

Group 15

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An aerial photograph of a city at sunset, with a large, modern glass building in the foreground. The sky is a deep red, and the city lights are visible in the background.

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1 | Introduction

The goal for the realization, RPC, and Testing course (4WSU00) will focus mainly on creating a sustainable device (designed in the ideation and preliminary design phase) to assist a chosen demographic. More specifically making the EcoExplorer device a reality, capable of assisting tourists in exploring new locations sustainably.

Following the ideation and preliminary design course, it was decided to continue working on the chosen representation of the decided design. It is now required to follow up on the chosen design and to create a MVP (minimum viable prototype) that will show the outline of one major aspect of the chosen design with a significant level of technological complexity.

The MVP will be developed through a process involving several key steps. Firstly, a thorough evaluation of the preliminary design will be conducted. This evaluation will focus on identifying specific goals that the MVP must achieve. Following this, the necessary means to create the MVP will be determined. Subsequently, rigorous testing of the MVP will take place to ensure its functionality and effectiveness. Future strategies will then be defined, considering factors such as desirability and feasibility, to enhance the design's marketability. Finally, the design will be assessed as a sellable product.

This report will represent the process of group 15 and how the creation of an MVP for a product that promotes sustainability was achieved. This overall process will include a recap of what has been done and how to move forward, a collaborative approach between creators and consumers, the electrical and economical characteristics of the MVP, and steps that will be taken in the future to ensure that EcoExplorer can fulfill the most positive results as possible.

2 | Evaluation of Preliminary Design Solution

The sustainable design that was made for tourists which was come up with in the ideation and preliminary design course is called EcoExplorer. EcoExplore consists of two separate parts, an app for mobile device connection and a navigation guide in the form of a physical device. The EcoExplorer products were designed for young adult tourists within the age group of 18 to 30 years.

With the EcoExplorer app, a user can select a random sustainable activity from a few different categories. After choosing a category the device will present a relevant trivia question. Once a user answers a question correctly, they will then be prompted with a list of sustainable activity choices. If a user answers the question incorrectly, they will be prompted with another question until they answer one correctly. The data from that destination will then be transferred to the physical product, which functions as a GPS. When the question is answered correctly, points will be awarded to the user. The points may later be exchanged for puzzle pieces of an important monument of your specific location. After the trivia question is answered, the product will act as a GPS, guiding the user to the selected location.

The primary goal of the additional physical product is to reduce users' screen time by introducing a device that effectively prevents distractions from notifications on their phones, allowing them to fully enjoy activities without interruptions. The app categories and the initial preliminary design of the physical product are visible in [Figure 2.1](#)



Figure 2.1: App design and physical product preliminary design

This design was reached by firstly choosing one idea from multiple concepts. This design was then discussed with the target audience in the form of user interviews. Competition was also compared to the product to decide how this idea differentiated from the market and presented something new. Due to the realistic constraints of the project. The scale of functionality is limited to within the range of Eindhoven. This means that the design of the EcoExplorer is not meant to function outside of Eindhoven.

The chosen format for outlining the features of the EcoExplorer product is a MoSCoW list, which specifies all of the must have's, should have's, could have's, and won't have's of the design, this can be seen below in [Table 2.1](#).

Must Have	Should Have	Could Have	Won't Have
Encourage sustainable behavior by promoting sustainable options	User friendly	Support multiple languages	Global availability
Teach users something new	The user can comfortably hold the device	Provide landmark information	AR functionality
Trivia question	Minimum battery life of 3 hours	Personal recommendations	
Network connection; the app requires internet access	Maximum charging time of 5 hours	Enable users to view and share experiences	
	Point system	Customizable options for the app	
	Be entertaining	Ensure that the app follows privacy laws and keeps user information safe	
		GPS integration	

Table 2.1: MoSCoW list

The MoSCoW list is made to visualize the current priorities of EcoExplorer and to evaluate what was first decided upon as aspects of the MoSCoW list. The Must have's now consist of the make or break aspects of the product. EcoExplorer would not function without these parts and a user friendly layout, for example, is not a part of this and therefore not a must have, but a should have since it is still valued as important.

The information or trivia quizzes have been prioritized a lot more since the first draft of the MoSCoW list and have been changed from a could have to a should have and customizable parts of the app have

not been discussed in detail and have been moved from a should have to a could have. The won't have's remain unchanged due to the complexity or scope of the aspects.

Changes like these have been made due to the changing perspective and understanding of the EcoExplorer product and priorities have been defined. By redefining and making the final MoSCoW list, the final vision of the MVP and product is now clear and complete bringing a good overview of the project

3 | Definition of the MVP-goal, parts and processes

The MVP is developed to test the must-have functions from the MoSCoW List which are trivia questions, GPS navigation and a user-friendly interface. By implementing trivia questions, the users will be provided with an educational and engaging travel experience. The physical product with GPS navigation will prevent the distractions of phone notifications. Lastly, the product must be enjoyable and comfortable to use. Thus, our MVP goal is to test the ability to create a user-friendly handheld design that can provide the users with trivia questions and guide them to their chosen destination.

To achieve the MVP goal, multiple electronics were required. A physical prototype that could fit in the hand while accommodating all the electronics was essential. Therefore, preference was given to smaller components that could perform the same tasks. This approach ensured the creation of a compact prototype capable of fulfilling the MVP goal efficiently.

3.1 | Micro-processor

To utilize all the electronics simultaneously, a microprocessor or controller is essential to achieve the MVP Goal. After narrowing down the options to Arduino and Raspberry Pi, which are commonly used in prototypes, the group opted for the Raspberry Pi, specifically the Raspberry Pi Zero W. This decision was driven by its built-in WiFi, compact size, and sufficient processing power. As mentioned previously, the Raspberry Pi Zero W would be responsible for programming the entire device, as well as showing the desired output on the LCD Display.

