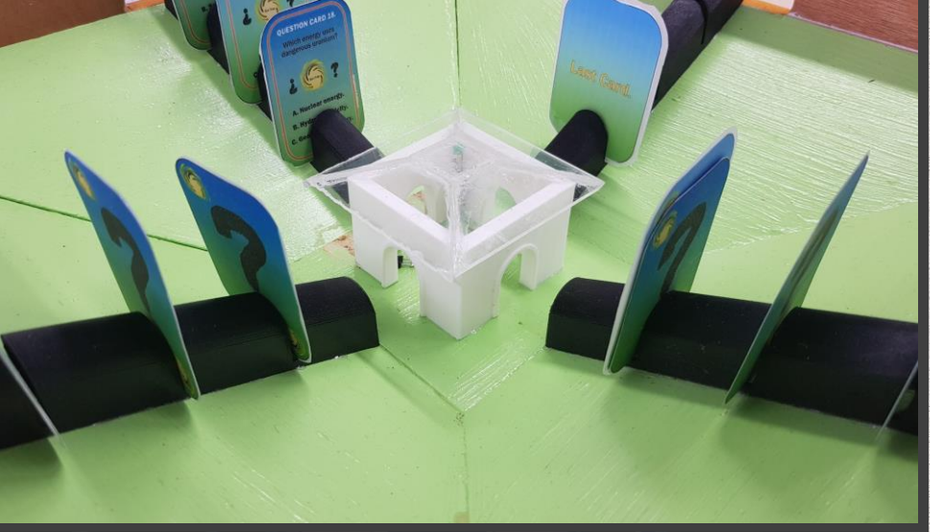
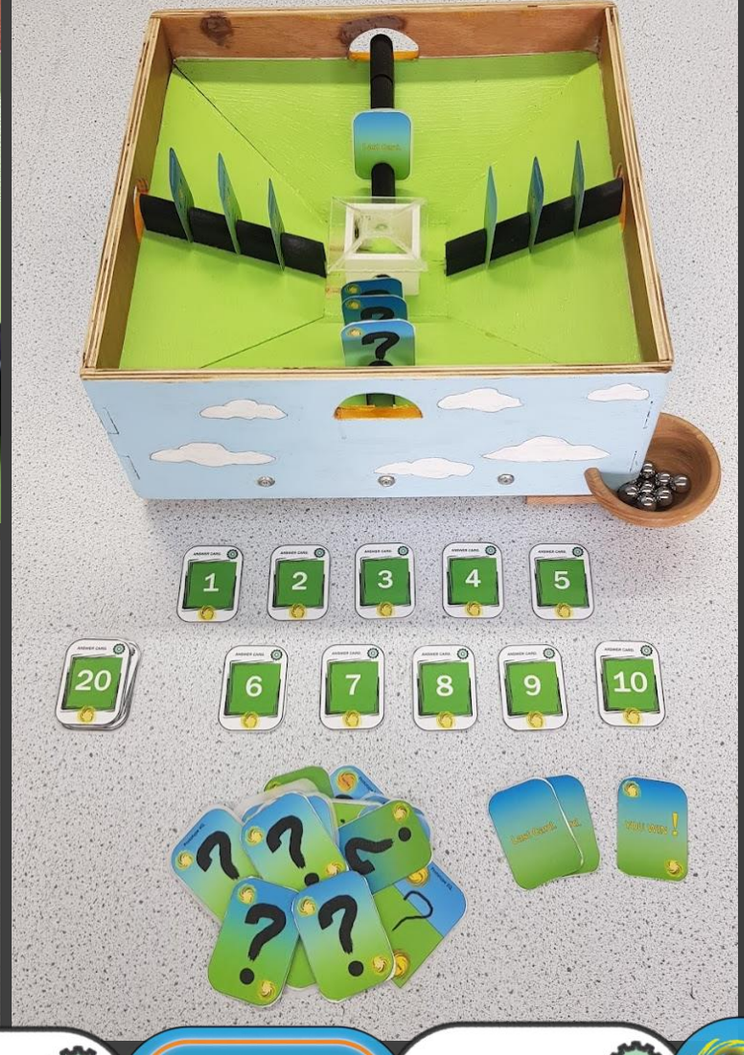
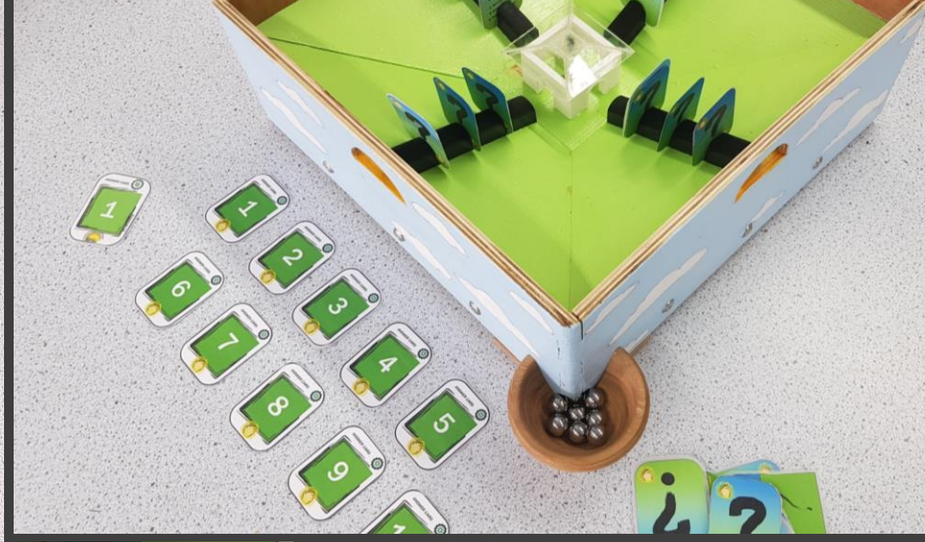
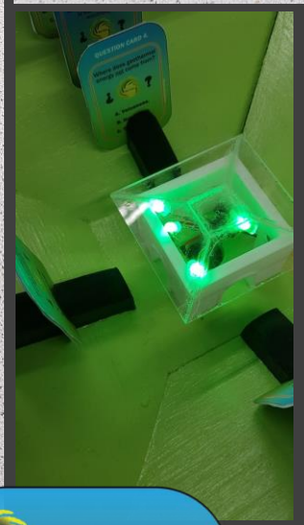
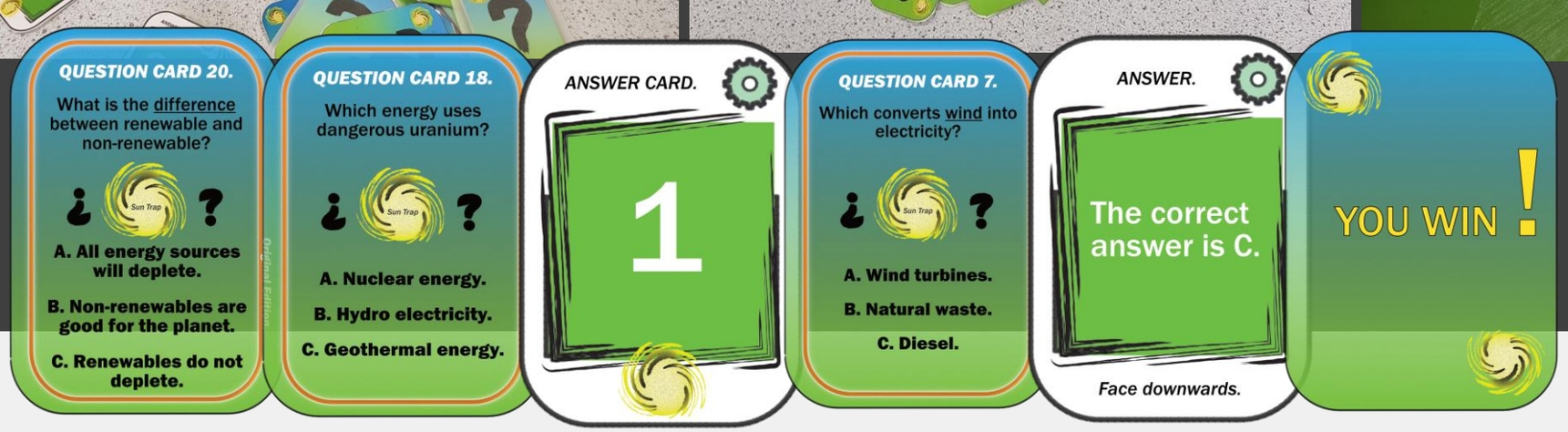






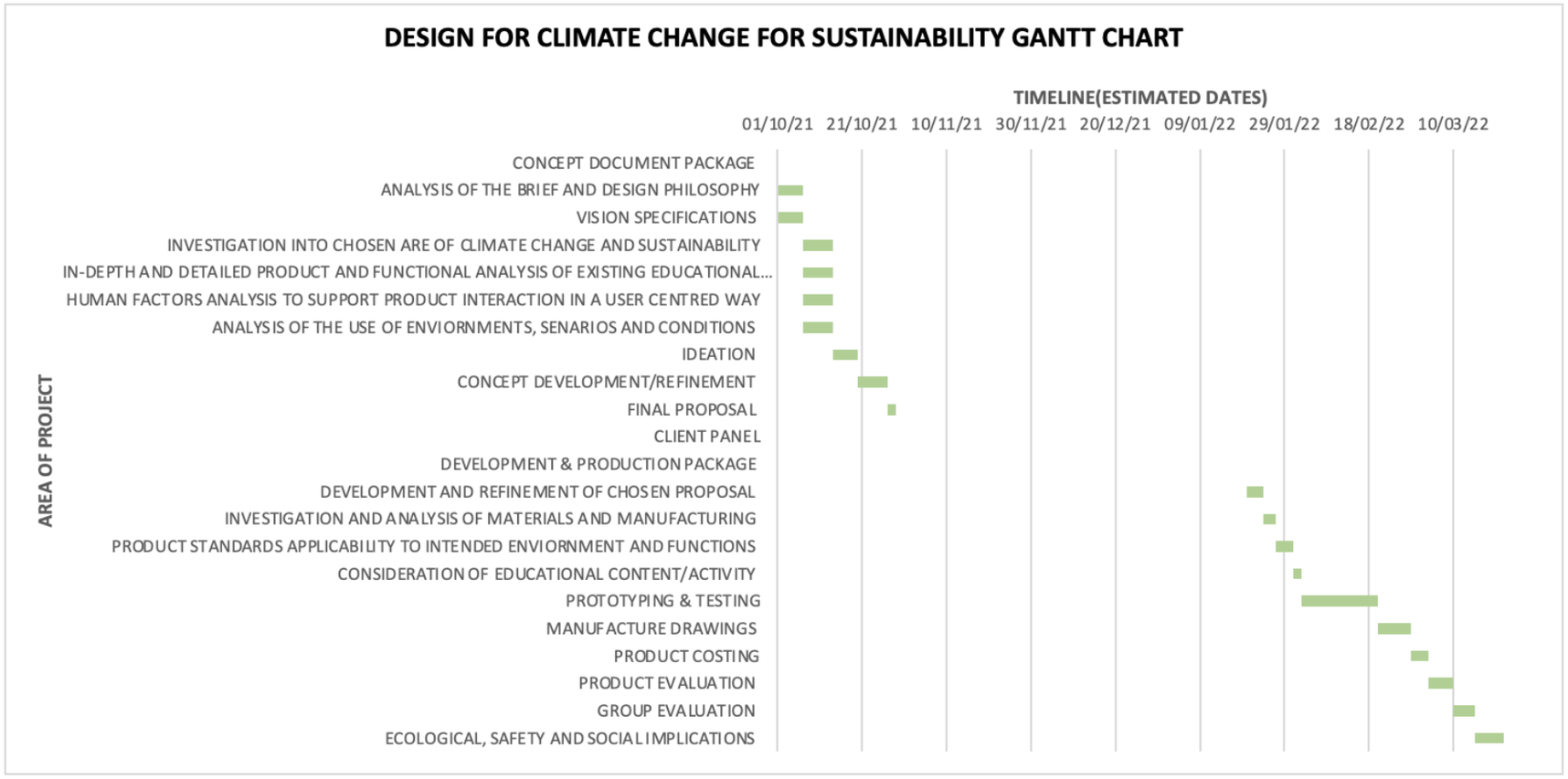


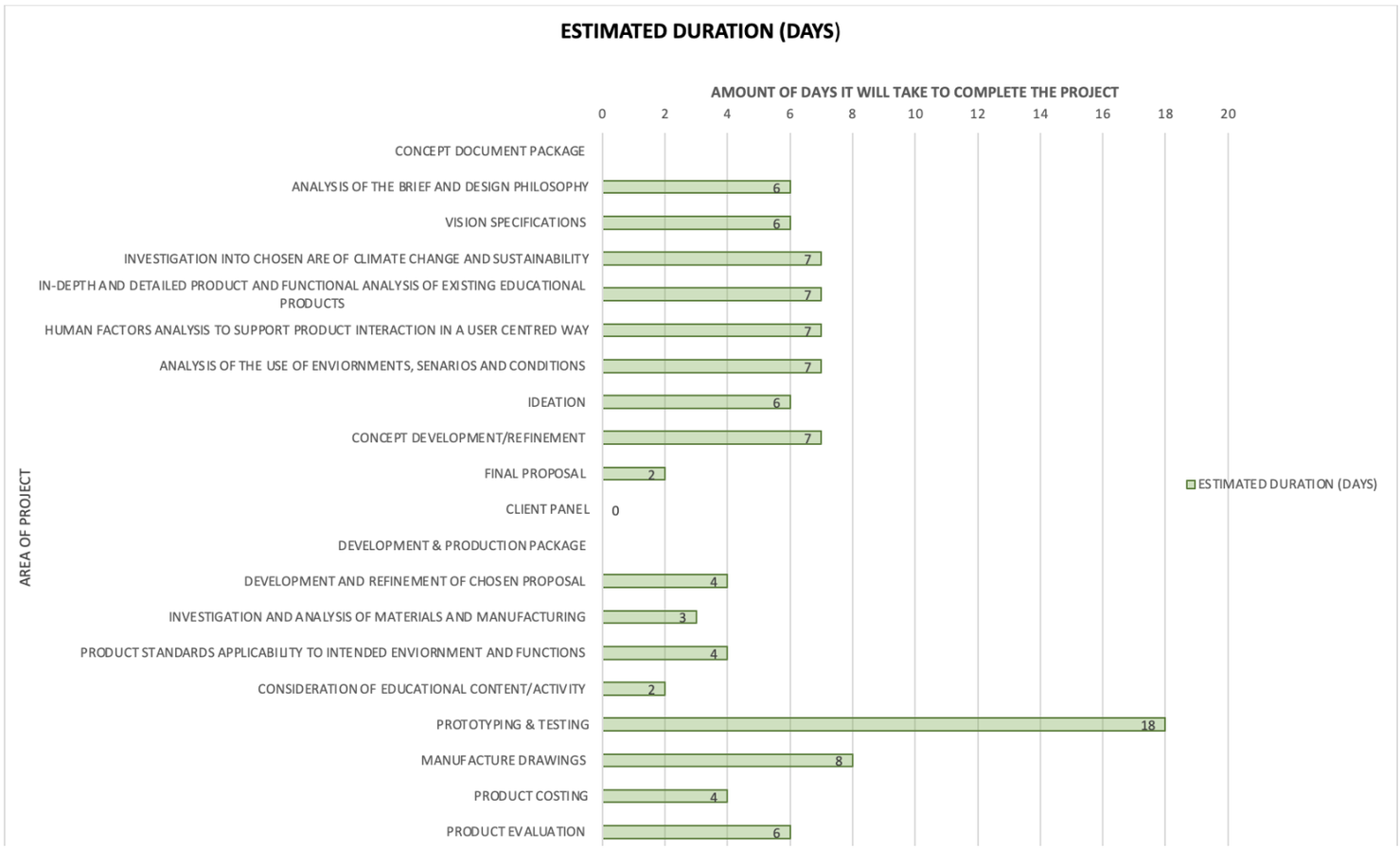



# Development and Manufacture Portfolio.

# Climate Change - Green Energy Boardgame. Education for Schools.

Student IDS: 2464472S, 2151378T, 2509612O, 2481078M & 2466515R.




