# ESC101 Design Report

Group 25 - Beckett Deschamps[1], Mike Liu[1], Luyu Vankerkwijk[1] ,Yang Wang[1]
[1]University of Toronto Faculty of Engineering, Engineering Science

---

Word Count : 2958

# 1. Introduction

Bananas are a convenient source of nutrition for Engsci students, but there are many inconveniences when peeling them. Students often consume food during lectures due to the lack of breaks in the first year engineering curriculum. However, bananas can leave pulp residue on student's hands, interfering with the use of laptops and writing utensils. Since students may have issues leaving class in lectures to clean hands, this causes inconvenience in their daily lives.
Additionally, some less ripe bananas are harder to peel causing students to struggle with the peeling process. Therefore, a portable banana peeler that can reduce residue and minimize peeling force is a practical and valuable engineering design opportunity.

## 1.1 Stakeholders

**Primary stakeholders:**

- Engsci students: This design opportunity is all about addressing the inconvenience and lack of cleanliness of students eating bananas.

**Secondary stakeholders:**

- Cleaning staff: Fruit pulp residue increases difficulty of cleaning work.
- Campus administrator: Pulp may damage sensitive electronic devices such as keyboards and screens, increasing maintenance costs.

## 1.2 Identifying Primary Stakeholder Needs and Requirements

EngSci students need a clean, quick and convenient way to open bananas that they can take to class. Banana peeling can be messy, as seen in Figure 1. When peeling bananas, EngScis cannot have pulp on their hands as they have to use their hands on laptops, tablets, and papers. These may be damaged because of the sticky and slimy nature of the pulp. EngSci students must also walk across campus to different lectures and tutorials while carrying backpacks, therefore the design must be portable.

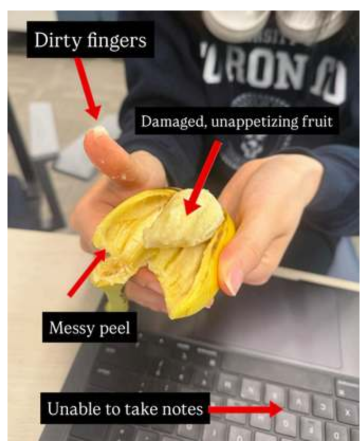



Figure 1.2.1: Image showing messy hands following banana peeling process. Extracted from original design report.

## 1.3 Determining Goals and Objectives

Below is a goals and objectives table modified from the original design brief:

| Goals and Requirements | Metric | Testing method | Equipment | Justification |
|---|---|---|---|---|
| **Goal 1: The method can peel most bananas.**<br><br>Requirement 1.1: The method can open bananas with peel thicknesses between 2.5mm and 4.0mm. | Peel thickness (mm) | Calipers are used to measure the peel thickness at 3 points along the length of each banana. The same caliper is used on 5 bananas of varying thickness. | Calipers | The multiple measurements accounts for the typical variation of bananas from thickness 2.5-4.0mm [1]. Verifies each design can be successful on a range of banana peel thicknesses |
| **Goal 2: The method does not get the users' hands dirty.**<br><br>Requirement 2.1: The user's fingers must not touch the inside fruit with force which adheres residue to the user.. | Contacts hand (boolean) | Peel bananas using gloves and record any residue left on the glove. | Gloves and scale | The use of gloves allows for testing if the pulp came into contact with the hands of the user. |
| **Goal 3: If the method requires physical objects, they must be portable.**<br><br>Requirement 3.1: Any physical parts should combine to a total mass of less than the average weight of a banana, 126g. [1] | Mass (g) | The weight of the tool can be measured by weighing it with a scale. | Scale | Ensures that the portability can be tested and met. It would be impractical to carry around tools that weigh more than the banana. |