3.2 | GPS module

The NEO-6M GPS module is a Global Positioning System (GPS) receiver with a built-in ceramic antenna. With the ability to track up to 22 satellites, this module enables global positioning, typically achieving accuracy within 2.5 meters CEP (Circular Error Probability) as can be shown in [Table 3.1](#). Its low power consumption makes it suitable for battery-operated devices.

The GPS consists of 24 satellites orbiting Earth. The position of these satellites in space is known because they constantly transmit information about their position and current time to Earth in the form of radio signals. Each satellite transmits a unique signal, allowing GPS receivers to determine their precise location by measuring the time it takes for signals to arrive. By receiving signals from multiple satellites, GPS receivers calculate their exact location using trilateration.

The GPS module can achieve a high level of tracking sensitivity i.e. -161 dB, while consuming just 45 mA. It can perform up to five location updates in a second and has a Time-To-First-Fix (TTFF) of less than 1 second. It contains the pins needed for communication with the microcontroller over the UART. The module supports baud rates from 4800bps to 230400bps with a default baud of 9600 [\[4\]](#).

3.3 | LCD Display

When selecting the display for the project, the group prioritized finding a small, affordable option with lots of documentation, due to the limited experience with Raspberry Pi and displays among group members. Ultimately, it was decided that a Waveshare 2.4-inch LCD TFT Display Module would be used. This display is perfect for achieving the MVP goal due to its small size, affordability, and resolution. As mentioned earlier, the LCD Display will be responsible for displaying the trivia quizzes, as well as the directions that the user must follow to get to their destination [\[5\]](#).

Specification	Value	Unit
Operating Voltage Range (DC)	3.3-5	V
TX and RX Signal Voltage	3.3	V
Default Baud Rate	9600	
Current Draw	45	mA
Length		mm
Width		mm
Weight		g
Positioning Accuracy	2.5	m
Frequency	1 (up to 5)	Hz

Table 3.1: Technical specifications

3.4 | Battery

To power the device an external battery can be attached to the Raspberry Pi, as long as it adheres to the specified voltage limits of the board. The allowed voltage range for the board is 4.75 to 5.25 V. Supplying a voltage higher than 5.25 V can result in power loss due to heat dissipation. A rechargeable Lithium-Polymer (LiPo) battery was used to make the device more cost-effective in the long run while also being better for the environment. A LiPo cell typically has a nominal voltage of 3.7 volts, which means that a single cell battery can supply approximately 3.7 volts. This nominal voltage is the average voltage that the cell operates at. However, it is important to note that the voltage of a LiPo cell can vary within a safe range; typically between 3 volts (discharged) and 4.2 volts (fully charged) depending on the state of charge [2].

Specification	Value	Unit
Cell Voltage (nominal)	3.7	V
Cell Voltage (minimum)	2.5	V
Cell Voltage (maximum)	4.2	V
Capacity	2500	mAh
Maximum Continuous Discharge Current	1.5	A
Maximum Charging Current	1.5	A
Under Voltage Protection (UVP)	2.5	V
Over Voltage Protection (OVP)	4.25	V
Over Current Protection	3.5	A
Length	62.5	mm
Width	50.5	mm
Height	8.1	mm
Weight	48.3	g

Table 3.2: Technical specifications

The safety features include short circuit protection, and protection against under voltage, over voltage and over current. However, to safely use and recharge the battery, an additional protection circuit and charging module are necessary. Since the Raspberry Pi Zero W requires an input voltage of 5 V and the LiPo battery typically supplies 3.7 V, a step-up (boost) converter is needed. The DC-DC converter elevates the battery's voltage to a level that meets the board's requirements.

3.5 | Charger/Booster

The LiPo Rider Plus is designed for Lithium-Polymer (LiPo) batteries. It serves as both a charger and a power boost, seamlessly integrating LiPo batteries into electronic devices. It can charge at up to 3A using USB Type-C, but it is important to note that the LiPo battery has a maximum charging current of 1.5A. The LiPo Rider Plus boosts LiPo battery voltage from 3.7V to 5V, providing up to 2.4A output current. Its compact design makes it ideal for portable applications.

Specification	Value	Unit
Charging Current (maximum)	3	A
Output Voltage (USB A)	5	V
Output Current (maximum)	2.4	A
Additional Output Voltage (pin headers)	3.3	V
Additional Output Current (pin headers)	250	mA
Length	41	mm
Width	25	mm
Weight	8	g

Table 3.3: Technical specifications

3.6 | Design Material

To realize the physical prototype, selecting an appropriate material was crucial. It needed to be user-friendly, ergonomic, capable of safely housing all electronics, and sustainable. Considering these criteria, 3D-printed PLA (Polylactic acid) stood out as the optimal choice. Its accessibility, rapid prototyping capabilities, and versatility allowed the group to test multiple designs rather quickly, all while being sustainable. PLA proved to be an obvious choice for the group, due to its low energy consumption, minimal greenhouse gas emissions during production, and the added benefit of recyclability [3].

3.7 | Buttons & Button Placement

As discussed previously, the user must be able to select options on the device. Without a touchscreen display, the next best option is buttons. The group opted for 4 buttons, in a 2 x 2 array, as this would make answering the trivia questions rather easy, as each button would correspond to a specific answer. Buttons were rather affordable, and 4 breadboard tactile pushbuttons were chosen for the design.

The push buttons used in the device were soldered onto a perfboard. Each button has four pins, which are internally connected in two separate pairs. When the button is pressed, all four legs are internally connected. To function properly, one of the pins must be connected to ground, while the other is connected to a digital pin on the Raspberry Pi. These digital pins serve as inputs to the Raspberry Pi, allowing it to detect when a button is pressed. Each button is connected to its own digital pin, designated for specific functionalities or actions. Consequently, the buttons are connected to the digital pins on the Raspberry Pi via individual wires: red, yellow, green, and blue, each corresponding to a specific button. Additionally, all buttons share a common ground line, which is then connected to the ground pin of the Raspberry Pi using the black wire. This grounding ensures proper functioning of the buttons and establishes a reference point for the electrical circuit.