## THE PROJECT PLAN

2464472S

DESIGN FOR CLIMATE CHANGE AND SUSTAINABLITY

DESIGN STRUCTURE MATRIX

**X when row depends on column.**

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **CONCEPT DOCUMENT PACKAG** | ANALYSIS OF THE BRIEF AND DE | VISION SPECIFICATIONS | INVESTIGATION INTO CHOSEN A | IN-DEPTH AND DETAILED PRODU | HUMAN FACTORS ANALYSIS TO | ANALYSIS OF THE USE OF ENVIO | IDEATION | CONCEPT DEVELOPMENT/REFIN | FINAL PROPOSAL | CLIENT PANEL | DEVELOPMENT & PRODUCTION | DEVELOPMENT AND REFINEMEN | INVESTIGATION AND ANALYSIS | **DEVELOPMENT & PRODUCTION** | DEVELOPMENT AND REFINEMEN | INVESTIGATION AND ANALYSIS | PRODUCT STANDARDS APPLICA | CONSIDERATION OF EDUCATIO | PROTOTYPING & TESTING | MANUFACTURE DRAWINGS | PRODUCT COSTING | PRODUCT EVALUATION | GROUP EVALUATION | ECOLOGICAL, SAFETY AND SOCI |
| 1 | **CONCEPT DOCUMENT PACKAGE** | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | ANALYSIS OF THE BRIEF AND DESIGN PHILOSOPHY | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | VISION SPECIFICATIONS | | x | | x | x | x | x | | | | | | | | | | | | | | | | | | |
| 4 | INVESTIGATION INTO CHOSEN ARE OF CLIMATE CHANGE AND SUSTAINABILITY | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | IN-DEPTH AND DETAILED PRODUCT AND FUNCTIONAL ANALYSIS OF EXISTING EDUC | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | HUMAN FACTORS ANALYSIS TO SUPPORT PRODUCT INTERACTION IN A USER CENT | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | ANALYSIS OF THE USE OF ENVIORNMENTS, SENARIOS AND CONDITIONS | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | IDEATION | | | x | x | x | x | x | | | | | | | | | | | | | | | | | | |
| 9 | CONCEPT DEVELOPMENT/REFINEMENT | | | x | x | x | x | x | x | | | | | | | | | | | | | | | | | |
| 10 | FINAL PROPOSAL | | | x | x | x | x | x | x | x | | | | | | | | | | | | | | | | |
| 11 | CLIENT PANEL | | | | | | | | | x | | | | | | | | | | | | | | | | |
| 12 | **DEVELOPMENT & PRODUCTION PACKAGE** | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | DEVELOPMENT AND REFINEMENT OF CHOSEN PROPOSAL | | | | | | | | x | x | | | | | | | | | | | | | | | | |
| 14 | INVESTIGATION AND ANALYSIS OF MATERIALS AND MANUFACTURING | | | | | | | x | | | | | | | | | X | | x | | | x | x | | | x |
| 15 | PRODUCT STANDARDS APPLICABILITY TO INTENDED ENVIORNMENT AND FUNCTIONS | | | | | | | | | | | | | | | | | X | | | | | | X | | |
| 16 | CONSIDERATION OF EDUCATIONAL CONTENT/ACTIVITY | | | | | | | | | | | | | | | | | | X | | | | | | | X |
| 17 | PROTOTYPING & TESTING | | | | | | | | | | | | | | | | X | X | | | | | | | | |
| 18 | MANUFACTURE DRAWINGS | | | | | | | | | | | | | | | | | | | | X | | | | | |
| 19 | PRODUCT COSTING | | | | | | | | | | | | | | | | X | X | | | | | | | | |
| 20 | PRODUCT EVALUATION | X | X | | | | | | | | | | | | | | X | X | X | X | | | | | | X |
| 21 | GROUP EVALUATION | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | ECOLOGICAL, SAFETY AND SOCIAL IMPLICATIONS | | | | | | | | | | | | | | | | | X | X | X | | | | | | |

DESIGN STRUCTURE MATRIX

2464472S

Our task dependencies are displayed in the design structure matrix, which also serves as a visual representation of our project. The letter 'X' represents a task that is dependent on another task. When a 'X' appears after the red diagonal centre point, it indicates that the task is dependent on a task that has yet to be completed on our timeline, allowing us to plan for potential problems ahead of time.

# Response to Feedback/Identified Concept Issues

## Client Panel Recommendations

*-The team should focus/develop how energy is used in the function of the product*

To maximise the sustainable aspects of the product the group has decided that additional energy sources are not required for the playing of the game.

*sources to aid functionality*

The team plan to investigate the use of solar power to provide energy to the small internal circuit used to power the LEDs in the house.

*end user and how the product function will meet these.*

A set of questions appropriate for the sage and stage of the target market will be developed, considering the best ways children are able to retain information, this will hopefully increase the educational value of our product, making it appeal to the target buyers which will be schools, parents and other educators.

## Team Identified Areas for Further Development

-Current structure of game is rather boxy and not the most visually appealing to engage with.
-Each component of the game needs to be finalized in a way that will aid product functionality but appeal aesthetically to our target user.
-Will parts need to be removable to retrieve the balls from the game
-How will the electronics be housed within the game and will these be easily accessed to enable repairs if needed.
-How will the question cards be appropriately incorporated within the game/is there a way they can contribute to the functionality?
Is there a way to add more question stages into the game?
-Which materials will be the most suitable for each component whilst remaining as sustainable as possible?
How can we ensure safety when using the game, given that our target audience is young school children?

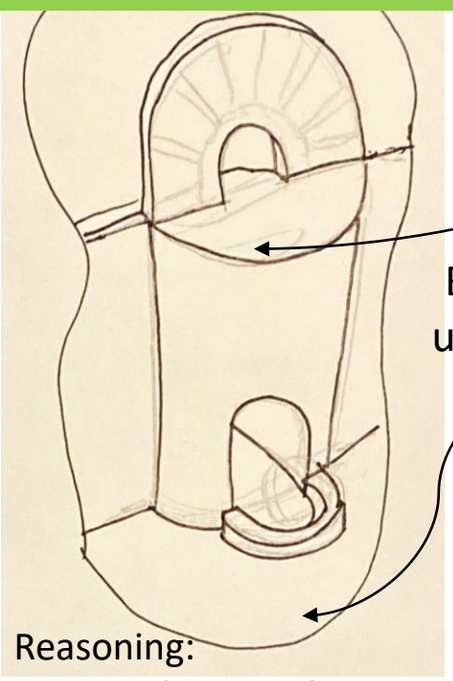
## Stages of 'The Sun Trap' Board Game

| | |
|---|---|
| Start: | -Each player is provided with a small ball which represents Solar power.<br>-Players aim their ball through the start point (the sun) and the ball will travel down a slope into the tunnel (energy convertor) |
| Q Stage: | -Players will be asked a serious of questions to allow their sunbeam to travel through the tunnel and be converted into solar energy.<br>-The first player to answer all questions correctly will be freed from the tunnel and will travel down a path to the house in the center of the board. |
| End: | -When the sunbeam enters the house a bright light will shine, declaring the winner of the game. |

Game Development Required:
The order in which questions are asked to ensure fairness and inclusion of all players still needs to be addressed.
Prior user trials highlight the need to lengthen the duration of the game to increase educational aspects.

# Concept Refinement/Embodiment Phase

## Additional Function Ball Retrieval




Reasoning:
A manual retrieval system eliminates the need for removable parts within the game, enhancing the safety features considering our target user.

Reasoning:
New Open layout allows for more visual interaction of the ball ('Sun

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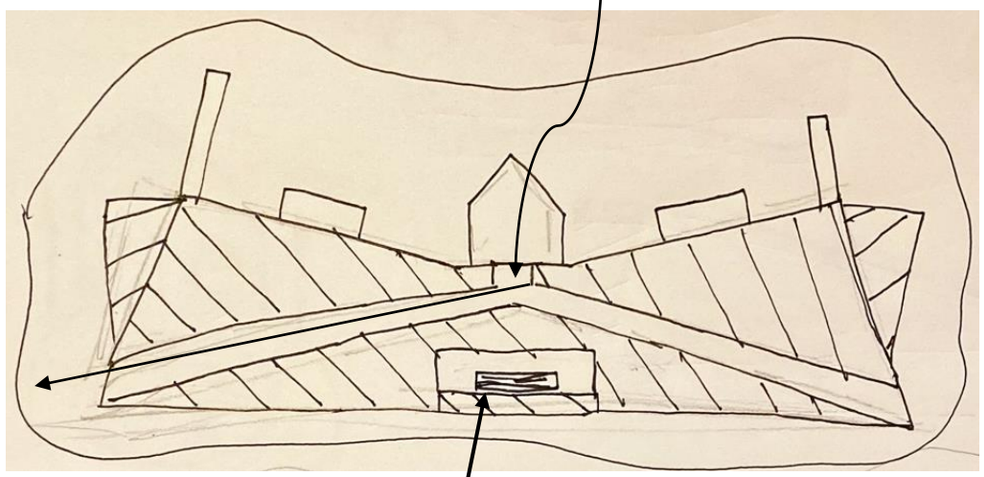
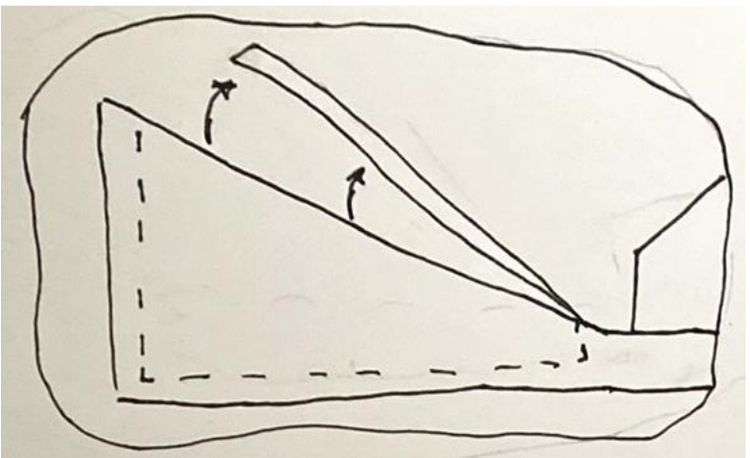
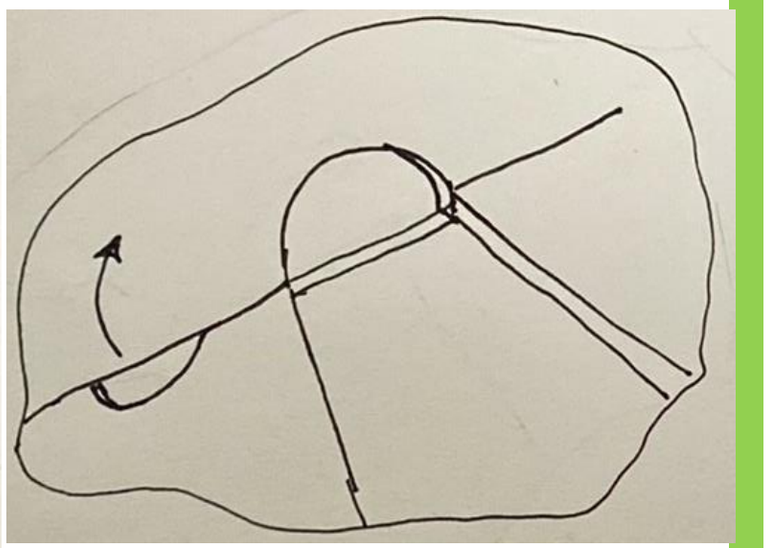


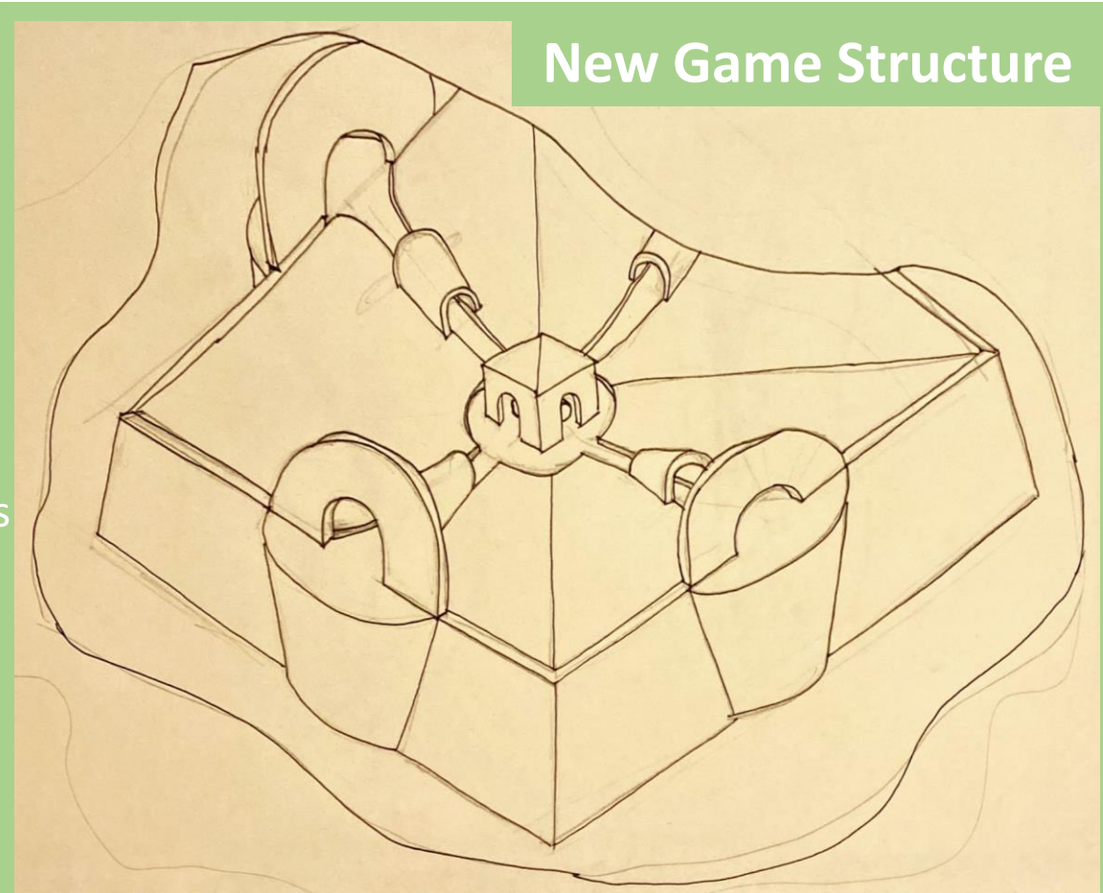

## Housing of Electronics

Removal of slope to store electronics:



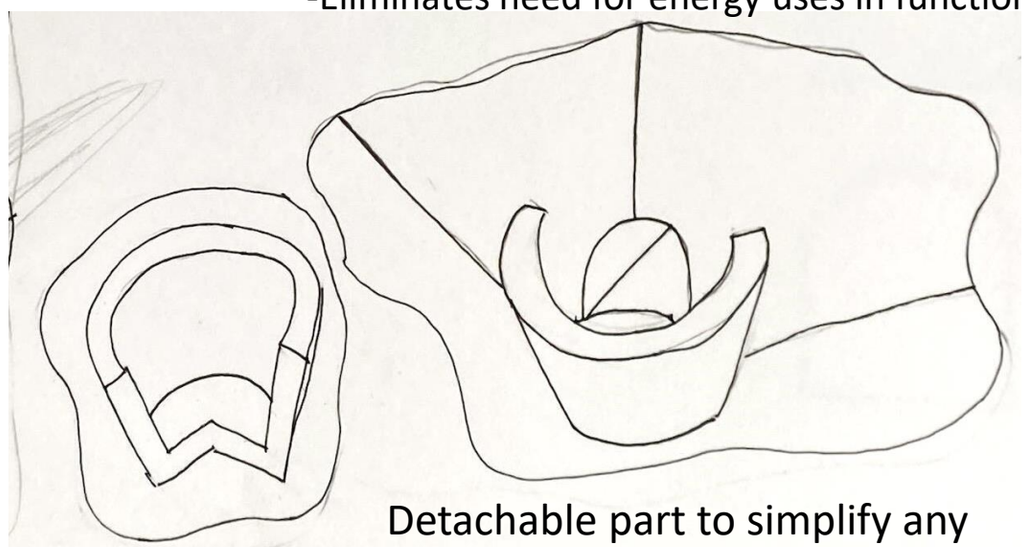


## New Game Structure



## Ball Retrieval Final Solution

Justification: Removal of multiple ball retrieval mechanisms:
-Reduction of labour/manufacturing costs
-Minimizes removable parts
-Eliminates need for energy uses in function



Detachable part to simplify any packaging/storage/transportation requirements in final solution

# Concept Refinement/Embodiment Phase

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## Additional Educational Value

In order to maximize the educational value within the game the team will be developing a deck of cards with questions relating to the topics of green energy, recycling and sustainability in general. Research into educational card games suggested the following strategies:

1. Games must focus primarily on fun with the questions taking the backseat in order to allow the children to engage in the game freely and without pressure. (Garcia, 2022)
2. Questions should focus on small chunks of a topic as to avoid over complicating the question for young children. (Garcia, 2022)
3. Visual triggers are a valuable tool in engaging a child's working memory. (Garcia, 2022) (10 Games To Help Improve Memory, Concentration & Thinking Skills, 2022)
4. The most popular children's card games involve fun and colourful graphics that are relevant to the question. (15 Simple, Easy and Fun Classic Card Games for Kids, 2022)
5. The use of familiar vocabulary and prior learning are essential. (Scaffolding in Education: Proven Tips to Uplift Kids' Academia | SplashLearn, 2022)


Figure 1: Method of information retention for children.

