Zhiying, Gao. "Reducing material consumption: a literature review on sustainable consumption." Crowdsourced Science Briefs on Sustainable Development, 12 Mar. 2015, pp. 1-5.

<https://sustainabledevelopment.un.org/content/documents/6077GSDR%20Brief%2027CN.pdf>

Zimmerman, John, et al. “An Analysis and Critique Of Research through Design.”

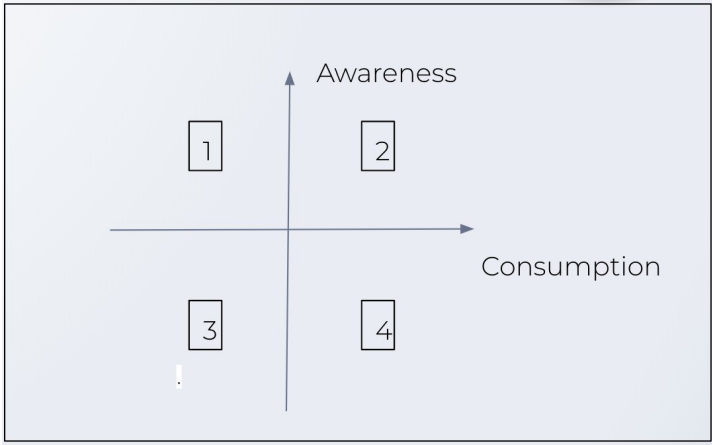
Proceedings of the 8th ACM Conference on Designing Interactive Systems - DIS 10, 2010, doi:10.1145/1858171.1858228.

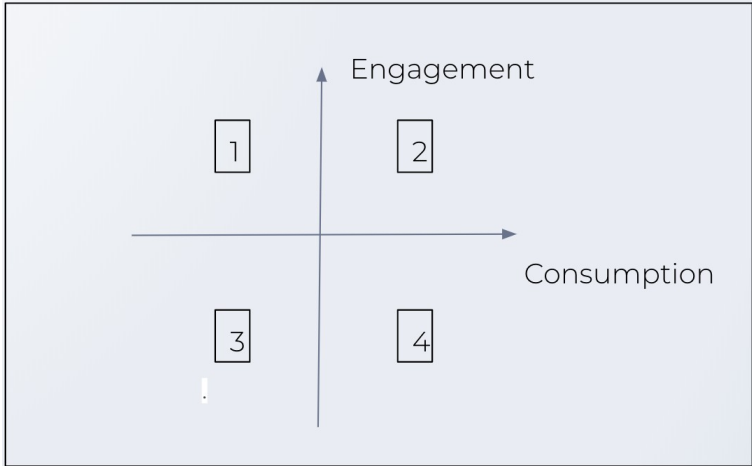
Ziyan, Chen. “China's Alipay Uses AI, AR to Help Sort Garbage.” China's Alipay Uses AI, AR to Help Sort Garbage - Chinadaily.com.cn,

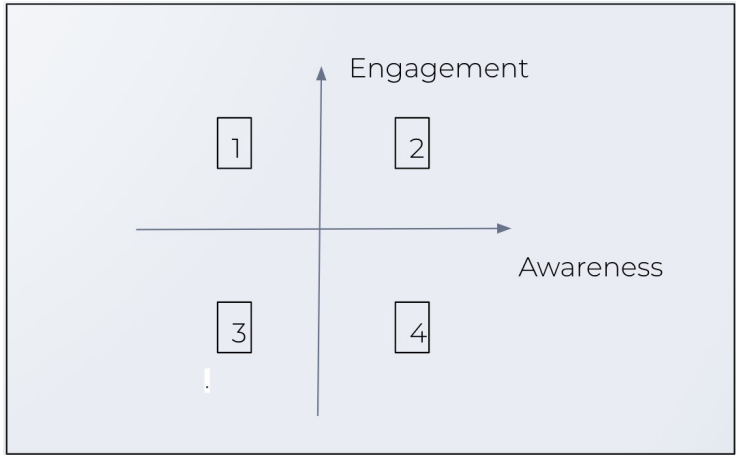
[www.chinadaily.com.cn/a/201907/16/WS5d2d6af8a3105895c2e7db39.html](http://www.chinadaily.com.cn/a/201907/16/WS5d2d6af8a3105895c2e7db39.html).