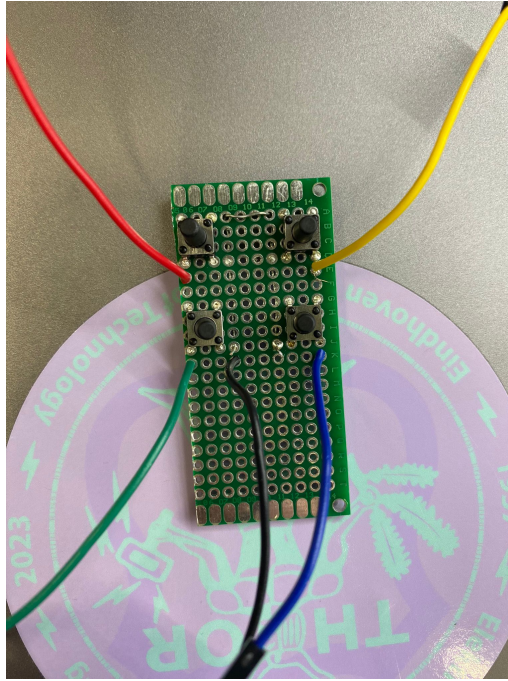


Figure 3.1: Button placement

3.8 | The Physical Product and User Involvement

3.8.1 | User Involvement

After doing research on electronics, the decision was made to continue with a rectangular screen instead of a circular one. The initial design (**Figure 3.2**) was made with the intention of using a circular screen. Using this design with a rectangular screen would look less aesthetically pleasing and therefore new shape explorations were done. To come to a final design, user interviews played an important role in finding the one that is experienced as most user-friendly and aesthetically pleasing.



Figure 3.2: Initial circular design of the EcoExplorer

3.8.2 | The first iteration

The design process of the physical product involves several steps. Firstly, extensive research was conducted to explore various design possibilities while prioritizing both comfort and aesthetics. Subsequently, simple shape sketches were made to explore potential design options (**Figure 3.3**). These sketches served as a foundation for developing three differently shaped physical prototypes using foam that could be used during the first interviews (**Figure 3.4a**).

1. The ergonomic shape. This was designed based on research on what lays comfortable in the palm.

2. The mushroom. This was designed to emphasize the sustainable aspect of the product.
3. The hexagon. This was designed to create a universally shaped product that most people will feel comfortable with.

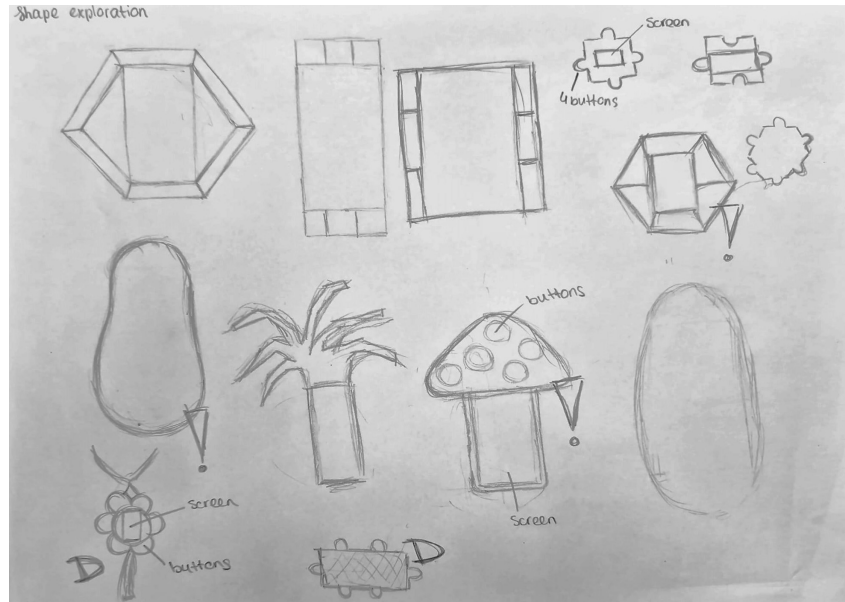
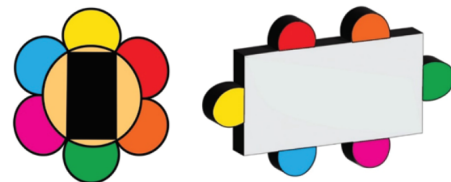


Figure 3.3: Shape exploration.



(a) Prototypes used during the user interviews



(b) Visuals used during the user interviews

Figure 3.4: Prototypes and visuals used during interviews

The sizes of electronics were taken into account while prototyping so the shape would be as realistic as possible. Having the prototypes gave potential users a chance to feel how it fit in their hands and to experience carrying it around. To enhance comfort, specific attention was given to ergonomic aspects, resulting in the incorporation of rounded edges, particularly for the mushroom-shaped design and the mouse shape. The hexagon shape focuses solely on aesthetics and thus no rounded edges were made. Additionally, visual representations were made for designs such as the puzzle piece and flower (Figure 3.4b). These five designs were then presented in user interviews to gather feedback and insights, aiding in the selection of the most suitable design option.

3.8.3 | First round of interviews

During the interviews, participants were asked to rank those 5 designs and explain their choice. Besides, more general questions were asked about how much they would pay for Exo-Explorer and where they

would use it. Lastly, there was asked how they would like to carry it around, for example as a bracelet, in their pocket, or in their hand.