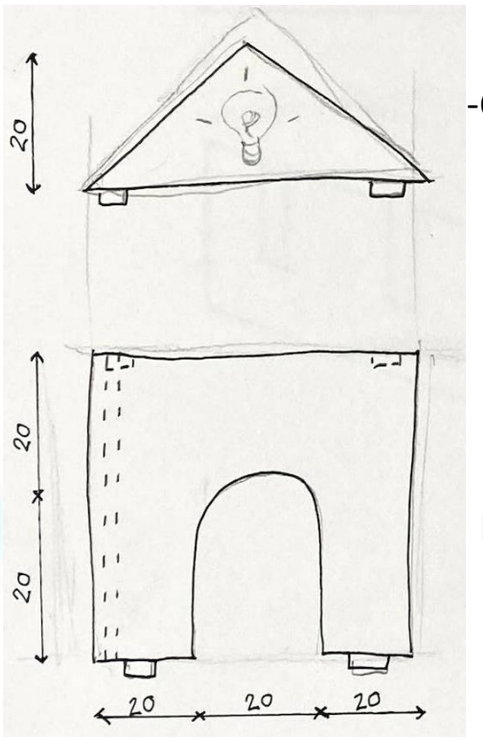
(Scaffolding in Education: Proven Tips to Uplift Kids' Academia | SplashLearn, 2022)

## Component Refinement/Embodiment Phase

### House Original Shape

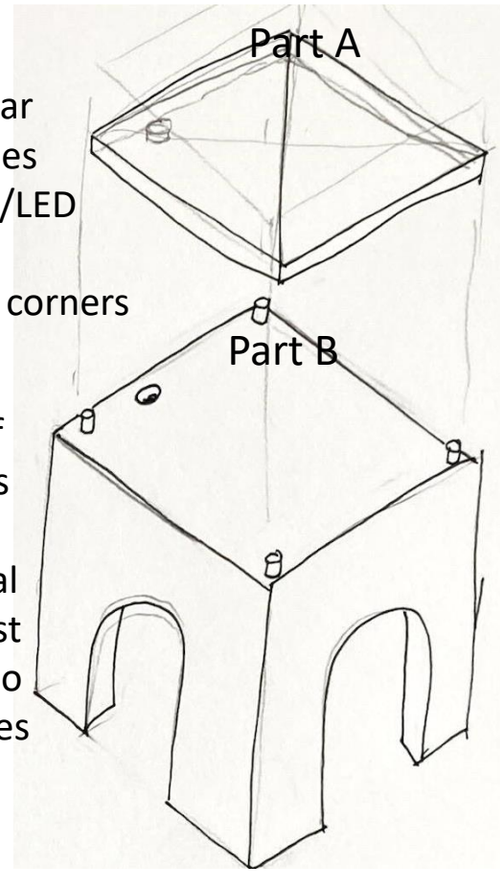
House Component Requirements
-Must be fitted within the center of the game
-Accessible entry for balls by all four sides of the Suntrap
-Must provide feedback(ideally LED Bulb to indicate the game has been won)
-Will require electronics to be fitted internally

### House Refinement



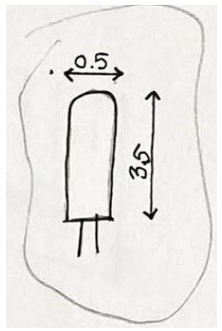

Part A:
-Opaque or clear
-No base(enables electronics repair/LED replacement
-Connects to base at corners

Part B
-Simplified base of house with 4 doors
-No need for component removal
-Wall thickness must be drilled through to house electrical wires




Exploded View

### Final sizes for

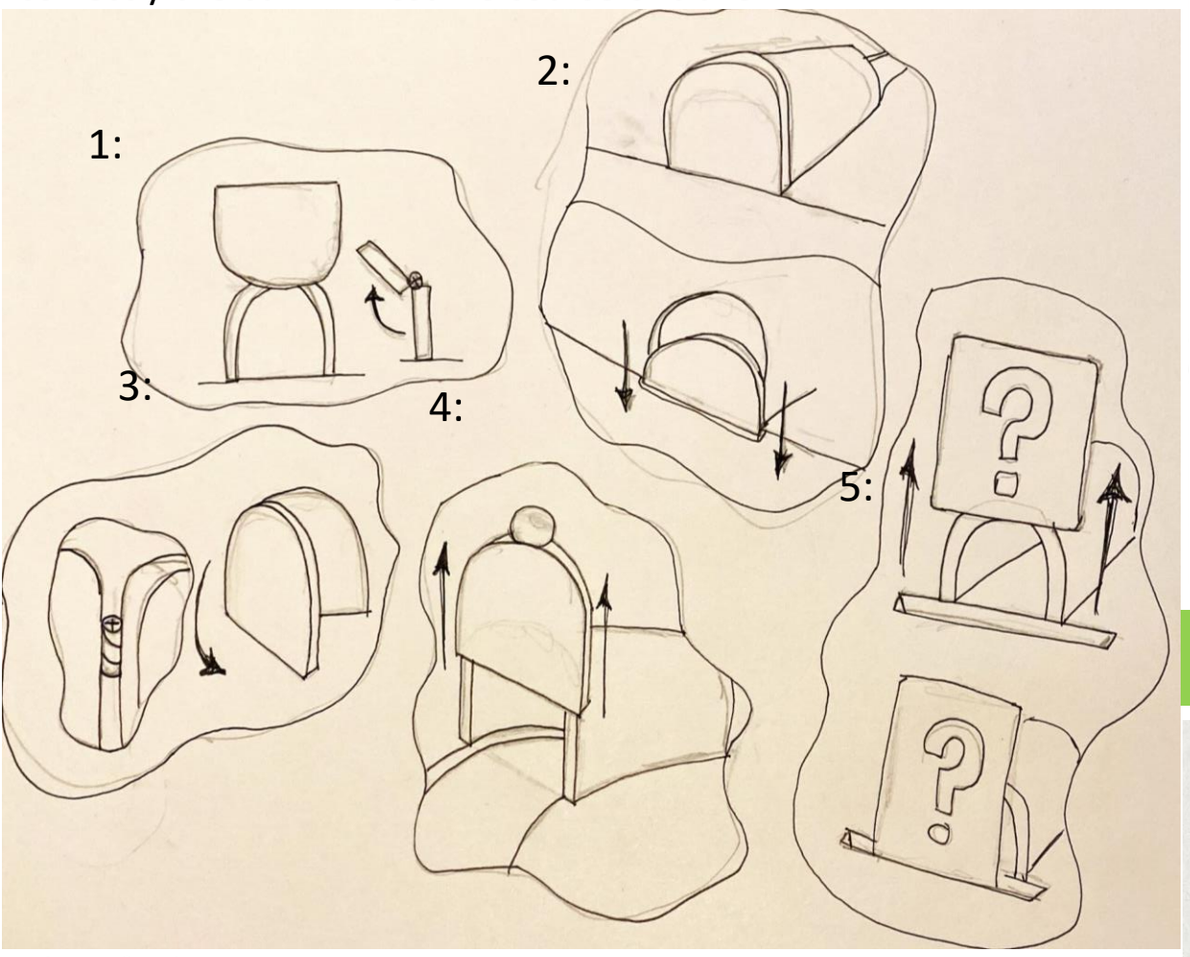



### Final LED Dimensions (green bulb)

# Component Refinement

## Tunnel Proposals

Function: Tunnel must block the progress of the ball in order to allow time for question cards. Once question has been answered correctly the ball will resume course of travel.




Identified Issues:

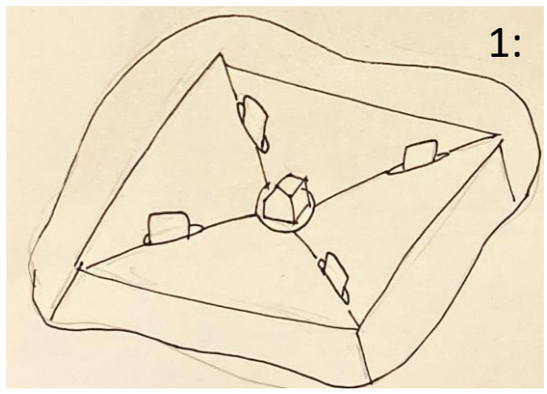
1- Hatch door could work but would require handle suitable for both child and adult average anthropometrics

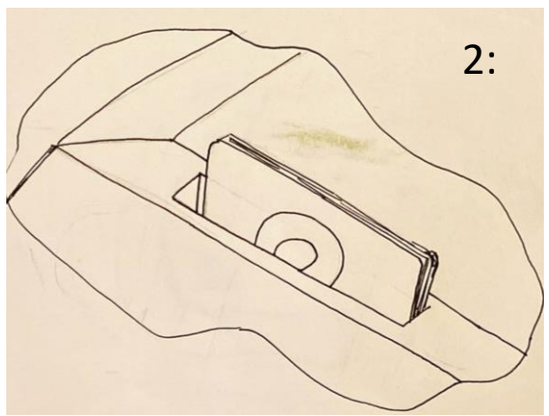
2-Dissapaeraing door would work but may prove difficult to retract to original state due to scale.

3-As tunnel will be on a sloped platform the door would not open in this state.

4-Easy to remove door with handle, most suitable for removal.

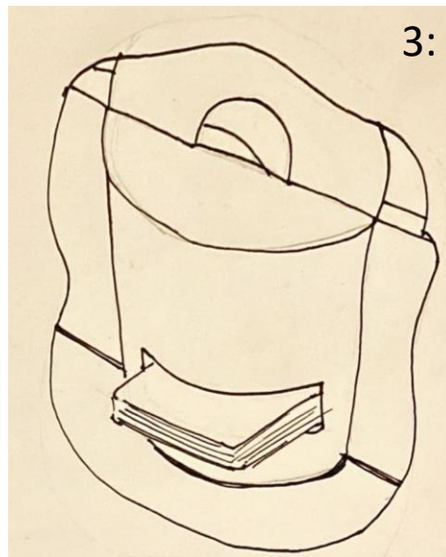
5-Using cards to block balls path of travel-arguably the most sustainable option as it keeps material use to a minimum



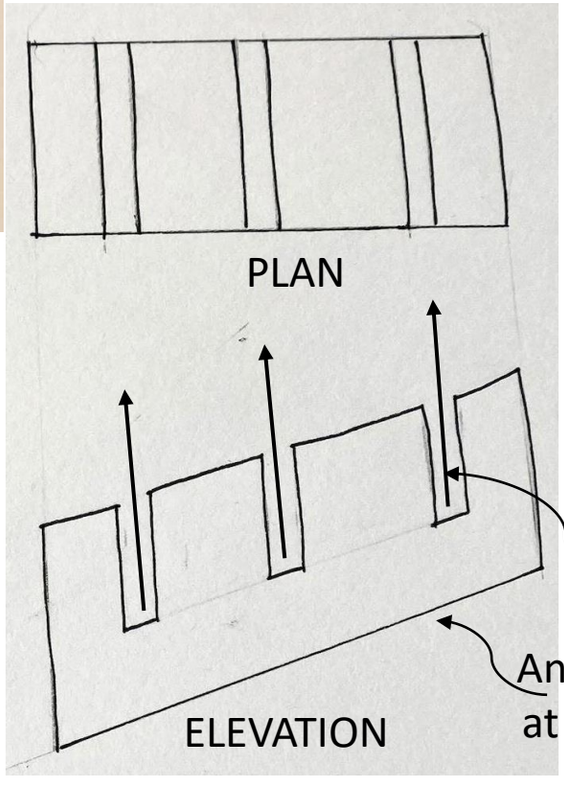

## Q Card Storage Variables

Purpose: Cards will be used to add educational value to the game, asking questions relative to green energy.

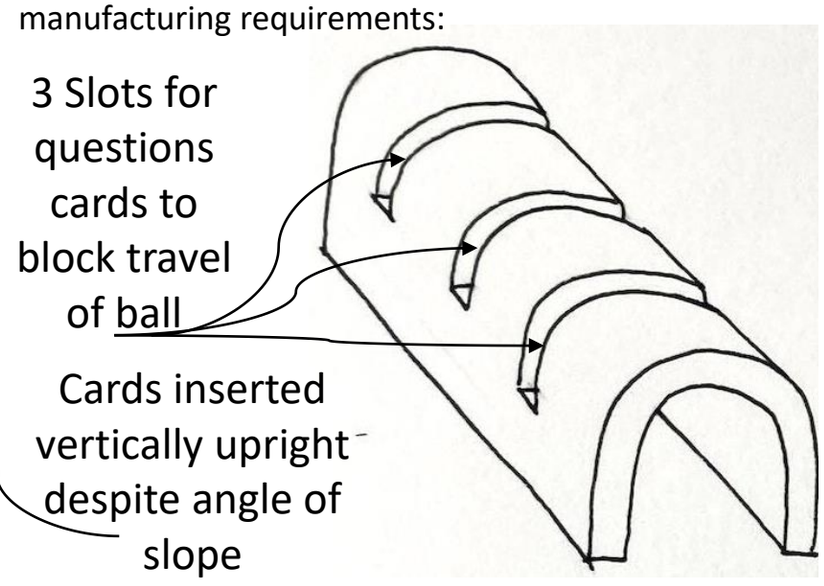



1- A section for each player to select cards from.
2-A compartment for the full deck to be stored.
3-A slot at each players starting point to select a card

## ”Energy Convertor” and Q Card Storage Final Solution




Combination of tunnel and Q card storage will reduce manufacturing requirements:



# PROTOTYPES

I thought a good place to start with our prototype was to source some scrap ply-wood and work on modelling out the walls ,or the main structure of our design.

I used a simple finger joint technique and created a square (fig. 1), this will be used as the outer walls of our model. I repeated the process on a smaller square for our interior walls and sat in inside the larger square (fig. 2).

The next problem we faced was how are we going to break this square into 4 individual compartments. I trialled a few different methods, my first thought was to create a V shaped groove on the edge of a piece of ply-wood using a router and building a jig to keep all the grooves the same throughout our model. This proved to be quite tricky and the results weren't great (fig 3). I tried cutting the wood with a tenon saw, the results were worse. The best results came when we glued two 6mm pieces of ply-wood together with the angle on both sides, to create the chevron shape we were after (fig. 4).

The interior walls needed some form of opening to allow the marble to roll into the house in the centre, so I marked them out and cut out with the jig-saw (fig. 5).