## Appendices

### Appendix A. 12 possible future scenarios.

<p style="text-align: center;"><b>Awareness &amp; Consumption</b></p> 		
Scenarios	Description	Future Cone
S1: High Awareness & Low Consumption	Global warming, biodiversity and other environmental issues are becoming more and more serious. Public awareness on sustainability increases, and they redefine their needs and cut unnecessary consumption.	Preferred
S2: High Awareness & High Consumption	People have enough awareness on sustainability. However, the intention of reducing cannot transform into action. With the development of the economy, the average consumption level is still very high. People may not have enough knowledge on sustainability.	Probable
S3: Low	People have low awareness of sustainable consumption, and their consumption level is very low. Maybe people are experiencing a financial	Possible

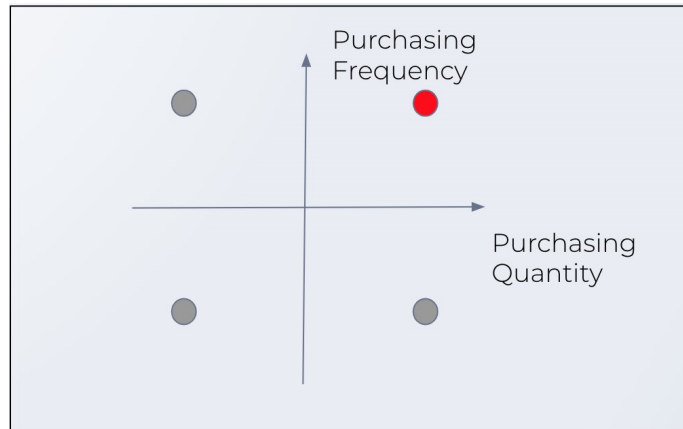
Awareness & Low Consumption	crash or a war.	
S4:  Low Awareness & High Consumption	People don't have enough awareness on their consumption behavior. They are greatly influenced by marketing and advertising. Mindless overconsumption is destroying their life.	<b>Plausible</b>
<p style="text-align: center;"><b>Engagement &amp; Consumption</b></p> 		
S1:  High Engagement & Low Consumption	People want to feel like every day they're making meaningful progress toward some meaningful goal which is to protect the environment. They actively participate in sustainability for reasons. Everyone is trying to live a simple or sustainable life.	<b>Preferred</b>
S2:  High Engagement & High Consumption	To encourage people to live a sustainable life, government, company and non-profit organizations are promoting sustainable consumption. Manufacturing produces more environmentally friendly products than before. People are very involved in environmental protection. However, they feel they are protecting the environment while purchasing sustainable alternatives, and consumption level increases.	<b>Probable</b>
S3:	The consumption level is low. No need for an engagement system.	<b>Possible</b>

Low Engagement & Low Consumption		
S4: Low Engagement & High Consumption	No strategies or actions have been taken to encourage people to protect the environment, reduce consumption, or promote sustainable consumption. Consumption level is high.	<b>Plausible</b>
<p style="text-align: center;"><b>Awareness &amp; Engagement</b></p> 		
S1: Low Awareness & High Engagement	This scenario is not very likely to happen. People are actively participating in sustainable consumption promoted by the government, companies, or non-profit organizations with the help of technologies. However, the awareness of sustainable consumption is low.	Possible
S2: High Awareness & High Engagement	This is a perfect world where people have high awareness and high engagement. This may be because the government attaches great importance to environmental protection having corresponding policy. Citizens have enough knowledge and awareness of sustainability.	Preferred
S3: Low Awareness & Low Engagement	This is a world where people have low awareness and low engagement. The root cause of this situation is the lack of awareness on environmental protection.	<b>Plausible</b>



<p>S4:</p> <p>High Awareness &amp; Low Engagement</p>	<p>People already have high awareness of their consumption behavior and they already realize the importance of sustainable consumption. There is a Value-Action- Gap. They just don't have enough motivation to transform attitudes into actions.</p>	<p><b>Probable</b></p>
---	---	------------------------

## Appendix B. Four Personas



	Household	Company	
High Purchasing Frequency & High Purchasing Quantity	Moms at home do most shopping for her entire family	Restaurant owners dealing with suppliers need to make many decisions for their businesses.	Target
High Purchasing Frequency & Low Purchasing Quantity	Students live alone. They decide what, where, how much, how often to buy, but the quantity of goods shopping is very low.	The small grocer's, the small dress shop, the beauty salon, all are decision makers with small businesses, but they don't do a lot of grocery shopping.	Not my Target
Low Purchasing Frequency & Low Purchasing Quantity	Dads at home. They just need to meet the simple needs of life.	There are many possible roles.	Not my Target
Low Purchasing	Children at home. They don't do shopping but it doesn't	Chiefs at a restaurant. They use a lot of food material but they	Not my Target

Frequency & High Purchasing Quantity	mean their consumption level is low.	don't make decisions on suppliers.	
--	---	---------------------------------------	--