14 interviews were conducted using open-ended questions (Appendix A). Those interviews were analyzed to come to a final design to increase the likelihood of satisfaction. The analysis of the ranking of the 5 designs shows that the ergonomic shape and mushroom were the most popular (Figure 3.5). Another question shows that it depends on personal preference on what type of trip they would use the product. Some answers that were mentioned were with friends, family, or on a city trip. Regarding the budget, they are willing to pay for the product, a range between 10 and 150 euros was answered. The average amount is around 37 euros while the median is 25 euros. One participant mentioned that they would prefer to rent it on the location of the trip. Most participants mentioned they do not want to carry the EcoExplorer in their hands the entire time. However, different answers were given, such as a bracelet, necklace, and a clip on their jeans. Therefore, a design should be considered where the user can adapt it to their preference.

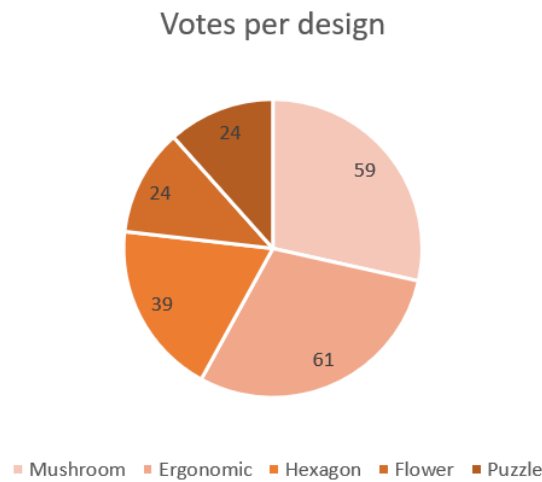


Figure 3.5: Pie charts user interviews

3.8.4 | The second iteration

After having chosen two designs based on the preferences of the users, 3D models were created using the program Blender (Figure 3.6, Figure 3.7). During the modeling, the aspect that was focused on was ergonomics since the aim is to give the users a pleasant user experience.



Figure 3.6: 3D model of the ergonomic shape

Before finalizing the dimensions, several fit tests were done. The first fit test was done by simply recreating the electronics using paper and fitting them inside the housing made out of paper as well (Figure 3.8).

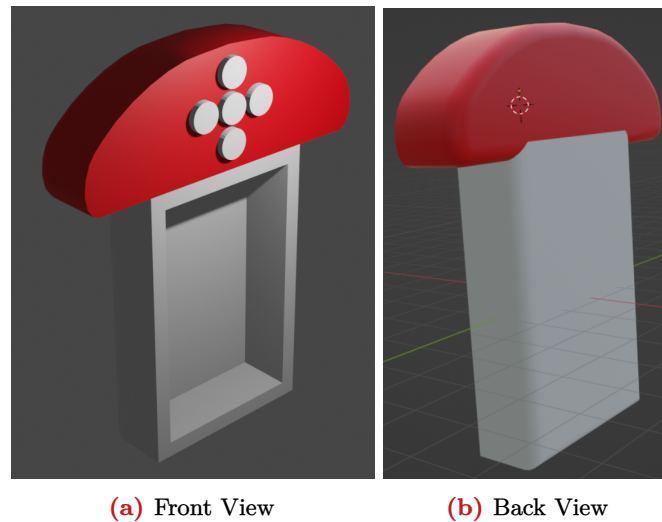


Figure 3.7: 3D model of the mushroom shape



Figure 3.8: First fit test using paper

After using Blender for the initial product designs, Fusion 360 was used to create the final 3d model that can be used for 3D printing. It was decided to continue with the ergonomic shape because this is more universal than the mushroom, which might target more people. Multiple versions were created and printed to see what features are most user-friendly.

Throughout the creation of the 3D model, the fit test was done by placing the electronics in the 3D model and adjusting the dimensions until it fit all the components inside. The model in [Figure 3.9](#), has a casing for electronics inside, five holes for buttons, one hole for charging, and a rounded back. The screen and button compartment are connected via two holes so wires can go through.

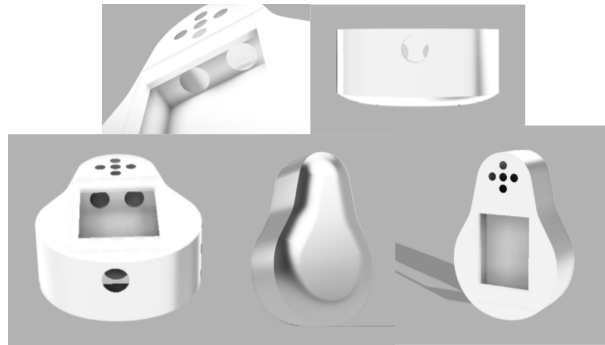


Figure 3.9: Pear-shaped ergonomic design.

3.8.5 | Third iteration

After analyzing the 3D model and receiving feedback, the following insights were found:

- The edges on the front of the device should be rounded as well.
- The edges on the back of the device should be rounded more.
- Have four buttons instead of five buttons.
- Look at the user-friendliness of button placement.
- Have a different 3d model for the electronics.

Based on those findings, three new 3D models were created (Figure 3.10, Figure 3.11, Figure 3.12).

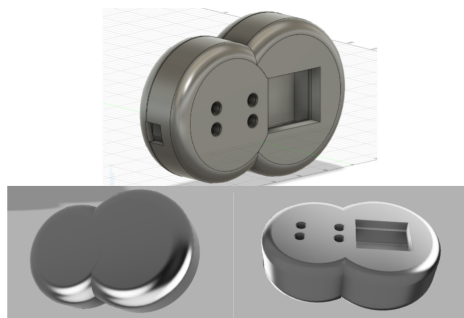


Figure 3.10: First 3D-model.

The first model has a more round shape. However, after printing this model, it turned out to be too big to fit nicely in the hand. Also, the button placement was not optimal since the buttons have too much space between each other.