Fig.1

Fig.2

Fig.3

Fig.4

With the doors cut, the next step was to trial out ways of stopping and releasing the marble, to allow for questions throughout the game. We had 4 sides, so our plan was to come up with 4 different ideas and pick the one that worked best. Option 1, I slid a piece of 6mm ply behind one of the openings and constructed a simple lever from aluminium sheet (fig. 6).

Due to the teams further development of the game, it was decided that we would drop the interior walls altogether, and opted to just have the house in the centre.

The new idea is that a tunnel will run from the outer wall to the house in the centre, and we will use the question cards to stop the ball at certain points within the tunnel

Fig.5

Fig.6

The base for our model was the next thing to think about, I knew that we had to get the marble to return to the outside of the game after dropping into the centre of the house. I thought the easiest way to do this would be to create a sloped channel within the base material. With this in mind I would need quite a thick material, so I started with 25mm medium density fibreboard (MDF). To create the channel I started by drilling a hole in the centre of the board to a depth of 18mm, I then used the router and a couple of angled fillet pieces to create our desired slope (fig. 7). I glued an additional piece of 6mm ply-wood on top of the base and drilled another hole in the centre to hide the channel. The marble can now drop into the centre and roll out to the outer corner of the board.

The original plan was to glue the outer walled finger joints together, but through further development and discussions with the team, we have decided to make the outer walls removable to allow for easy replacement of broken or worn walls. We have achieved this by simply screwing the walls to the base (fig. 8).

I then had to create a hole in one of the corners for the marble to roll out. This ply-wood can be quite brittle when machining, so I trialled out different methods. Drilling it split the wood (fig. 9), the second attempt was more fruitful using the multi-tool. With the hole in the corner we now needed something to catch the marble as it rolled out.

Fig. 7

Fig. 8

Fig. 9

I decided to turn a little bowl on the wood lathe, I started with a piece of soft pine, to get the dimensions right and cut a segment out so it could fit on the corner of the game (fig. 10). When we were happy with the dimensions I turned a new bowl out of oak, a harder more durable wood.

After a meeting with the team, we decided not to have the bowl fixed to the corner as it would be easy to knock off or break, we had to come up with an idea to make it removable. We decided the best way would be to raise the board slightly using some feet and attach the bowl to a piece of wood so it could be slid under the game and removed when finished (fig. 11 & 12).

This created a new problem, in that when the timber feet were screwed into the base it made the whole game slide about on the surface of the bench, we over came this issue by sticking rubber disks onto the feet which gave us more grip and solved the problem (fig. 13).

Fig. 10

Fig. 11

Fig. 12

Fig. 13

We weren't happy with the way the marble was wasn't rolling into the middle of the bowl, it kept rolling back into the channel which made it difficult to take out. I solved this problem by cutting a little recess in the centre of the bowl for the marble to roll into (fig. 14).

The next stage was to develop the internal sloped sides to allow the marble to roll down into the house. I started by cutting the struts to length, soft pine was used for them. I created the desired angle on the belt sander (fig. 15).

We will use 6mm ply-wood for the sloped sides, which meant I had to put a small square of 6mm in the centre to allow for a smooth transition from slope to house (fig. 16). 3 of these sections were fixed into place, one however, will have to be removable because we will be housing the electronics inside. If anything goes wrong with the circuit we will need access to fix it.

We went through a few failed attempts until we cam up with one that worked. Firstly we tried spring clips, they didn't work very well at all (fig. 17).

Fig. 14

Fig. 15

Fig. 16

Fig. 17

Fig. 21

Fig. 20

Fig. 19

Fig. 18

Secondly we tried a simple hinge, this worked however, we could only open the hatch a little bit. This made getting the electronics in, and out a bit tricky. The final attempt was with magnets, I glued small magnets to the strut and steel strips to the ply-wood (fig. 18). We chose this method as it produced the best results.

The next step was to cut out the semi-circles on each of the external walls, this will be to represent the sun-rise, and to allow the marble to be introduced into the game. I achieved this by drawing the shape, drilling it out and cutting with the jig-saw (fig. 19).

This lead us to our next problem, where the removable section meets the hole in the external wall, the ply-wood section is a bit flimsy where the marble will enter the game. We tried to solve it with more magnets, but they weren't strong enough. The next option was to drill a hole in the external wall, and to attach a small block of pine with a hole in it to the removable section, and to use some sort of pin to go through the holes locking the section in place (fig. 20 & 21). This worked really well however, the pin I used was from a kitchen worktop jig, so I had to return it. I had to then make my own, I turned one from steel bar (fig. 22) and one from oak (fig. 23). The team decided to go with the oak pin because it tied in more with the whole model, and it was more aesthetically pleasing.

With the section now locked in place and the electronics ready, it was time to trial it all out. We were relieved when all the circuitry fitted into the space provided and that they worked (fig. 24). I glued the pressure sensor into the hole where the marble will fall through (fig. 25). However, our joy was short lived when we realised the 13mm glass marble was too light and not falling from high enough to set off the sensor. We had two options, either get a more sensitive sensor or a heavier marble. We tried the easier of the two options first and changed the 13mm glass marble to a 16mm grade 25 steel ball bearing. This change has solved the problem, the marble sets of the sensor and still small enough to roll down the channel.

Further development by the team has suggested that we round off and chamfer any sharp edges on our model to reduce any of the young kids from injury. So I filled in any chips and cracks in the ply-wood using a dark wood filler and using a palm sander took all the edges off the model. I used the belt sander to round the 4 main external edges, which also exposed the finger joints for a really nice finish (fig. 26).

Fig. 29

Fig. 28

Fig. 27

Fig. 22

Fig. 23

Fig. 24

Fig. 25

Fig. 26

I used the palm sander to rough up all the surfaces ready for painting. Our colour palette had to relate to climate change. We decided on green for the slopes to represent the marble rolling down a grassy hill, on the outside we opted for blue and white to represent the sky and clouds, and the semi-circle will be yellow to represent the sun rise (fig. 27).

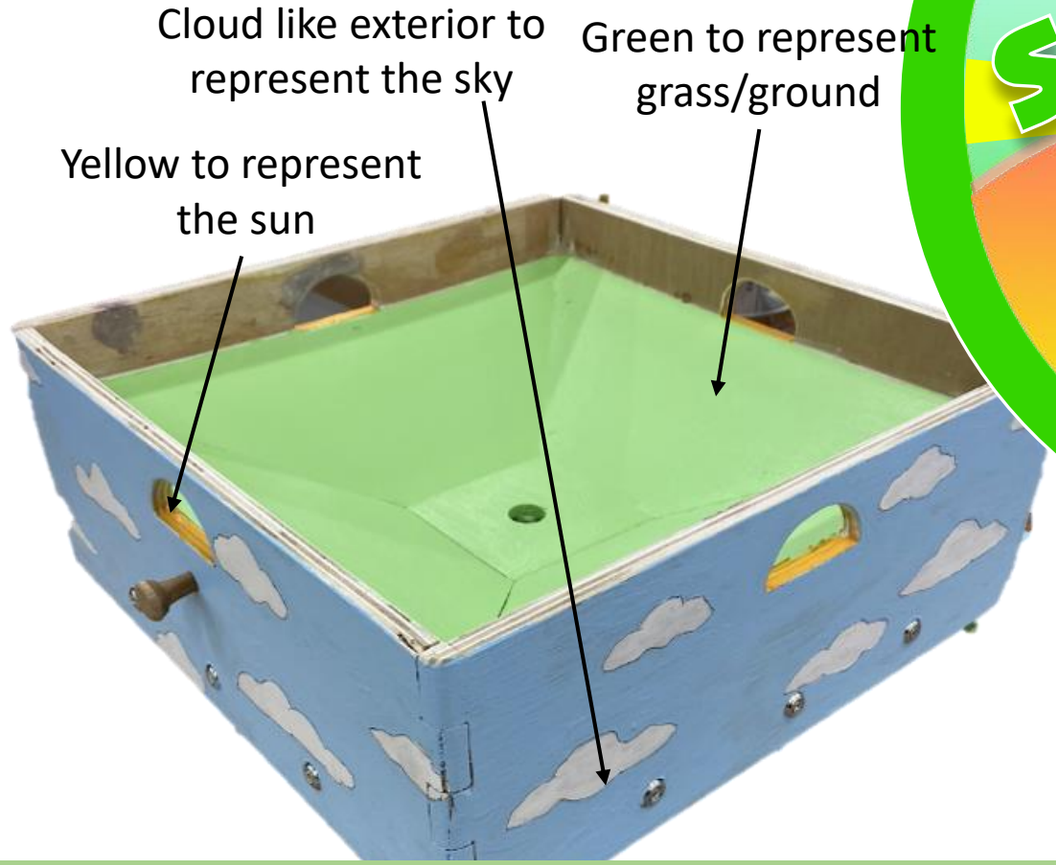
The final stage of the model was to install the 3-D printed components (fig. 28 &29), these pieces were glued into place using a very strong mitre bond adhesive.

With all the components now in place, the final concept was complete and ready for user trials.

## FINAL PRODUCT

# Aesthetic Refinement

Research dictates bright colours relative to their real-world inspiration:




**Product Packaging Mock Up**
-Advertising in schools.
-Box for transport of product.
-Packaging made of recycled materials.
-Lightweight cardboard

# Brand/Product Identity

**Product Logo**
-Relevant colour scheme
-Imagery reflect of game
-Used for packaging, advertisement and promotional media.


# Educational Marketing Strategy

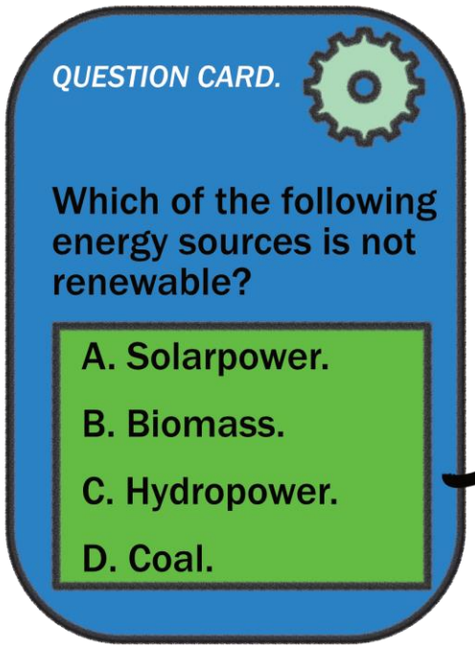
**Research on establishing a product on the current educational market suggests the importance of:**

1. Increase your online presence
2. Decide whether 'old school' selling is best value for money for your business
3. Add your business to the National Register of Education Suppliers
4. Enable schools to benefit from collaborative purchasing
5. Show off your accreditations
6. Share your testmonials
7. Become an approved supplier
8. Develop your social media presence
9. Get to grips with Google Adwords
10. Attend trade shows
11. Know your target market
12. Consider your message
13. Understand your reputation is your most prized asset
14. Know your competition

(20 Tops Tips For Selling To Schools in 2022 from Incensu, 2022)

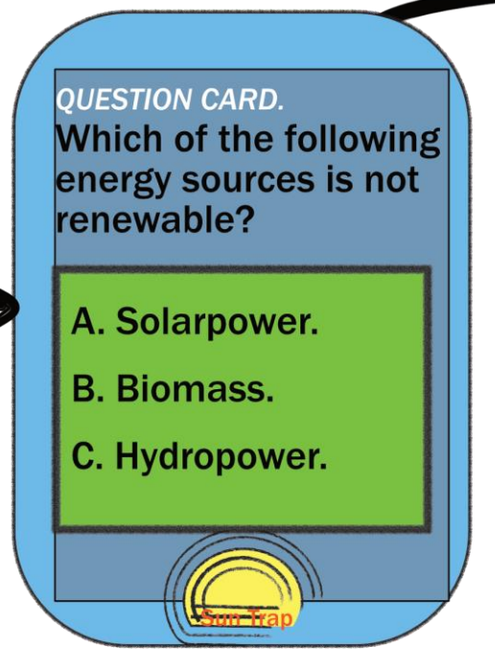
# Question Cards - A User Centred Design Approach.

**Prototype 1.**

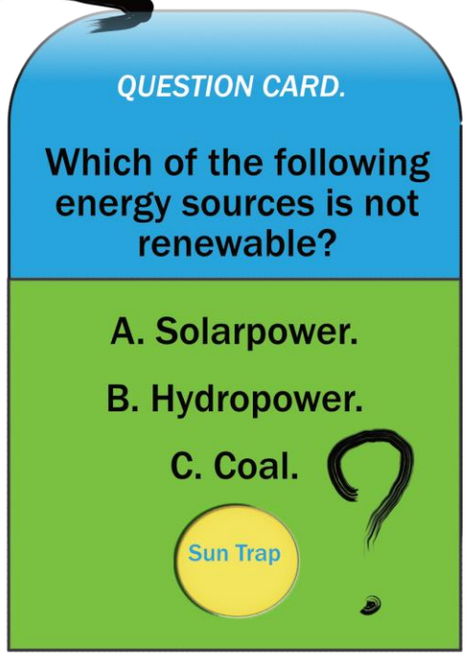


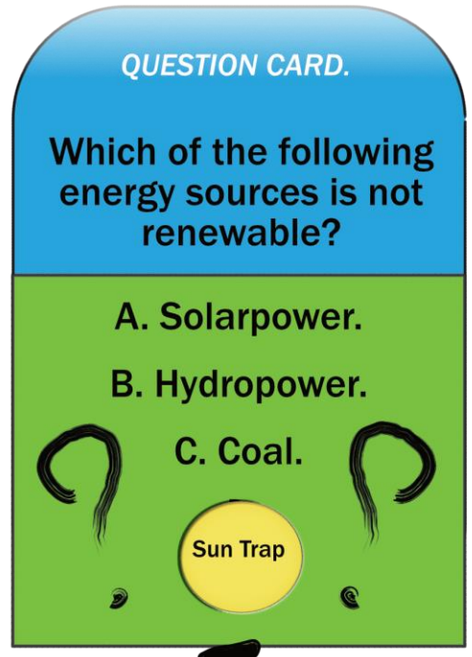

Font “Franklin Gothic Medium.” was introduced as a game inspired font.

Aesthetic colour changes were made to harmonise with the aesthetic values of the playing field.



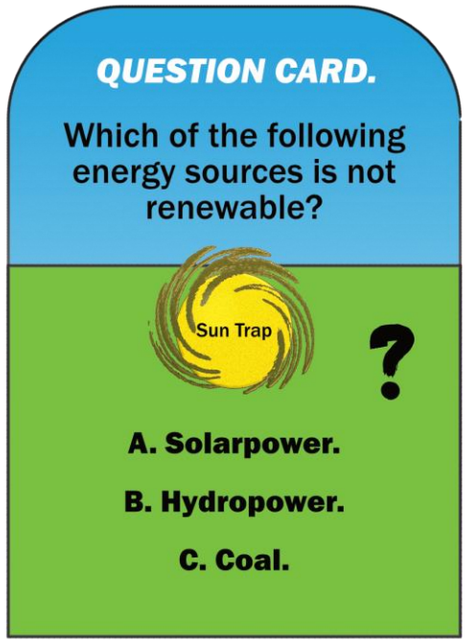

After user testing the answers are being shrunk from 4 to 3 choices because this fits the retentive memory of our target user group 6 - 11 more which enhances user experience. Miller G. (1956).