| | | | | |
|---|---|---|---|---|
| Requirement 3.2: The volume should not exceed the average volume (~120 $cm^3$) of an average banana. [1] | Volume ($cm^3$) | Wrap each design in plastic wrap then submerge in a beaker with a known volume of water. The change in volume of water is the volume of the tool. | Plastic wrap, Beaker, and Ruler | The specific number is chosen to reflect the tool's use (see Requirement 3.1). This method works for the irregular shapes, in addition the plastic wrap ensures that the designs are not damaged by the water. |
| **Goal 4: The method does not threaten the user or bystander's safety.**<br><br>Requirement 4.1: All contacting surfaces involved in the method not contain unsafe compounds as specified in GHS Rev. 10e. [2] | Safe (Boolean) | Food safety will be tested by investigating GHS food safety of all materials used. If any are listed as food unsafe, they must not contact the banana. This will ensure compliance. | Research | This requirement was chosen to satisfy food safety regulations. |
| Requirement 4.2: All contacting surfaces involved in the method with internal angles of 135° or less must have a minimum radius of 3 mm. Sharp corners (<90°) must be avoided. [3] | Angle in degrees | Measure internal angles with protractor | Protractor | Ensures safety and cleanability. |
| Requirement 4.3: In storage, any elements with edges of BSI (blade sharpness index) < 0.5 used on the tool must be concealed with openings of width less than 10mm. | Opening width (mm) | Measure the width of openings which conceal blades using a caliper. Verify an adult finger simulated as a 10mm diameter dowel cannot contact the blade when stored. | Calipers | Prevents accidental cuts. 10mm dowel simulates the least average finger width found. [4] |

| | | | | |
|---|---|---|---|---|
| | | | | |
| **Goal 5:** The method allows users with varying physical abilities to open a banana independently.<br><br>Requirement 5.1: The method should not require more than 100N of force from the user to open the banana. | Force (N) | The most significant force will be the only one measured (i.e., the pushing force for a tool and not the force for holding). Additionally, only investigate the highest force required.<br><br>This will be done measuring the critical leverage weight to start the motion of the tool. | Newton Scale | The peak force simulates the actual force the user must apply. Combined tool weight and operational force gives total user effort.<br>96N is calculated as the minimum in the range of pushing strengths observed. [5] |
| **Goal 6:** The method allows for quick and convenient access to the banana pulp<br><br>Requirement 6.1: The method should not require the user to spend longer than 13s opening the peel.[1] | Time (s) | Average the time of 3 trials using a stopwatch from the beginning to the end of the attempt to peel the banana.<br>A "peeled banana" is defined to be so that the pulp is accessible to eat | Stopwatch | Taking much longer than the time it takes to peel a banana by hand is unlikely to be appealing to EngSci students who are very busy. We must therefore quantify how much time a concept should take at most. |

# 2. Design Concepts

Three design concepts and the null design were chosen to address the splartz. Details of CTMF processes used to diverge and converge to the final design concepts may be found in Appendix B.

## 2.1 Rolling Clip

The Rolling Clip concept is a 20 cm long device which is split into three parts, the handle, the neck and the blade. The blade has an angled design as seen in Figure 2.2.1, which reduces the force to peel from the non-stem end (see Appendix A).

[1] This specific number is chosen based on averaging the time it takes students to peel a banana by hand. This is such that the user does not get frustrated by the tool.