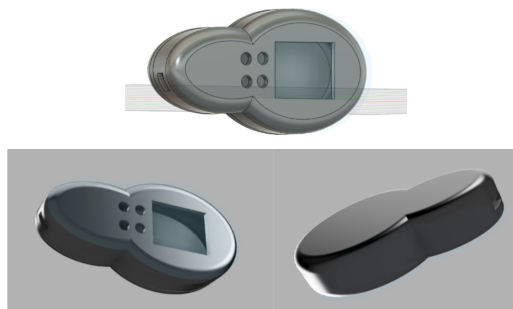


Figure 3.11: Second 3D-model.

The second 3D model exists of two oval shapes. After 3D printing, tests show that the device lies comfortably in the hand. Besides the edge in the middle, decreases the chance of it slipping out of the hand. The buttons are placed close to each other and more to the center of the device.

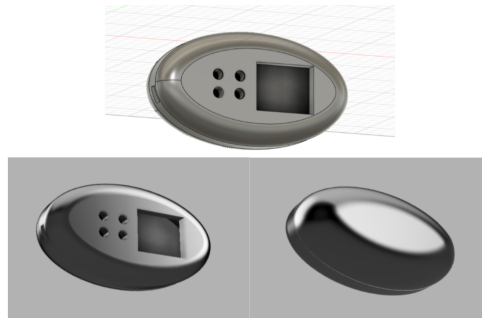


Figure 3.12: Third 3D-model.

The third 3D model is an oval shape. The buttons are more centered at the bottom and the back is more rounded than the previous models.

3.8.6 | Conclusion of third iteration



Figure 3.13: 3D printed models

The first 3D model is too bulky to hold comfortably in the hand. Besides, the position of the buttons is not user-friendly and forces users to use two hands. The second 3D model lies comfortably in the hand because of the oval shapes. Also, the button position of this device is user-friendly. The third model is most likely to lay comfortably in the hand because of the rounded back, however, because it does not have a crease in the middle, it will probably fall easily out of the hand. Based on this analysis, the decision has been made to continue with the second 3D model.

3.8.7 | Fourth Iteration - ergonomic product

After choosing the design of EcoExplorer, some changes were made to the design using past information from the user interviews (Figure 3.14). In the early stages, the users were asked how they would carry the product around and most of the ways involved something attachable, thus a hook was added to the design. Moreover, the size was considered to be too bulky so the model was scaled down by reducing the margins for the electronics inside. After including these changes, the product was user-tested regarding its shape and comfort (Figure 3.15) (Appendix A).

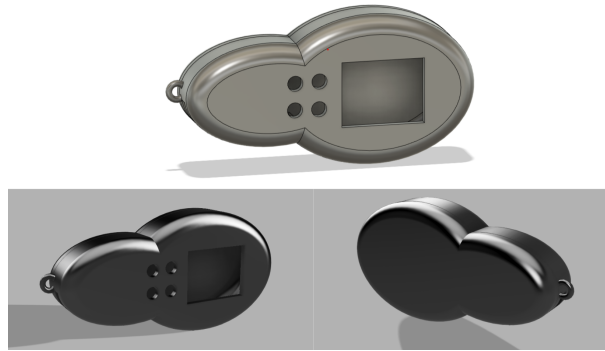


Figure 3.14: Ergonomic shaped 3D model



Figure 3.15: 3D print ergonomic shaped product

The biggest insights from the interviews were that the product was too bulky and that the comfort of the device mainly was influenced by the size of the user's hand. Some found the bigger size to be more comfortable to hold due to their larger hand size. The roundness of the product was also appreciated since it resulted in a better grip. Many participants also mentioned that they preferred a smaller product that could easily fit in their pockets. Moreover, neutral colors or color-changing with the outfit was mentioned as what color the product should have. An observant participant stated that black should be avoided because this color could take up the summer heat which might become too hot for the hands.

3.8.8 | Final Physical Design

One of the feedbacks from the past interview was that the product was too big and not fitting in the pockets, thus it was decided to merge the design of the housing for the electronics with the ergonomic design. The housing of the electronics was created by looking into the perfect fit to place all electronics inside. It is compact and all electronics cannot be moved when using the product. The process of the housing's creation can be seen in [Figure 3.16](#).

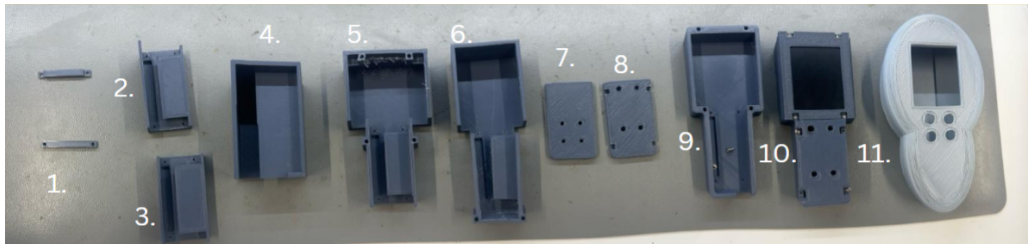


Figure 3.16: Process housing creation.

The hook to attach the product to a clip was removed (Figure 3.17) since people still preferred to put the device in their pockets. This design, shown in Figure 3.18 was again user tested and afterwards the previous design was shown to let the users make the ultimate decision of which design they preferred. The questions from the previous interview were asked about the new model. Questions regarding weight, roundness, and preference were added to the interview (Appendix A).