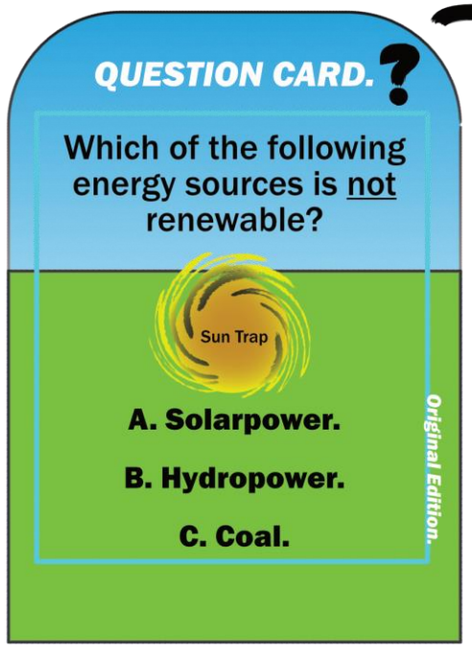


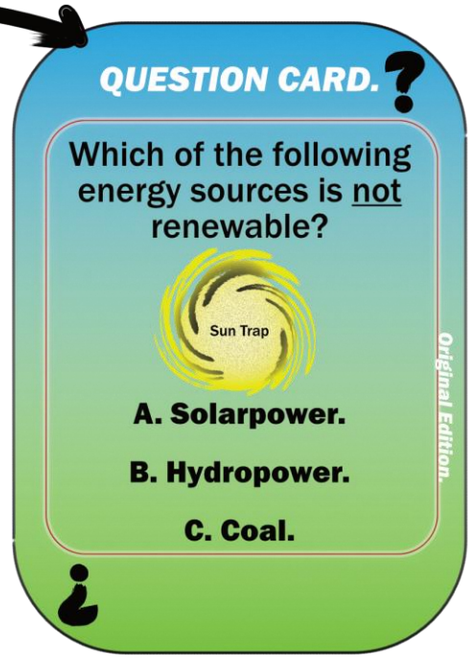




Higher contrast needed to be created to create more readability / accesibility.

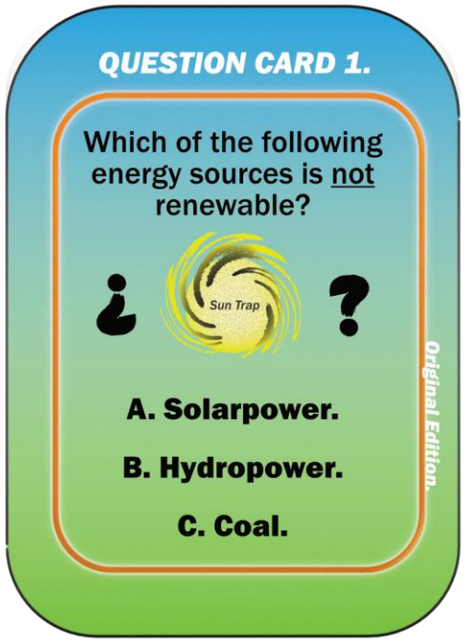
**Prototype 2.**




All edges were softened to create a more ergonomically friendly experience.




A glowing effect was added around the borders and position of the question marks adjusted to make the question the focal point to make it easier for the user to focus on the question.

# User Trial

We had two groups of users trial the ‘Sun Trap’ so we gather feedback on how the product would work within our target market. We got this feedback by asking questions and taking observations as they played with the product.

- User Group One was a group of 4 children aged 6 (youngest target age).
- User Group Two was a group of 4 children ages 11 (oldest target age).

Each group played 5 rounds of the game so that we could get some consistent data returned from the user trial.

## User Group One Feedback

User group one found the concept of the game to be captivating and enjoyable. The users thought the game was aesthetically pleasing when we asked what they thought in this sense. The users said that the product looked eco themed.
In terms of questions the group struggled answering them due to complexity of word choice as many had to ask what certain words meant etc. Some of the questions themselves were slightly too advanced for the pupils to answer and get correct and many were just hazarding guesses. The overall weight of the model was slightly too heavy for the pupils of this age to manoeuvre themselves. When thinking of the mechanics of the game themselves the game worked well with this group until the ball drops into the tunnel within the house where it should activate the force resistor, however this only worked 2 of the 5 rounds and this left the winners unsatisfied once complete.

## User Group Two Feedback

User group two found the concept exciting and enjoyed the competition that the product promoted for the users.  The second group said that the product looked environmentally friendly. In terms of the questions, the children has a greater understanding but there was still a few words that they were not sure of and there were some concepts from the questions that were not understood. These pupils could set the game up a lot easier as the weight was less of a restriction for their age range. Once again, the overall flow of the game worked well until it was broken down when the ball should activate the force resistor, but it did not activate them every time and activated 3 out of the 5 rounds that were played by this group.

## Conclusion From Trial

To tackle the issues, we have found and identified from our user trial we would change the material of the base to become a hollow and made from plywood as the main weight of the product comes from the base that we have installed. The next problem of the cards could be addressed by having different packs of cards graded at different levels such as beginner, intermediate and advanced questions that could then be used for the appropriate age levels or competence levels.  This could then bridge the gap by scaffolding the questions for the different users. In terms of the issue with the force resistor we will have to make it so the ball itself will sit on the force resistor and make contact for long enough that it will activate when the ball reaches the house so that the game is more amusing and has an end goal.

# Design for Ergonomic Optimisation.

**Size concept 1 .**

(65mm x 90mm)

Exploding kittens SOURCEoriginal = concept **SOURCE** 1.

**Concept 2 .**

(76.8 mm x 97 mm)

Original playing card values **SOURCE** x 1.1.

**Concept 3.**

(78mm x 108mm)

Prototype A version: large scaled down by x .0.75 )

**Concept 4.**

(71mm x 99mm)

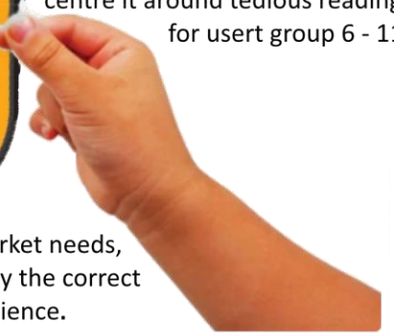
Exploding kittens **SOURCE** scaled by x 1.1 = concept 4. Rounded the width down to increase the % length to create an elegant aesthetic.

**Concept Analysis.**

Testing with user group 1: User trials showed the longer quiz questions were more easily recognizable on the larger cards due to the ability to have a larger font on it. **Going forward with concept 4** after user trials because readability was increased. This uer study also results in shortening question length to enhance the experience of fun and not centre it around tedious reading which is work for usert group 6 - 11.??

Analysis: Concept size 1 and 2 was too small to show information with a readable font for younger target users. To suit target user group age 6 - 11 anthroprometrics sizes hand / fingers need to be met and readability.

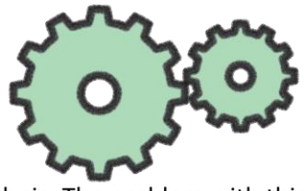
Scrum design calculations used to analyse market needs, standard size pack and pupils SEN reading ability the correct size and optimising usability / user experience.



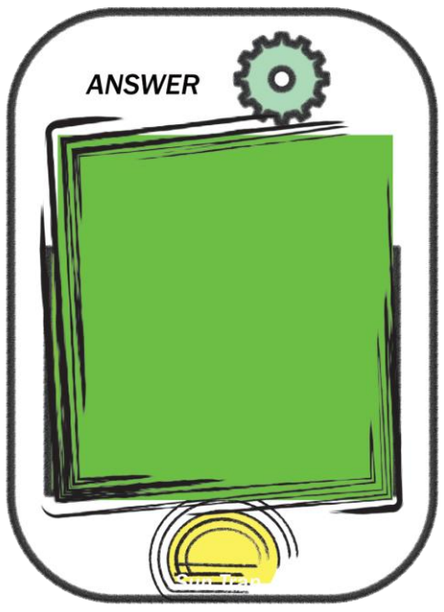
# Answer Mechanic Design.

It can not be smaller than what Don Norman, Califoria University refers to as “UX for better readability.”

**Design challenge: How does the user reveal the answer without the other team seeing it?**



**Concept Design A.**




- Option 1 -

**On the back of the card.**

Analysis: The problem with this is if a student holds the card up to read it the other team or a team mate might see the answer on the back

- Option 2 -

**The teacher knows the answer.**

Analysis: The problem with the teacher knowing the answer is they cannot interact with every group at the same time.

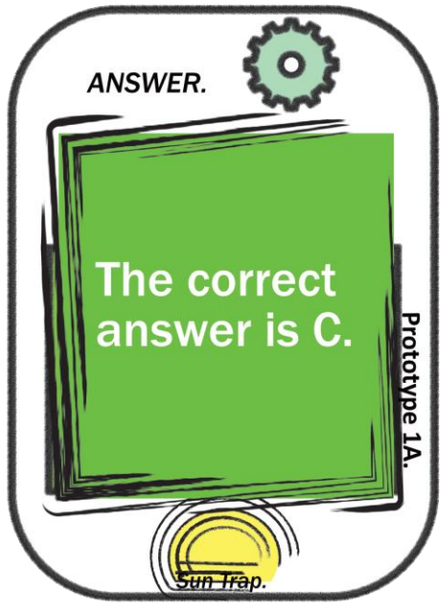
- Option 3 -

**Design a second card with a number on the front matching the number of the question card and the answer oom the back.**

Analysis: **Going forward with option 3.** This way players are able to safely check their answer once their final vote is in. The process sources only minimaly more material and qualifies as a suistainable design solution.

**Concept Design B: answer mechanic design option 3.**

**Back View.**




**Front View.**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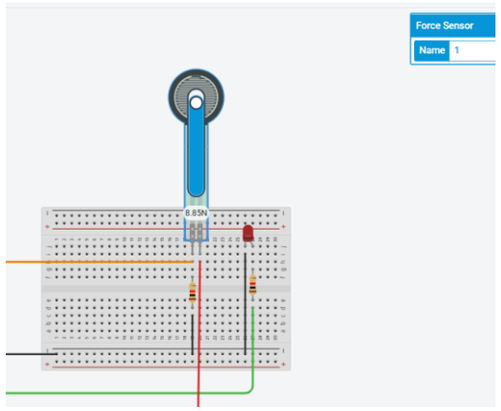
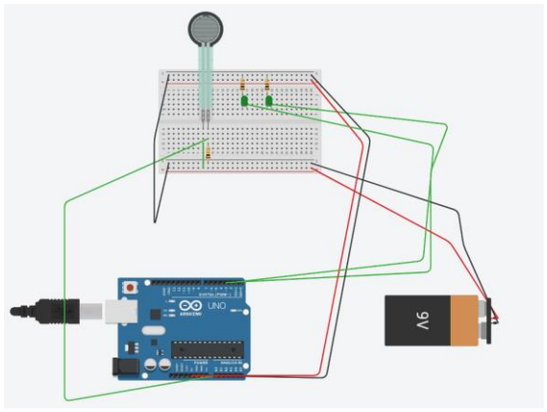
# Electronics 1 – Marble Mechanism.

**Figure 1.** Analogue Tinker CAD circuit Prototype 1.




First an analogue prototype of the circuit was created but it was **not sufficient to program FR1 and concept speaker device.**

**Figure 2.** Digital Arduino IDE Tnker CAD Circuit Prototype 1.




To adjust for missing capabilities in analogue and the enablement of future modifications if needed:

**Figure 3. FR1. I**nterlink Electronics) 2015.

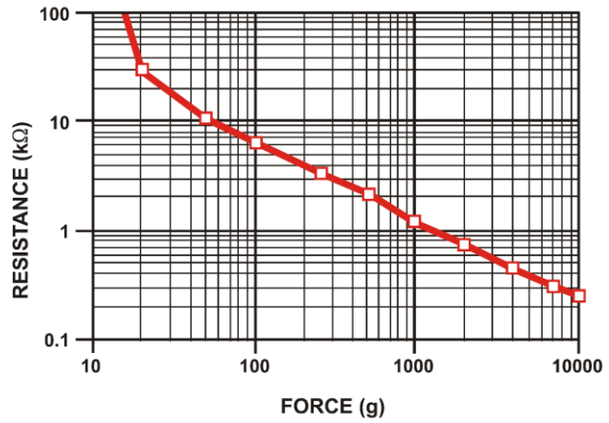



**Figure 3.** ( Highlights the behaviour of variable FR1. Interlink Electronics) 2015.

**Figure 4 .** Force Resistor 1 (FR1).

In C++ The Force Resistor FR1 activates by float 0.1 > and can sense a marble. Integer = 1 was too low.

**Figure 5.** Circuit Schematic Prototype.

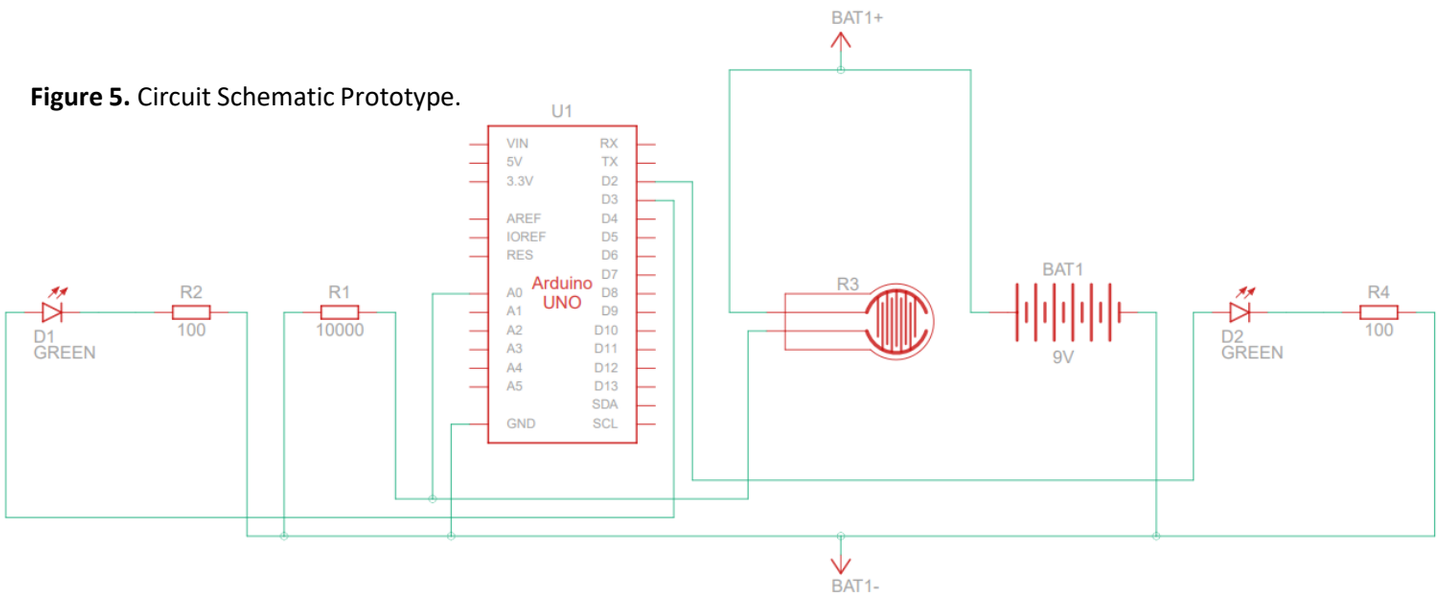
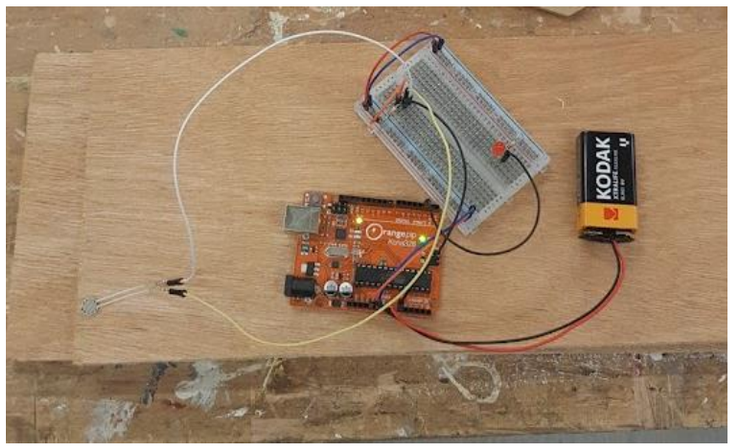



**Figure 6.** Physical prototype 1.0 in assembly.

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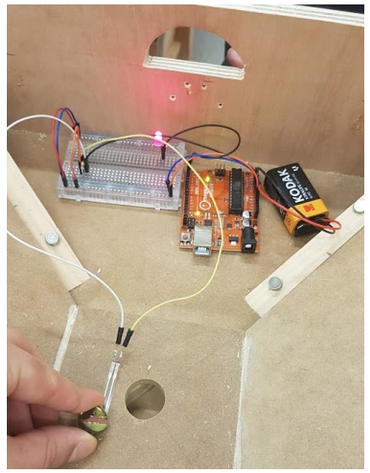
# Electronics 2 – Marble Mechanism.