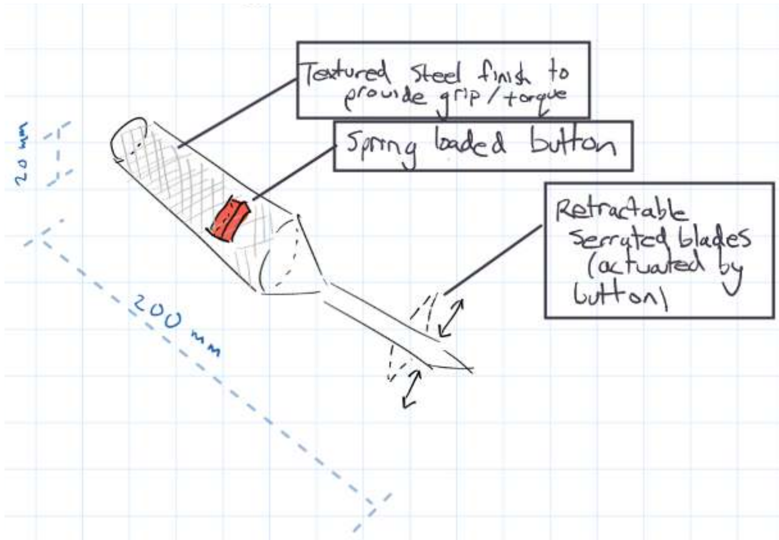



Figure 2.2.1: Sketch of Rolling Clip. The retractable blades were not included in the prototype.

The user inserts the tip of the blade of the Rolling Clip into the head of the banana, then applies torque to roll the banana peel off. A demonstration of this process can be found in this video.

Figure 2.2.2: Clip from video using rolling motion to peel banana. This was a proxy device as the geometric prototype was unable to complete the motion.

## 2.2 Hand Blender

The Hand Blender concept blends the banana into a drinkable smoothie using the peel of the banana as a cup. The design involves a 9V battery hooked up to a switch and motor with a whisk on the end. A handle gives the user fine grained control over the blending.

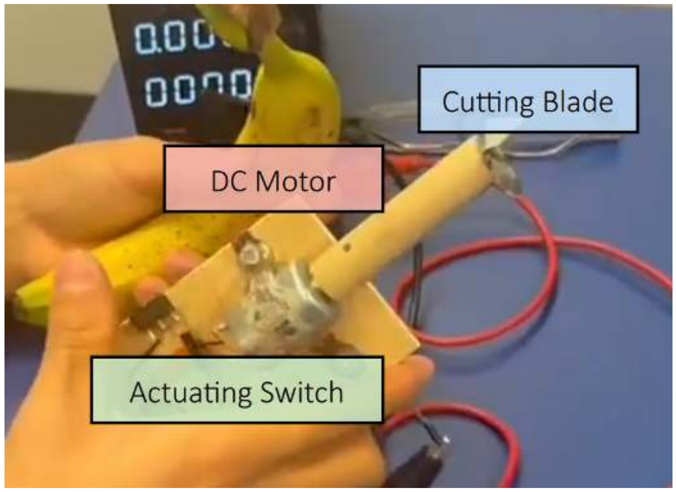



Figure 2.3.1: An image of the Hand Blender prototype in use.

The user punctures either end of the banana then activates the motor once it is inside the peel and sucks on the straw to drink the pureed pulp. A video of blending the banana can be found here, while a video of cutting open the banana can be found here.

## 2.3 Banana Corer

The *Banana Corer* operates similarly to an apple corer. It incorporates a cutting mechanism that slices the peel along the banana, allowing the user to eat the banana by pushing on the ends of the peel as seen in this video. The *Banana Corer* is a hollow cylinder with an outer diameter of 45 mm, inner diameter of 40 mm and a length of 30 mm. The three internal blades cut the peel and some of the flesh, allowing the peel to easily come off. The stainless steel blades are 30 mm long and 10 mm tall to minimize the amount of cut up flesh. That ensures the pulp does not spill onto the hands.

Figure 2.4.1: Picture of Banana Corer being used (left) and inner structure (right)

# 3. Comparison of Ideas

In this section, we compare the design concepts using converging tools to select the most optimal solution.

## 3.1 Pairwise Comparison

Below is a pairwise comparison table our group completed. Here, each vertical column represents the con design while the horizontal column represents the pro design. The number in each cell represents the number of topics that the pro design lost to the con design in.

| | Banana Corer | Rolling Clip | Hand Blender | Hand Peeling | Total |
|---|---|---|---|---|---|
| Banana Corer | | 2 | 2 | 2 | 6 |
| Rolling Clip | 1 | | 1 | 2 | 4 |
| Hand Blender | 3 | 4 | | 5 | 12 |
| Hand Peeling | 1 | 2 | 1 | | 4 |

While we did not find the numbers useful in converging, it brought up a number of specific concerns with the designs. For instance, safety was brought up as a large concern for the Hand Blender.