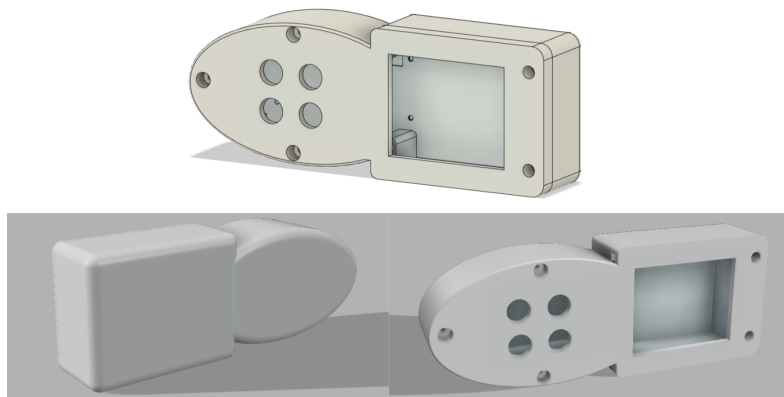


Figure 3.17: Final Design: Merged compact design



Figure 3.18: Final design 3D print

The first impressions of the device were very diverse; noticeable was that several people mentioned the contradictory shapes (rectangle and oval) and the light weight of the design. Similar to the previous interviews, participants mentioned that the comfort depended on the hand size. Moreover, the grip was not enough, and suggestions such as adding a handprint were mentioned. The majority would want the back to be more round even if the device gets thicker due to the lack of grip and comfort. The answers to the ultimate question conclude that the smaller design is preferred over the bigger more rounded ergonomic version. But, some alterations need to be made for it to be the best product:

- More round
- Adaptable handle size (for people with bigger hands)

3.9 | The User's Interaction with the Device

After the final design has been realized, the function of the device can be explained and tested.

After the user pulls the device out from their pocket, they are prompted with an activity selection question, asking what they want to do. They can choose between 4 categories: sport, nature, food and shopping. After the user selects a category, they will be prompted with a confirmation selection, which was implemented to account for accidental button presses. The user will then be prompted with a trivia question based on their activity selection. This trivia question will not only be related to their activity of choice but also to which city they are currently in. If the user answers the question correctly, they will then be prompted with a destination screen. If they answer incorrectly, they will have to answer another trivia question until they get one correct. Then the user will be able to choose a destination based on their activity choice, and after making a selection the GPS will guide them to that destination.

The entire process can be shown below in **Figure 3.19**.

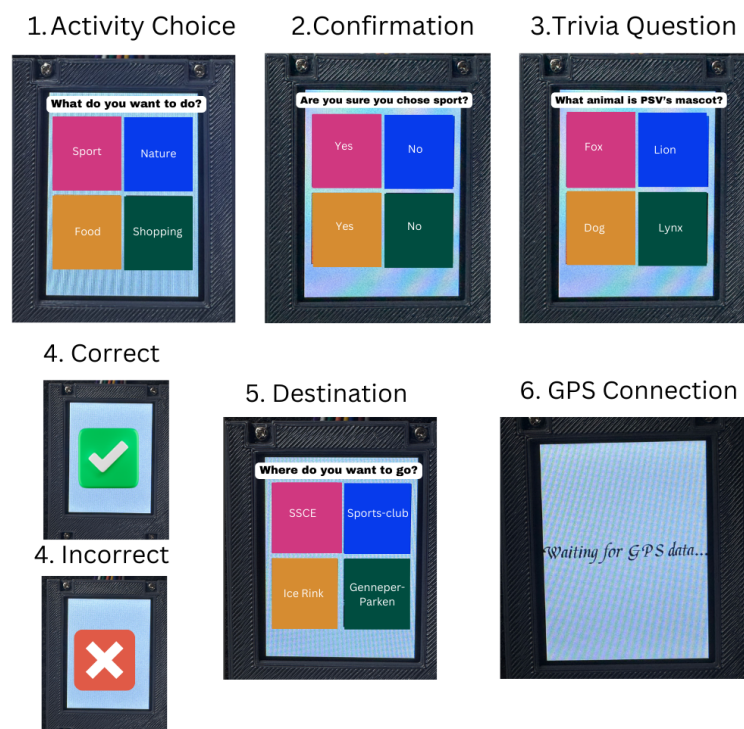


Figure 3.19: Trivia Question Function

Some received feedback was to use colorblind-friendly colors, hence the colors of the boxes are chosen from a colorblind-friendly palette [1].

4 | Budget control (BoM)

Due to the scope of this course, the maximum budget for the MVP was set to €80. This section of the report will be dedicated to highlighting where the group allocated the budget and the rationale behind those choices. By creating a list of the chosen electronics highlighted in the last section, a cost overview can be shown.

Item	Cost (€)
Raspberry Pi Zero W	16.00
GY-NEO6MV2 GPS Module	13.50
Waveshare 2.4 inch TFT-LCD Display	13.00
Lithium Polymer Battery 2500 mAh	12.00
Sseed Studio Lipo Rider Plus	6.50
3D Printed PLA 71g	1.36
Breadboard Tactile Pushbuttons x4	0.60
Total	62.96

Table 4.1: Project Budget Control

The MVP can be successfully developed using solely the listed materials, ensuring a sustainable approach by minimizing unnecessary expenditures, as shown in Table 4.1. Typically, the total price of these products would have exceeded the budget constraint. Therefore, the group sought out cost-effective alternatives from different suppliers to remain within budget.

5 | Specification test and evaluation-plan

This section outlines all the testing done to evaluate the product's functionality, reliability, and user experience. The purpose of putting the device through these tests was to ensure that it satisfied the expectations of both the creators and the end users. The evaluation plan considers a variety of factors, including user comfort, device performance, and overall usage. Table 5.1 provides an overview of the ongoing tests, their respective targets, purposes, expected results, current status, and future actions. Each test helps to evaluate different aspects of the device's functionality and performance, ultimately helping to improve it.

6 | Test results and evaluation

In this chapter, all the tests from the test plan will be discussed to ultimately arrive at a definitive evaluation for the product as it is right now.

6.1 | Letting customers hold the device

The housing of the early prototypes was tested with the target audience. After receiving feedback about the overall bulkiness of the design, the product was ultimately scaled down to improve customer comfort, while still being able to fit all the internal components.