**Figure 7.** Physical prototype 2 in assembly interacting with the playing marble.

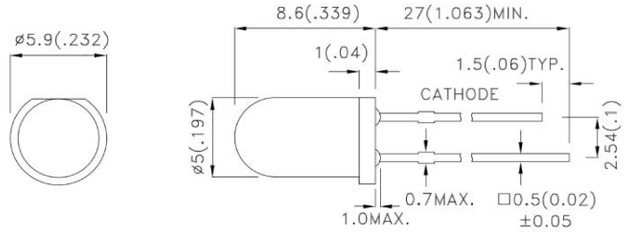


The marble did not activate.

Analysis: I = V / R.

V = 9 / 10000Ω = 0.0009mA. Decrease theresistor value to 1000 to enable the marble to be detected.

**Figure 8**. LED dimensions.(Technical data sheet) 2018.




The suitable dimensions for the LEDS for the wood prototype. Required to create the optimal material efficient dimensions for the housing.

**Figure 12.** Battery casing.

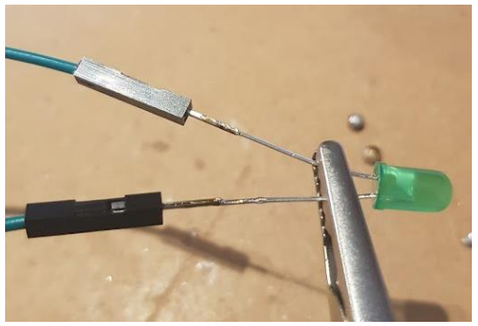

A no hazard safety approved battery casing with ON / OFF switch to save energy when not in use.

**Figure 14.** A prototype of an embedded system, Arduino IDE.

```
prototype4_FSR_turns_on_LED
int LED2 = 2;
int LED3 = 3;
int LED4 = 4;
int LED5 = 5;
float fsrPin = A0;
int fsrReading;

void setup() {

pinMode(LED2, OUTPUT);
pinMode(LED3, OUTPUT);
pinMode(LED4, OUTPUT);
pinMode(LED5, OUTPUT);
Serial.begin(9600);

}


void loop(){

fsrReading = analogRead(fsrPin);

  if (fsrReading > 0.1){

       Serial.println(" - Marble touch");
```

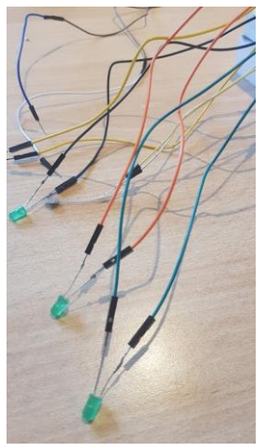
Due to FR1 not activating in figure 6**. fsrPin was changed from an int to var** variable to a enable decimal input values of force allowing a fraction of weight to activate the mechanism.

**Figure 9.** Secure wire soldering.



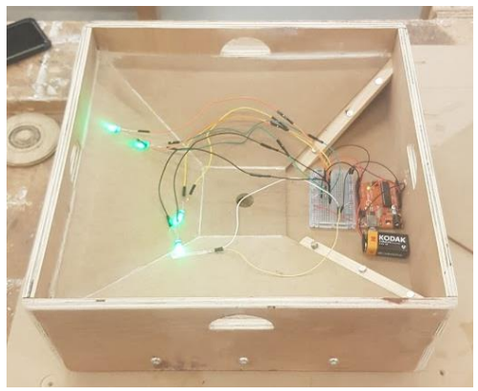
Precise solders of the green LEDS were established.

**Figure 10.** Extension of components.



Individual components were configured and extended. In order to fulfil design specification: reach the top layer of the 3D printed housing.

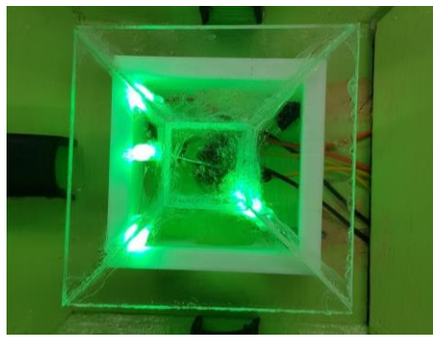
**Figure 11.** Physical prototype 3.



LED mechanism LEDS reflecting the winning achievement were configured in prototype 3. C++.

.

**Figure 13.** Physical Prototype 4.



Visible are the wires which were causing a safety concern. Concept design of a trough guiding them underneath the model was created and technical specifications made for prototype 5.

**Figure 15.** Electronics Bill of Materials.

| Name | Quantity | Component |
|---|---|---|
| U1 | 1 | OrangePip Arduino Uno. |
| R1 | 1 | 10000 Ω Resistor. |
| R2,R3 R4,R5 | 4 | 250 Ω Resistor. |
| D1, D2,D3,D4 | 4 | Green LED. |
| FR1 | 1 | Force Sensor. |
| BAT1 | 1 | PHOTO VOLTAIC CELL.. |

## Electronics Rationale.

Aiming to create a sustainable and viable design solution for mass manufacture the processes should be made available in a rechargeable solar format. Photo voltaic cells can be montaged to the top of the roof powering system to achieve this. Durability and cost efficiency improvements can be made by adjusting wire lengths. Force resistor accuracy can be improved by increasing the overall size and position of FR1 to optimise for the shear stress the playing marble exerts on impact. The electronics mechanism can be expanded on by adding functions such as a speaker which adds to the game experience by e.g., rewarding players. Or a buzzer mechanism to quiz who is fastest to answer! A more compact analogue version can also be created: aiming to optimise the weight, material pricing and energy efficiency of the system.

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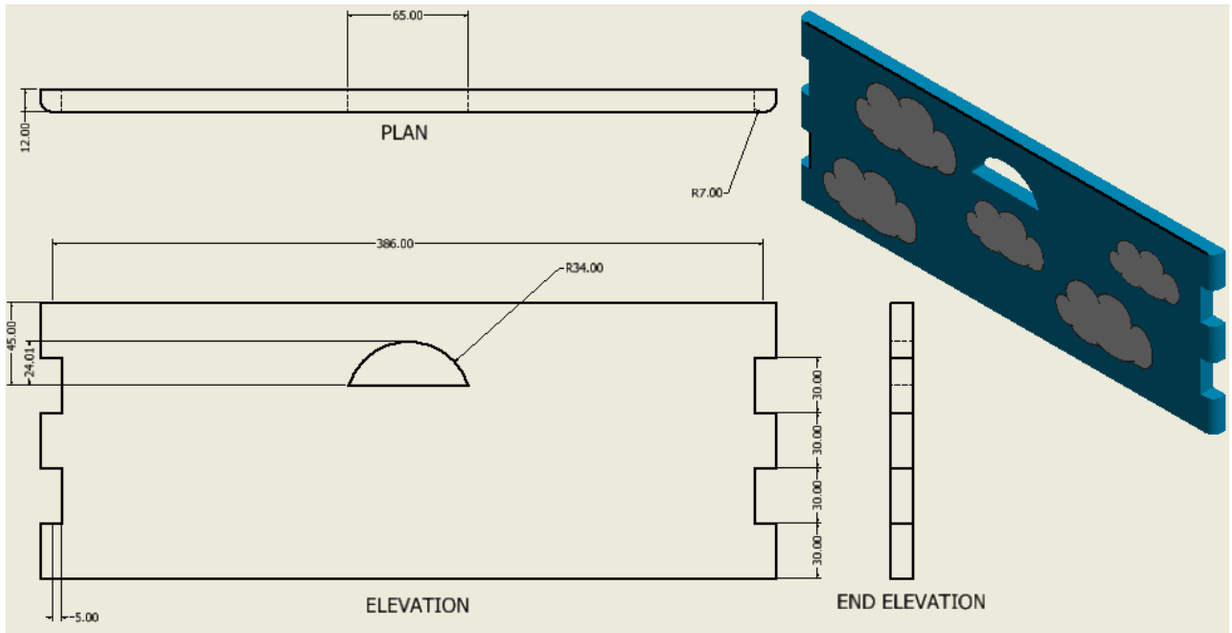
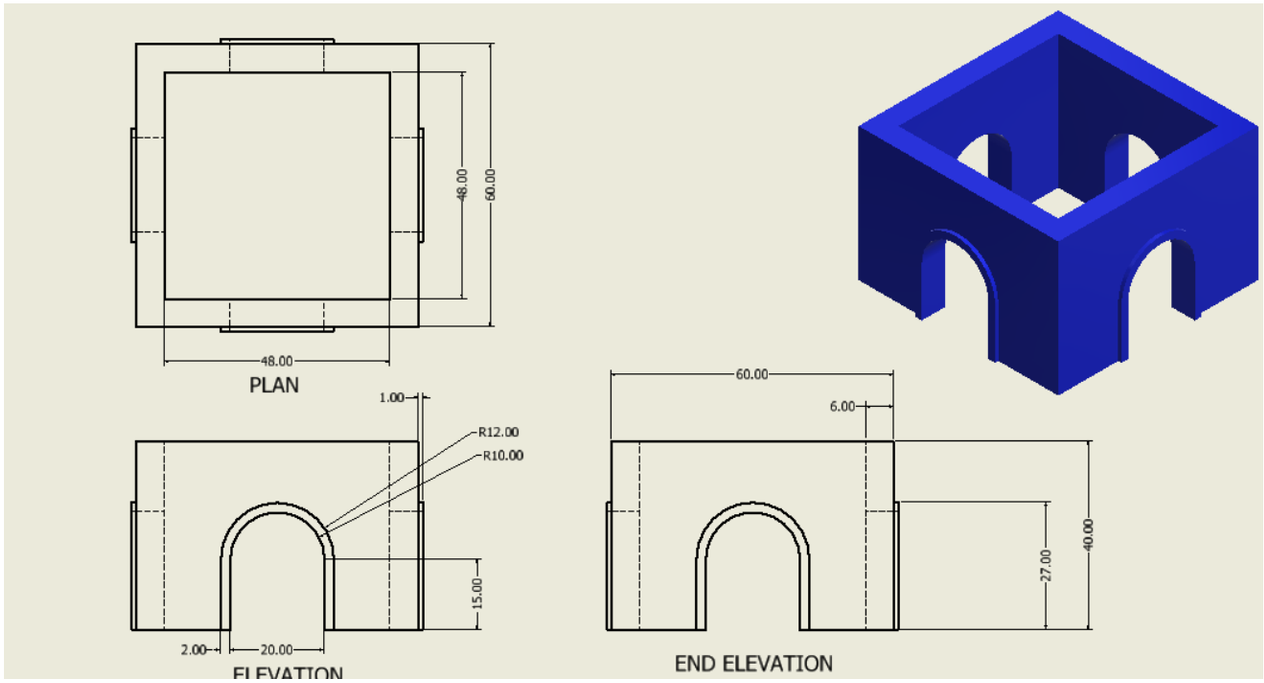
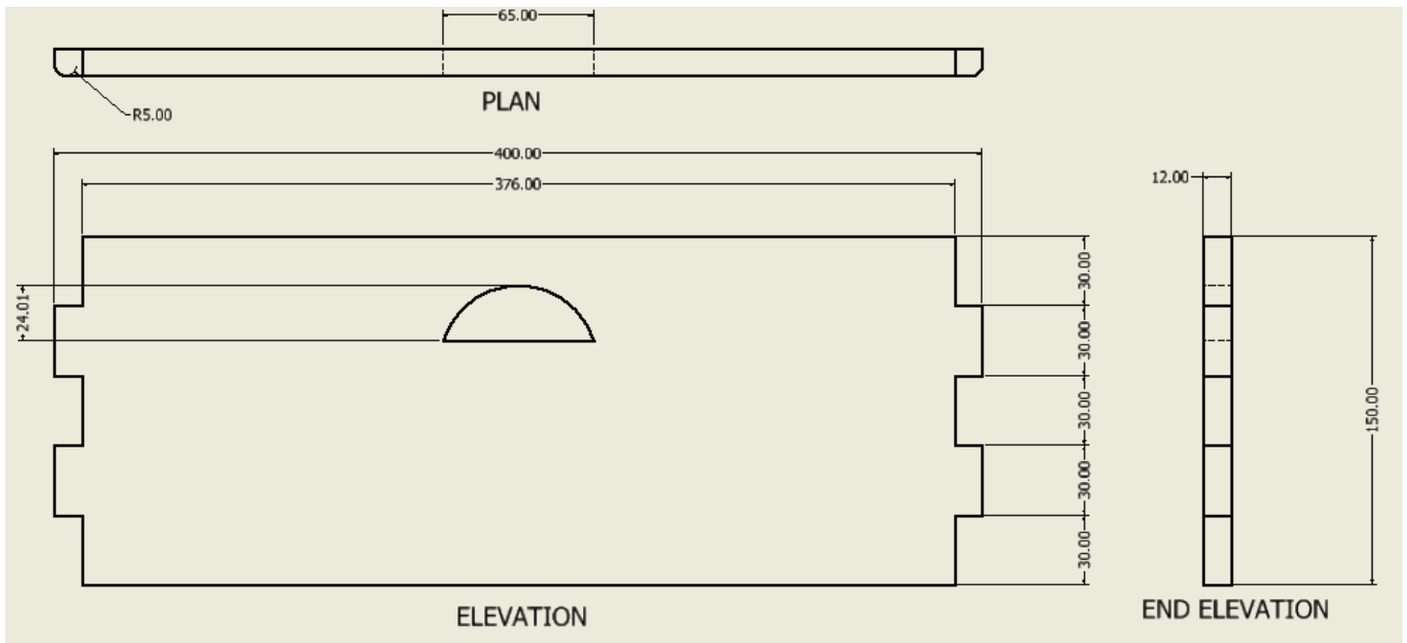
# Working Drawings