## 3.2 Critical Metrics

Following the pairwise comparison, we established critical metrics related to our objectives. These are based upon our identified objectives, as well as discussion in the pairwise comparison.

Evaluation Criteria

1. Tool Volume (lower is better) - Improves Portability
2. Tool Mass (lower is better) - Reduces force required to operate
3. Time to Open (lower is better) - Improves convenience for the user to consume the banana
4. Mass Loss (lower is better) - Quantifies cleanliness
5. Number of Components (lower is better) - Correlates to reliability, ease of cleaning, and manufacturability
6. Force Required (lower is better) - Quantifies Accessibility

## 3.3 Defensible Testing Protocol for Metrics

In this section, we describe testing protocols used to find values for each of the evaluation criteria. These were limited by the tools available to us, and thus differ from what is listed in the objectives table or use proxy methods. Weight was found using a kitchen scale, while the number of parts was assessed visually.

### 3.3.1 Volume of Tool

The prototypes were simplified into basic shapes. The volume is then found through measuring the prototypes using a caliper, then calculating the volume.

### 3.3.2 Peeling Force

The peeling force was found by counting the number of hands placed on the tool before the tool started to cut/peel the banana. The hands are all an arms length away so there is a constant moment. Assuming the weight is proportional to force, we find the force. This provides a decent approximation for the actual force applied by the user's hands during use.

### 3.3.3 Measuring Banana Residuals

Banana residuals is a proxy measurement for the cleanliness of the tool. We measure it by using objects in the video as references (for instance, the typical length of a banana is approximately 180mm) to estimate the area of the residue. We assume its thickness to be between 1~4 millimeters since the residue is irregular, then calculate its approximate volume. As the residue found on the table correlates to the residue on the user and the tool, this is a valid proxy.

### 3.3.4 Time to Peel

The time to peel was measured by allowing each person in the group to peel the banana using the tool and averaging the three trials.

## 3.4 Measurement Matrix

Following the finalized procedure, we obtained data for all design concepts as well as the original design.

Table 3.4.1: Measurement matrix.

| | Banana Corer | Rolling Clip | Hand Blender | Peeling by Hand |
|---|---|---|---|---|
| Weight (g) | 26 | 20 | 91 | 0 |
| Volume of Tool ($cm^3$) | 10 | 33 | 62 | 0 |
| Average time to peel (s) | 5 | 9 | D.N.F[2] | 6.5 |
| Peeling Force (N) | 25 | 25 | 0 | 37.5 |
| Number of Parts | 2 | 3 | 6 | 0 |
| Mass Lost ($mm^3$) | ~200 | ~800 | ~15000 | ~300 |

## 3.5 Pugh Chart

Below, we draw several Pugh charts comparing our design concepts. Each one compares to a different baseline so common shortfalls and advantages can be identified. An orange spot means the two concepts are equal, green means the other design does it better and red means the other design does it worse.

Table 3.5.1: Peeling by Hand as Reference.

| | Banana Corer | Rolling Clip | Hand Blender | Peeling by Hand |
|---|---|---|---|---|
| Weight | - | - | - | = |
| Volume of Tool | - | - | - | = |
| Time to peel | + | – | - | = |
| Peeling Force | + | + | + | = |
| Number of Parts (cleanability) | - | - | - | = |
| Mass Lost (Dirtiness) | + | - | - | = |

Analyzing the pugh chart with peeling by hand as a reference, we see that most other designs are worse with our criteria. Their subpar performance it is hard to beat the convenience of using one's hands. However, the other prototypes do have a lower peeling force. Therefore the tools are better for DFUsability and DFAccessibility.