6.2 | Testing trivia questions

The trivia questions were tested and worked as intended. Something important to note is that feedback was given about the use of colors in the quiz question and that they were not compatible with color-blindness. This was quickly changed after the given feedback. Another aspect that was implemented due to user reviews was an answer confirmation choice for the first question, as sometimes the user would accidentally press the wrong button upon pulling it out of their pocket. This was fixed by adding a "Are you sure you meant to chose *category name*?".

6.3 | Testing LCD screen errors

While the startup of the LCD screen took one full minute at the start of making the design, this period was later shortened to about ten seconds. Besides that, the LCD screen works and responds to inputs from the buttons as intended.

Test No.	Target	Name	Purpose	Expected Result	Status/ Actual Result	Future Actions
1	Consumer	Letting customers hold the device	To test comfort when the product is held	The target audience will not complain about the shape, form and comfortability of holding the product	In Progress	In Progress
2	Device	Testing trivia questions	To test if the trivia questions are given and can be answered	The trivia questions will be given from the device and can be answered	In Progress	In Progress
3	LCD screen	Testing LCD screen errors	To test if the LCD screen does not crash, give a black screen or wrong visuals	The LCD screen is expected to work as it should and not give any errors, such as crashes or black screens	In Progress	In Progress
4	Device	GPS test	Test if the GPS functionality works on the device	The device will show how to get to a specific location	In Progress	In Progress
5	Device	Charging of the device	To test if the device is chargeable without any issues	The device will be able to charge up to 100% power without any problems	In Progress	In Progress
6	Device	Test individual components	To test all connections between components to not cause the product to overheat or give errors	With the appropriate parts used, no overheating is expected or errors	In Progress	In Progress
7	Device	Test device while being on	To test if no errors will occur if the device is left on for one hour	No consequences are expected to happen because of this	In Progress	In Progress
8	Device	Test taking device apart	To test if the device can be altered easily to fix any issues	It is expected that the device may be opened easily by the creators, but more difficult for the target audience	In Progress	In Progress

Table 5.1: Table of Tests

6.4 | GPS test

Ultimately, the GPS could not be implemented on the raspberry pi of the product, due to issues with importing the proper libraries to the raspberry pi. The raspberry pi failed to import the pynmea2 extension, which would decode longitude and latitude values, which were essential for GPS navigation.

6.5 | Charging of the device

The device is able to be charged by using a USB-a input. This can be completed by using a laptop, for example. The charging time for a laptop was estimated to be about five hours. This assumption is based on the following formula:

$$ChargingTime = \frac{CapacityBattery}{CurrentLaptopUSBAPort} = \frac{2.5[Ah]}{0.5[A]} = 5hours \quad (6.1)$$

With an efficiency of about 80 percent, a charging time of 6.25 hours was estimated and confirmed.

$$RealChargingTime = \frac{ChargingTime}{\eta} = \frac{5hours}{0.8} = 6.25hours \quad (6.2)$$

6.6 | Test individual components

All components do work as intended and no overheating was noticed during all forms of testing.

6.7 | Test device while being on

The device turns on and button inputs have an affect on the screen. Once the device is turned on, a category may be chosen for which a quiz question is picked. This question may then be answered. The battery life of the design is confirmed to be 3.467 hours, due to testing and by using the following formulas:

$$BatteryLife = \frac{CapacityBattery}{CurrentOfAllElectronicComponents} = \frac{2500[mAh]}{(45 + 165 + 300 + 67)[mA]} = 4\frac{1}{3}hours \quad (6.3)$$

$$RealBatteryLife = BatteryLife * \eta = 4\frac{1}{3}hours * 0.8 = 3.467hours \quad (6.4)$$

6.8 | Test taking device apart

The device may be opened by loosening the screws on the casing. This must be done on purpose and cannot be done by a customer that does it accidentally.

6.9 | Evaluation

All in all, the design accomplishes most of the set expectations. The design is a user-friendly, good to control and to hold device that is able to select a category and give a trivia question about a set category. One of the more major shortcomings is the failure of the GPS system, whose implementation has to be delayed to next quartile due to complications with downloading extensions.

7 | Risk analysis and strategy for continuation towards a sellable product

Process/Product Name: <u>EcoExplore</u>				Prepared By: <u>Group 15 - Smart Tourist Information and Navigation Tool</u>											
Responsible: <u>Group 15</u>				FMEA Date (Orig.): <u>02/Apr</u>				(Rev.): <u>02/04/2024</u>							
Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 10)	Potential Causes	OCCURRENCE (1 - 10)	Current Controls	DETECTION (1 - 10)	RPN	Action Recommended	Resp.	Actions Taken	SEVERITY (1 - 10)	OCCURRENCE (1 - 10)	DETECTION (1 - 10)	RPN
What is the process step, change or feature under investigation?	In what ways could the step, change or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step, change or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?									
Pricing	Users do not want to pay full price for the product	User will not use the product.	10	Design is too big, expensive, niche or undesirable	7	Innovative ways of implementing the product	6	420	Advertising the product as a tourist tool that can be rented at certain places	Group 15	In progress				
Comfortability	User does not find product comfortable to hold	User is less motivated to hold product	7	Design too big, bulky and heavy	8	The hands of the user	3	168	Making the product smaller with proper management of internal systems	Group 15	Middle has been found between part fitting and a small enough design	7	5	3	105
Quizzes	Coloured options are not accounted for color blindness	People with color-blindness cannot see the given answers of the quizzes	6	Boxes where the answers are cannot be read	2	The eyes of people with color-blindness	9	108	Change the colors of the answers boxes to appropriate colors for people with color-blindness	Group 15	Coros have been changed, so that color-blind users do not have a disadvantage in the quizzes	6	1	3	18
GPS	GPS cannot be implemented	The Customer can not use one essential feature of the product	9	Pynea2 cannot be installed on raspberry pi 0	5	Proper use of the pip(3) extension on raspberry pi	1	45	To seek professional help	Group 15	Longitude and Latitude values are coded, but not received, due to no pynmea2	9	5	1	45