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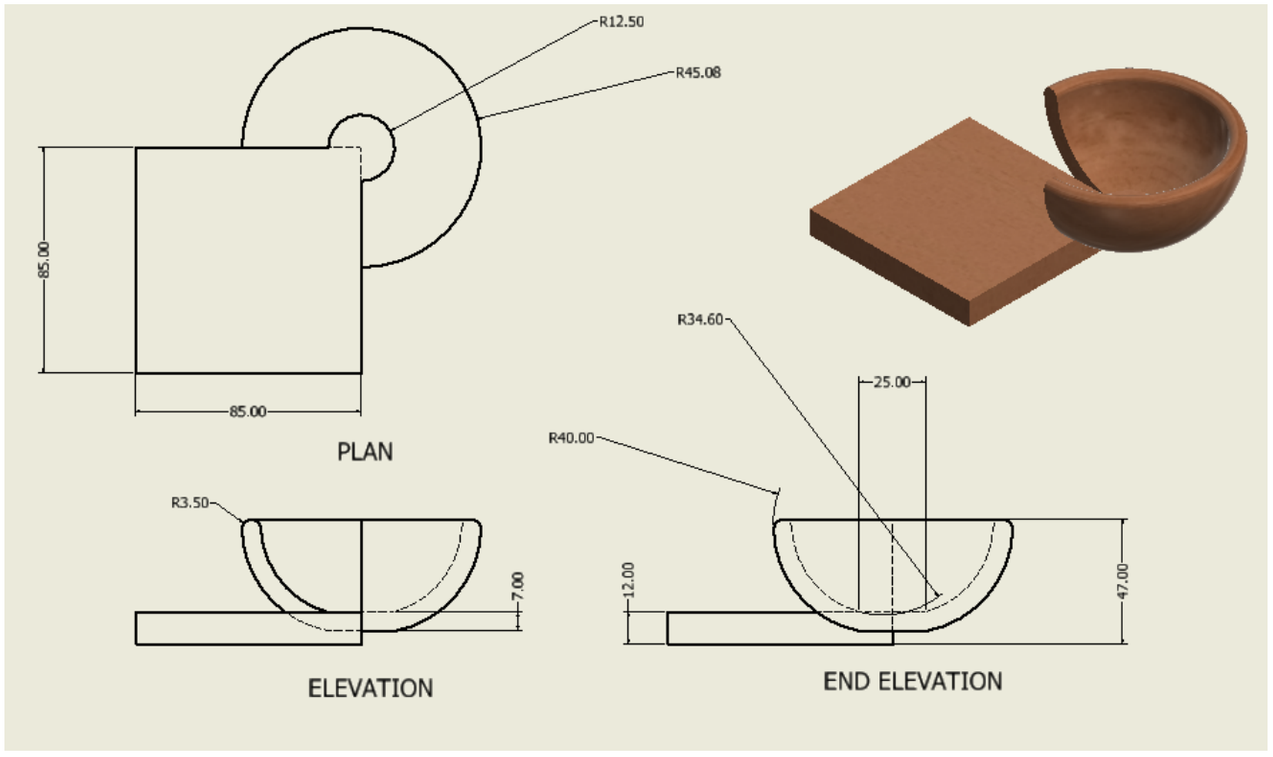
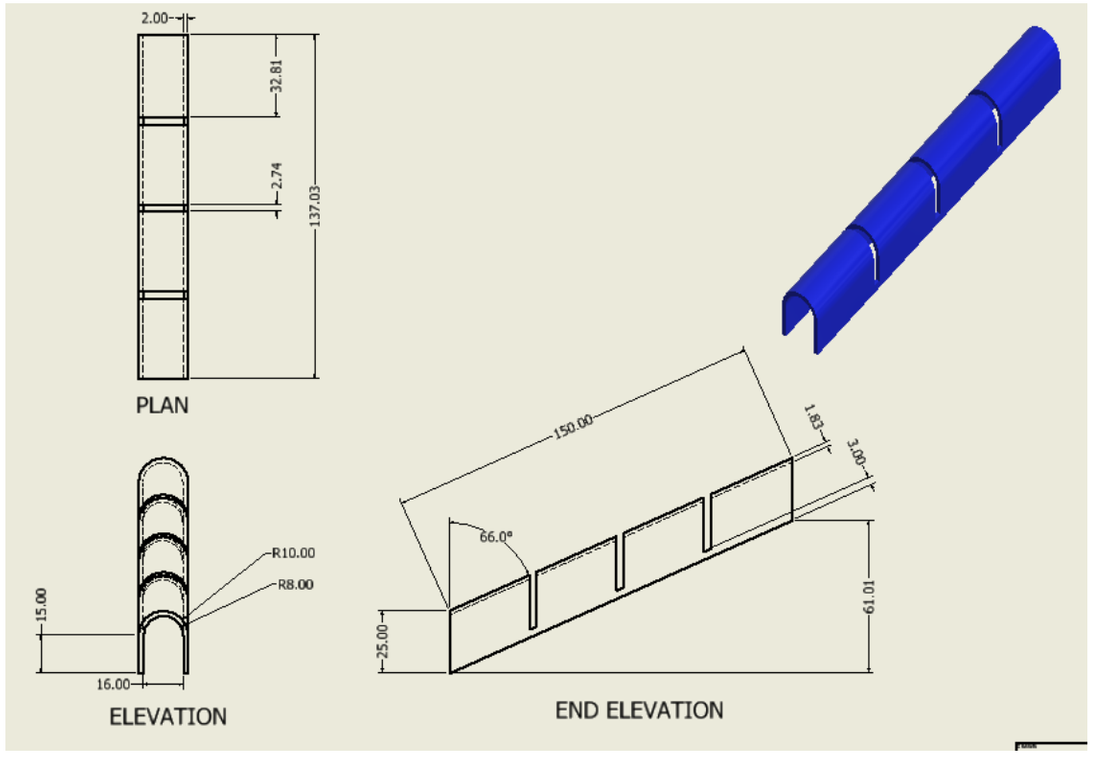
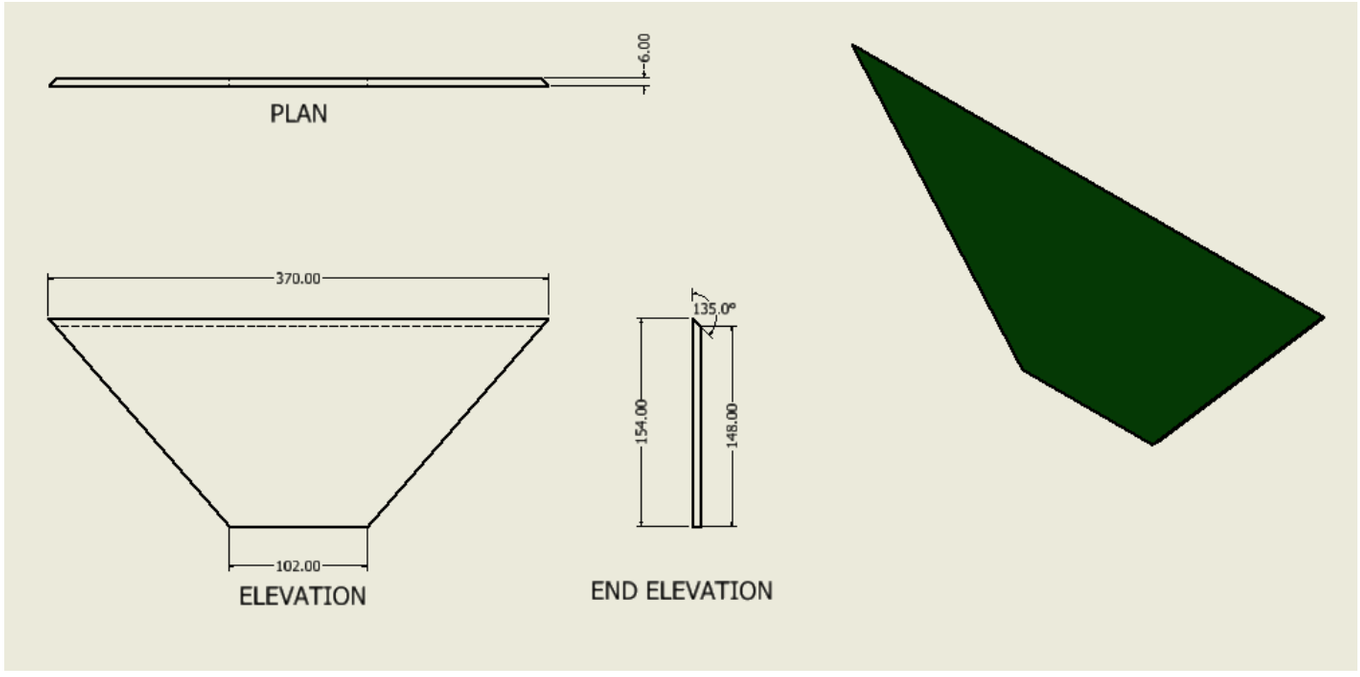
# Working Drawings

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## ECOLOGIAL IMPLICATIONS

According to My Kind of Meeple (online), the initial manufacturing of board games, as well as the shipping of them around the world, is bad for the environment.
A variety of materials and chemicals are used in the production of board games. However, one of the most significant environmental impacts is shipping them all over the world.
**How will "The Sun Trap," our board game, negotiate with these environmental implications?**
Because board games are reusable, they have a low carbon footprint, which helps to offset the high carbon footprint of shipping the product around American schools. This point is also supported by My Kind of Meeple (online), which mentions that when playing a board game, it has very little environmental impact. They use no power and produce no waste.
Taking raw materials to create a board game requires a lot of energy, which mostly comes from fossil fuels and causes pollution; thus, our physical board game should be made from recycled materials or materials that can be recycled in the future, which helps with lowering the overall carbon footprint of the board game and manufacturing, and this complements the educational factors of our 'The Sun Trap' board game.
The board game raises environmental awareness by teaching younger children about pollution and what it does to our planet, as well as promoting the concept of renewable energy. Persuading students to make small changes in their lives to help with climate change issues.

**Board game material suggestions to tackle ecological implications.**
Wood, being it is a highly biodegradable material.
Plastic that has been recycled can be melted down and reused.
Cardboard - Because cardboard made from recycled materials is so common, many boxes and tokens are made from recycled cardboard. Because it is biodegradable, cardboard boxes and pieces can be recycled alongside your regular paper and card recycling.
Metal – recycled metal is another option, though it may be too heavy given that the board game is for children. This also has an impact on the product's safety features.
This will be discussed further in the *Ongoing Investigation of materials.*

## SOCIAL IMPLICATIONS

According to Triay and Wood (2021), cooperative board games successfully bring groups together and create a sense of togetherness. They provide opportunities for players to immerse themselves in a theme while also encouraging collaborative problem solving. Because 'The Sun Trap' is a board game, it suggests that it will work well in schools, allowing students to work in groups and use their problem-solving skills to provide answers to the questions, while also using competitiveness to evoke these problem-solving skills and bring their knowledge to the forefront, beating the other players. Klayman (online) coincides, stating that board games help children learn important social skills such as waiting, turn taking, sharing, how to cope with loss, making conversation, problem solving, compromising, collaborating, and flexibility. These abilities are important in school-aged children so that they can respond appropriately in social situations both inside and outside the home.
The board game includes questions based on the American curriculum that revolve around the theme of renewable energy. Educating the children through the board game will interactively educate the students on aspects of renewable energy, which may persuade the students to make social changes to help with our real-world problems of pollution and climate change.

ECOLOGICAL / SOCIAL IMPLICATIONS

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# Materials

For the main carcase of our product, we will use wood. Due to one of the main factors of our specification being the environmental impacts of our product we have decided to use a man-made board due to their nature of being created from scrap parts of wood etc. From this we picked out the most important factors a wood material will need for our product, and we created a weighted objective table to decide the most suitable material to use.

**Weighted Objectives Table**

Ranked 1-5
1=Poor
5=Excellent

| | | Materials | | | |
|---|---|---|---|---|---|
| **Factor** | **Weight** | **MDF** | **Plywood** | **Chipboard** | **Blockboard** |
| Durability | 0.3 | 3 | 4 | 3 | 5 |
| Strength | 0.3 | 5 | 5 | 4 | 4 |
| Availability | 0.1 | 4 | 5 | 4 | 4 |
| Finishes | 0.1 | 3 | 3 | 1 | 1 |
| Cost | 0.2 | 4 | 4 | 3 | 2 |
| **Total** | **1** | **3.6** | **4.3** | **3.2** | **3.6** |

The results from this table show us that Plywood will be the most suitable material for our model due to its strength, durability factors etc outweighing those of other possible options, Plywood will be used for suitable areas of our final model.

Another main material type for our product will be plastics, once again due to the key idea of sustainability being highlighted throughout our group will only look are thermoplastics due to their ability to be recycled opposed to thermoset plastics that due to them 'curing' once subjected to heat are much more difficult to be recycled.

| | | Materials | | | |
|---|---|---|---|---|---|
| **Factors** | **Weight** | **PE** | **PVC** | **PS** | **ABS** |
| Strength | 0.2 | 4 | 5 | 4 | 4 |
| Durability | 0.3 | 4 | 4 | 4 | 4 |
| Sustainability | 0.3 | 1 | 1 | 1 | 3 |
| Cost | 0.1 | 4 | 1 | 3 | 2 |
| Ease of Manufacture | 0.1 | 1 | 3 | 3 | 4 |
| **Total** | **1** | **2.8** | **2.9** | **2.9** | **3.5** |

The results from this table show us that ABS is the most suitable and effective material that we can use for our product as it ranks highest withing the table. ABS can also be painted or comes in arrange of colours so it can meet any aesthetic standards that we choose for our product.



Ranked 1-5
1=Poor
5=Excellent

# Manufacturing / Finishes

The wooden parts of our products will be hand made using hand/power tools and machines within workshops. Our wooden products will however be finished with a paint to increase aesthetic factors and then a varnish over the paint to increase durability/finish. Research into suitable paints/varnishes will need to be undertaken.

**Paints**

Paint is a product that traditionally has a background attached to it of toxicity and harmfulness for both people and the environment itself. When choosing a paint to be used, knowing the wanted quality and use of the paint is effective, due to mass production etc it would be ideal to spray paint our product, this is due to the overall size of our product and the finish that we will be able to get when using spray paint on a product.

**Varnish**

The wooden objects of our product will need to have a protective coat added once the paint has been applied. This finish will be varnish, the main two types of varnish applied could be acrylic varnish or polyurethane varnish. Due to polyurethane being a harder wearing varnish that will be more durable and have an overall harder surface texture applied this outweighs acrylic varnish that is less durable and will wear in less time than the polyurethane counterpart.

However, like paint varnish also has a background of having toxic to human properties and we will need to use the water-based version of polyurethane opposed to the oil based as the oil based has toxins , whereas water based does not and will also dry quicker making the whole process quicker.

Polyurethane varnish comes in three different finishes being gloss, matt and satin, we have opted to use gloss to give a more aesthetically pleasing look to the final ‘Sun Trap’ model.

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When creating our plastic parts such as the house and the tunnels there are many types of processes, we can use that are suitable with the use of ABS, some of these being injection moulding, 3D printing, vacuum forming and pressure forming. Due to the size of our plastic parts being small and intricate we can initially rule out vacuum forming as it is used for larger products with less details and with thinner walls etc.

When debating between injection moulding, 3D printing and pressure forming all three processes can create extremely intricate and detailed products with little in-between the three process in terms of this. However, due to the vast time difference between 3D printing and the other two we can initially rule out 3D printing as it less beneficial when it comes to the mass production of our product. There are then little difference between the two processes however injection moulding has a slight advantage in terms of the finish produced so due to this injection moulding will be the process of choice.

# Bill of Materials

The bill of materials was created using information from both 2509612O, who used electronics, and 2466515R, who refined materials based on our final prototype.

**The Game Card Material**

As a group, we decided to use paper with a stiffener coating to make the cards last longer; while this is not sustainable, it is a low-cost, lightweight, and recyclable option.

| Material | Part Name |
|---|---|
| Plywood | Board Game Carcase (Base) |
| ABS ( Acrylonitrile butadiene styrene) | • House Component<br>• Tunnels |
| Steel Grade 25 | Ball |
| **ELECTRONICS MATERIALS** | |
| U1 | OrangePip Arduino Uno. |
| R1 | 10000 Ω Resistor. |
| R2,R3 R4,R5 | 250 Ω Resistor. |
| D1, D2,D3,D4 | Green LED. |
| FR1 BAT1 | Force Sensor. |
| BAT1 | PHOTO VOLTAIC CELL. |
| **Game Cards** | |
| Paper | Game Card |
| Paper Stiffener | Game Card Adhesive |
| **FINISHES** | |
| Spray Paint | Carcase |
| Gloss | Carcase |

# Cost Estimates

Estimated high/low purchase prices based on materials

| Component | Quantity | Low Price ($) | High Price ($) | Total Low ($) | Total High($) |
|---|---|---|---|---|---|
| Board Game Carcase (Base) | 1 | 4.00 | 10.00 | 4.00 | 10.00 |
| House | 1 | 2.49 | 5.99 | 2.49 | 5.99 |
| Tunnels | 4 | 1.00 | 3.99 | 4.00 | 15.96 |
| Ball | 1 | 0.20 | 0.30 | 0.20 | 0.30 |
| OrangePip Arduino Uno | 1 | 5.99 | 11.00 | 5.99 | 11.00 |
| 10000 Ω Resistor. | 1 | 0.09 | 0.60 | 0.09 | 0.60 |
| 250 Ω Resistor | 4 | 0.34 | 3.44 | 1.36 | 13.76 |
| Green LED. | 4 | 1.27 | 2.57 | 5.08 | 10.28 |
| Force Sensor. | 1 | 4.95 | 5.65 | 4.95 | 5.65 |
| PHOTO VOLTAIC CELL.. | 1 | 1.30 | 3.50 | 1.30 | 3.50 |
| Game Card | 40 | 0.09 | 0.11 | 3.60 | 4.40 |
| Game Card Adhesive | 1 | 5.27 | 6.99 | 2.99 | 5.87 |
| | | | | | |
| Assembly Costs $11/HR | | 30 minutes | 2 hours | 5.50 | 22 |
| Board Game Direct Costs | | | | 32.05 | 87.3 |
| Overhead @ 25% of Direct Costs | | | | 8.01 | 27.7 |
| Total Costs | | | | | 109.1 |
| Average Total Cost | | | | | $77 |

Estimated high/ low priced are provided by Amazon.com
Average hourly rate provided by PayScale (2021)

# THE SUN TRAP

# INSTRUCTION MANUAL

## OBJECT OF THE GAME

Be the first player to answer all questions correctly, and turn the lights on in the ***SUNTRAP!***

Use your knowledge of renewable energy and race your friends in a bid to be crowned ***SUNTRAP*** champion!

## CONTENTS

1 Gameboard - 10 Marbles

1 Re-movable game section

1 Marble catcher

50 Question cards - 4 Winners cards

1 Locking pin - 1 Set of electronics

1 Instruction manual


## HOW TO PLAY

1. Slide the marble catcher onto the corner of the game (where the hole is).
2. Shuffle the question cards.
3. Place a question card in each of the slots in the tunnels, the last slot (closest to the house) should also have "the winners card" placed behind the question card (both in the same slot).
4. The youngest player starts the game by flicking their marble through the sun and into the tunnel.
5. The player then draws the first question card out of the first slot.

- ⇒ Question answered correctly - play moves on to the player on the left.
- ⇒ Question answered incorrectly - a new question card is inserted into the first slot then play moves on to the player on the left.

6. The game continues until a player answers the final question correctly, this player can now remove their "winners card" and allow the marble to roll into the house, lighting it up, and claiming victory!

2481078M




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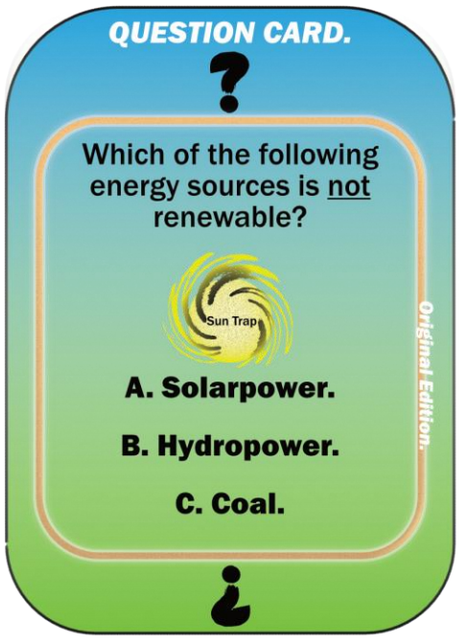
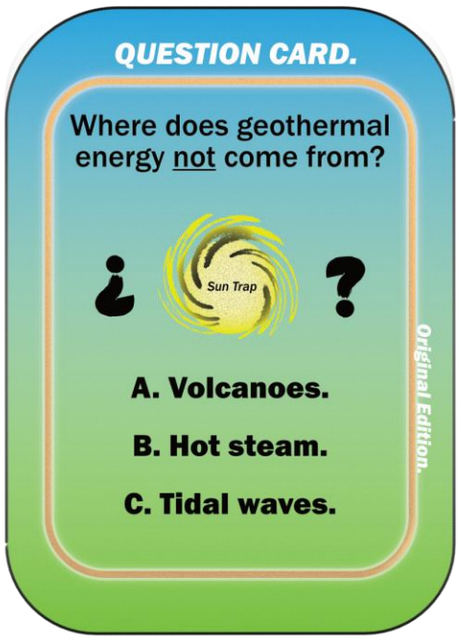
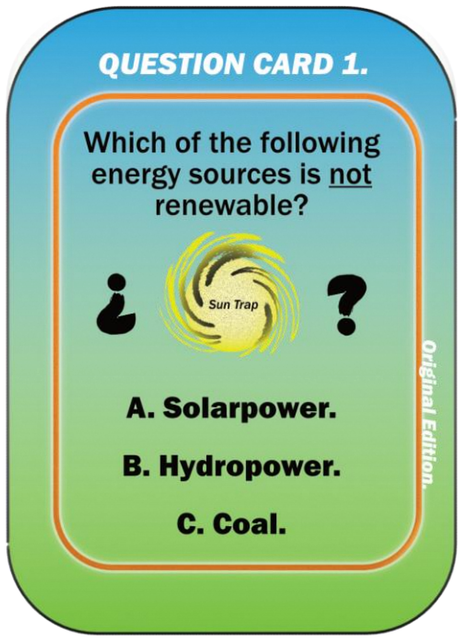
**Question types** are based on game design theorems and user experience studies, Csikszentmihalyi, M et al. (2009), Tekinibas, K.S and Zimmerman, E. (2003, 2004, 2005,2008).

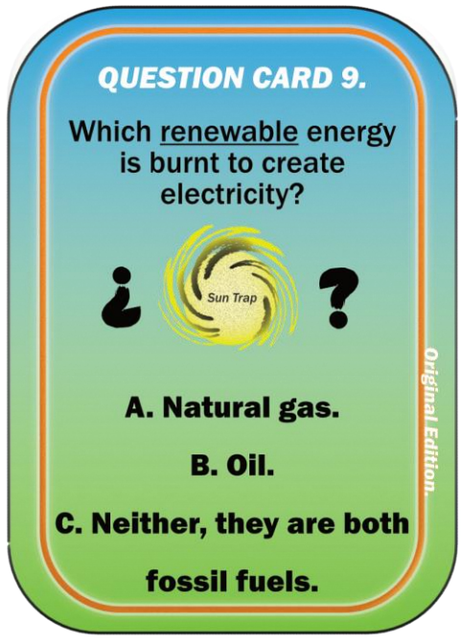
**Question content** is based on (Scotland CfE 2020,2022 USA curriculum 2019, Irish Curriculum 2016, Australian Curriculum 2018, 2020).

**Final Designs.**

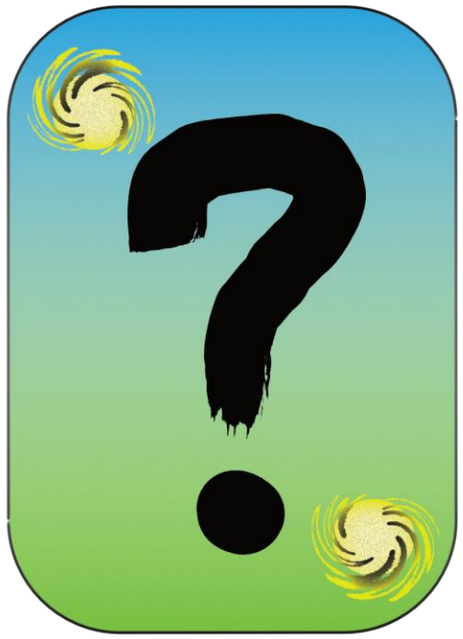


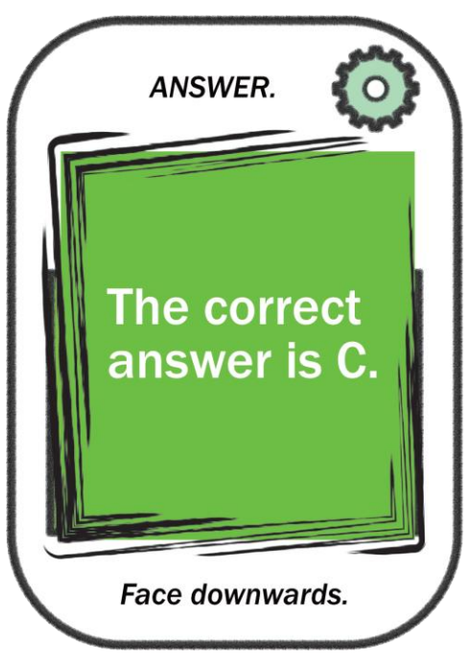




**Rear Plan View.**



**Plan View.**

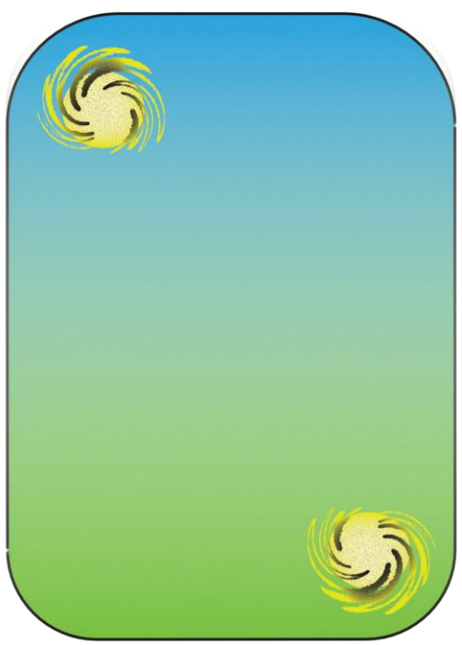

**Rear Plan View.**




**Answer Card Set.**

**Plan View.**

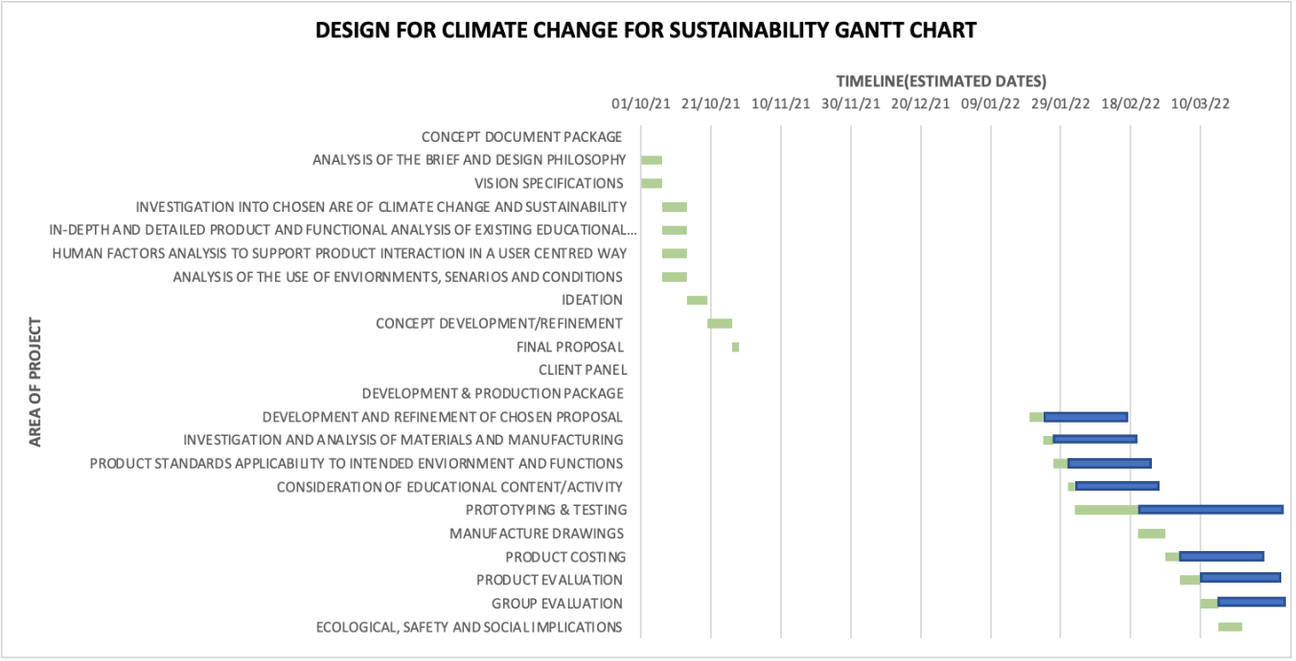

**Rear Plan View.**



**Plan View.**


**Winning Card Set.**

2509612O.




**Impact of COVID -19 on our work ethic?**

Because of COVID – 19, we had to spend the majority of third year socially distancing and primarily meeting on Zoom. Our group communication suffered because of the lack of weekly face-to-face meetings. Despite when Clyde College allowed us to work on the final prototype, which motivated us to meet the deadline.

**Problems with prototyping**

We ran into issues with the 3D Printing software while creating the final prototype. Originally, the plan was to 3D print the model at Clyde College, but the 3D printer broke while printing the components. As a result, we underestimated the time required for prototyping. We also had issues with electronics; we initially had all the electronics working, but one of the batteries died before we could complete the circuit, adding more time than we had anticipated. This caused following tasks that where dependent on the prototype completion. This was also a prediction in the DSM.

**How can we improve our Teamwork?**

The main one is to communicate more! Obviously, covid hindered our communication, but hopefully in the future, during collaborative work, there will be fewer social distancing measures and the university will have more frequent weekly face-to-face classes.

**FULLY DEVELOPED SPECIFICATION**

Requirements for the Target User:

**Target User**

T1.1 Pupils aged 6 to 11 who are studying climate change, with a focus on renewable energy.

T1.2 Teachers who are instructing the students.

**Function**

F2.1 The educational product's primary function is to give students with a clear way of thinking about climate change.

F2.2 The product should facilitate interactive learning between peers.

F2.3 The product must be strong but lightweight to reduce the risk of damage while increasing safety factors.

F2.4 To meet all safety requirements, the product must have no sharp hazards or edges.

F2.5 The product must be easy to clean to ensuring no dust affects the conductivity of the electrical elements.

**Ergonomics**

E3.1 Sizes in the 50th percentile must be configured in the product.

E3.2 To demonstrate hand placement, there must be an area indicating where students can use the mechanism to make the product work.

E3.3 Students must be able to engage with the product through buttons or mechanisms.

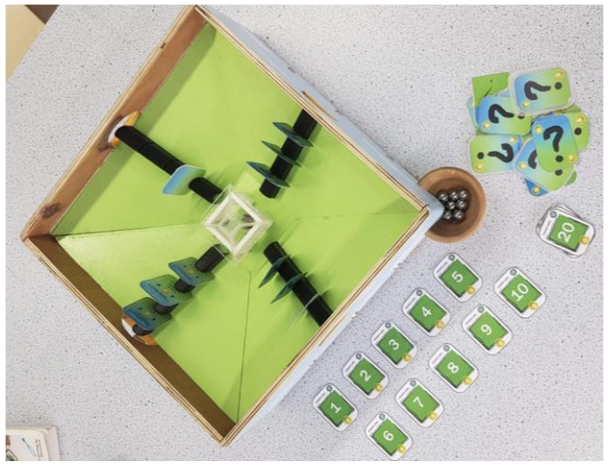
E3.4 The product must be lightweight, to be moved and stored with ease.

**Aesthetics**

A4.1 The colour palette should be related to climate change and renewable energy.

**Environmental Considerations**

**E5.1 E**nvironmentally friendly/ Sustainable materials used throughout



**If we had to change/improve the design or our decisions**

Overall, we felt that in the end, we were primarily focused on the design's manufacturing/prototyping process and evaluated that we could have paid more attention to minor details such as the LED mechanism, where we could have chosen a yellow LED to mimic the sun as the game is titled 'The Sun Trap.' Although this is a minor detail, it provides students with another form of feedback that ties the entire game together. This could have been changed, but due to the above-mentioned prototyping errors, we were time-constrained. As a team, we conclude that it is an effective model that provides the overall functionality for the intended users.

# The Sun Trap

**T1.1 & T1.2**As a design team, we were successful in developing an interactive form of learning for children aged 6 to 11 in the classroom. The board game is based on the renewable energy concept. The goal of the game is for the students to answer a question from a deck of cards, and if they do, they get to roll the marble down the tunnel, turning on the light and winning the game. We believe we incorporated the students' needs in **the hierarchy of needs**, in conjunction with the specification.

**F1.1,F1.2 & F.3** The prototype uses question cards to interactively converse between peers and provides them with additional information about renewable energy through the questions and curricula they are assigned from. When the pupil has won the game, i.e., correctly answered the question, the led in the centre of the lighthouse illuminates.

**E3.1 &E3.2 & E3.3**The game card sizes will universally fit everyone's hand sizes, with dimensions that fall within the 50th percentile. On each side of the board, a semi-circle is cut out to indicate to the pupil where the marble mechanism is inserted.

**A4.1** The overall colour scheme of the model is greens and blues, which represent the idea of renewable energy and sustainability. The colours are also bright, keeping in mind that the product is intended for use by elementary school students. It also allows the children to connect these colours to these topics at hand.

**E3.4 &E5.1** The primary material is plywood, which is used to reflect the boardgame's sustainability factors. The game cards are light in weight and limited to the 50th percentile, making them easy to hold for everyone.

## GROUP & FINAL PROTOTYPE ANALYSIS /EVALUATION.

# The Sun Trap.

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