Part fitting	Internal parts do not fit in the casing	Customer cannot buy a closed product	9	Too many internal components with not enough internal space	3	Design is large enough	2	54	Make the product big enough for internal parts and small enough for comfortability. Find this equilibrium	Group 15	Middle has been found between part fitting and a small enough design	9	2	2	36
Product crashing	Product will crash due to fragile parts	User cannot use the product anymore	10	Loose wires, fragile raspberry pi or faulty soldering	4	Proper testing	2	80	After evaluation of the product tests, it should be clear how durable the product is.	Group 15	Extensive product tests have been conducted to prevent crashing	10	2	2	40
Competition	Competition is better than the product	The product will ultimately fail to catch the attention of the consumer	10	Competitors come up with the same idea	1	Make the product innovative	1	10	The product as of right now, is innovative enough so that there are no direct comparisons on the market	Group 15	Completed	10	1	1	10
Battery life	Battery life is not long enough	Consumer uses the product less due to limitations	3	Battery with low capacity	4	Good quality battery and low energy cost components	3	36	Ensure that the battery life is for about 5 hours, so that the consumer can use the product for a half-day trip	Group 15	Completed	3	4	3	36
Boring design	Design on its own is too basic	Consumer will see no visual distinction between product and other products	5	Design is always the same	6	Mono color design	3	90	Product will be available in multiple colors	Group 15	In progress				
Durability	Keychain ring is not strong enough	Product will break more often	4	Hanging a keychain on the keychain holder	4	Durability of the keychain holder	3	36	Making durability tests to prevent fracture of the keychain holder in the product.	Group 15	In progress				

Figure 7.1: Newly added Failure mode analysis

As the project went into the realization and detailing phase, new risks started to appear. In **Figure 7.1**, risks are shown regarding the current progress of the product. Desirability, technical feasibility and first steps for viability are described here.

7.1 | Desirability

The user's comfort is addressed here, stating that the design must not be too big for the user or else it will feel too bulky. Meanwhile, the design must be big enough for all the parts to fit. Some color variations of the product are also considered, making the product stand out more.

7.2 | Technical feasibility

Due to some complications, the desired version of the GPS system has not been implemented yet into the product itself. Methods of achieving a working GPS system or a backup plan need to be decided on. Moreover, the product must not crash often to ensure stable behavior. Lastly, the battery life must be long enough, so that the user can spend at least an afternoon with the product without charging it.

7.3 | Viability

Pricing is one of the major issues that the product faces. From the user interviews, it became clear that not all users want to pay full price for the product. A smart way of implementing the product on the market must therefore be introduced. One of the more promising ideas is to introduce the product as something to rent out for tourists. Lastly, competition is one of the smaller risks that have been found. So far, not many products have been found that directly compete with the current product. Trip advisor and Google Maps still offer directions, but do not offer most of the EcoExplore's functions, such as the point system or quizzes.

8 | Next Steps

8.1 | GPS integration

The initial goal was to incorporate GPS into the project to help users navigate to various landmarks. However, GPS integration proved to be unfeasible, resulting in modifications to the initial MoSCoW list, where 'GPS integration' is no longer considered a must have. Consequently, the final product does not include a GPS module and is unable to guide users through Eindhoven. Several factors contributed to the failure of GPS integration. Firstly, the GPS module has difficulty receiving data indoors and is unable to precisely determine its location. It became apparent that the module performed better in open areas such as villages rather than cities due to obstructions posed by buildings. Despite this constraint, the GPS module worked well outside, even in Eindhoven.

Another challenge was the complexity of the data received from the GPS module, which included various parameters such as longitude, latitude, altitude, date, and time. To filter the data and extract only the required longitude and latitude, the Pyne2 library could have been used with the Raspberry Pi. However, connectivity issues hindered the installation of this library on the Raspberry Pi. Working with an Arduino, on the other hand, was easier, as it allowed for efficient data filtering using the TinyGPS++ library. For future projects, using an Arduino would simplify GPS integration significantly.

Originally, the goal was to give users turn-by-turn directions using Google Maps and the Directions API. However, integrating this API on Arduino proved to be too complicated within the project's time frame without prior experience. A simplified approach could be taken, in which the longitude and latitude of destinations are stored, and a directional arrow is used to navigate users to their destination, resembling a compass. The method requires users to find their own path, increasing involvement with their surroundings — an important goal of the product.

8.2 | From prototype to sellable product

Moving forward, the focus will be on transforming the EcoExplorer prototype into a sellable product. This will involve refining the design and ensuring cost-effectiveness without compromising on quality. Additionally, the decision will be made whether to offer the EcoExplorer for sale or to rent it out to tourists at various locations.

8.3 | AI statement

AI has been used to create the background image for the app.

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A | Appendix

First user test questions

1. On what kind of interview would you use exo-explorer?
2. Where would you want to have the product? (hands, necklace, wristband, a bag attachable to your jeans in which you can place the product)
3. If you could make a top 3 of these designs, how would you order them? Based on comfort in hands, aesthetics, in general?
4. How much would you spend on the product?

User Test Questions - ergonomic design

1. What is your first impression of the design?
2. What do you think about the comfort of holding the device? What would you change?
3. Considering the size of this device, how would you prefer to carry or attach the product?
4. What is your opinion about the button positioning? Do you like it or would you change it?
5. What do you think about the roundness of the back of the product? Would you want the back to be rounder or less round?
6. What color would you want the device to be?
7. Would you want to walk around with this product?

User Test Questions - Added questions final physical design

1. What do you think of the weight of the design?
2. Making it more round will make it thicker, would you still want it to be rounder?
3. Which of the two models would you prefer?