[2] Prototype was able to cut the peel within 30s, but could not blend the flesh.

Table 3.4.2: Hand Blender as Reference

| | Banana Corer | Rolling Clip | Hand Blender | Peeling by Hand |
|---|---|---|---|---|
| Weight | + | + | = | + |
| Volume of Tool | + | + | = | + |
| Time to peel | + | + | = | + |
| Peeling Force | - | - | = | - |
| Number of Parts (cleanability) | + | + | = | + |
| Mass Lost (Dirtiness) | + | + | = | + |

The Hand Blender only wins in peeling force because it's a power tool. However, due to its lackluster performance in other criteria, it is not a good solution.

Table 3.4.4 Rolling Clip as Reference

| | Banana Corer | Rolling Clip | Hand Blender | Peeling by Hand |
|---|---|---|---|---|
| Weight | - | = | - | + |
| Volume of Tool | + | = | - | + |
| Time to peel | = | = | - | + |
| Peeling Force | = | = | + | - |
| Number of Parts (cleanability) | + | = | - | + |
| Mass Lost (Dirtiness) | + | = | - | + |

The Rolling Clip is inferior to the Banana Corer in every criteria except weight, which is lesser by 6 grams.

Table 3.4.3: Banana Corer as Reference

| | Banana Corer | Rolling Clip | Hand Blender | Peeling by Hand |
|---|---|---|---|---|
| Weight | = | + | - | + |
| Volume of Tool | = | - | - | + |

| | | | | |
|---|---|---|---|---|
| Time to peel | = | - | - | - |
| Peeling Force | = | = | + | - |
| Number of Parts (cleanability) | = | - | - | + |
| Mass Lost (Dirtiness) | = | - | - | - |

While the Banana Corer beats the other design concepts in most categories, it still has significant shortcomings. It is still less convenient than using hands, which corresponds with hands winning in the weight and volume categories. These may be acceptable trade-offs as it still adheres to the requirements for weight and volume. Overall, this design concept is viable, and with further iteration could be a good candidate for this splartz.

# 4. Recommended Design: Null Case

After completing testing of all the prototypes and analysis using provided tools (Pugh chart, measurement matrix, pairwise comparison), we settled on the null case. We believe the original solution of hand peeling bananas to align most with stakeholder needs.

## 4.1 Rationale

Looking at the measurement matrix, we observe that peeling by hand outperforms all the other prototypes based on the evaluation criteria. Firstly, it is tool-less, meaning mass of 0 g and a volume of 0 $cm^3$. This is in comparison with the Banana Corer (26 g, 10 $cm^3$) the Rolling Clip (20 g, 33 $cm^3$) and Hand Blender (91 g, 62 $cm^3$). Meanwhile, the mess caused by the tools, the main issue plaguing EngScis, is oftentimes worse than peeling by hand (see Table 3.4.1). The only tool which was marginally less messy was the Banana Corer. The additional messiness caused by the Rolling Clip and Hand Blender immediately eliminated these as potential options.

Choosing between the Banana Corer and the null design, we qualitatively decided that while the corer does improve upon the reference design in three of our measured criteria, the trade-off was not appealing to any of us. Gains of 50% in peeling force, 50% in cleanliness and 30% gains in peeling time were not enough to justify bringing the tool to classes. The major issue is that these tools are all extremely specialized, making it unlikely that anyone will carry a tool only to peel bananas. Even with these extremely light and compact designs, the hassle of getting a tool everyday to do a task marginally better is not worth it.

Overall, combining our observations from the measurement matrix and Pugh charts, we select our null case, hand peeling, as the best option. Sometimes, convenience trumps all, even a better product.

## 4.2 Design Decisions of the Banana Corer

The leading design following the null case was the Banana Corer. As such, we present the key design decisions in the Banana Corer that may help further iteration in the future.

First, the blades have a 45° slant, as seen in Figure 4.2.1, which cuts the banana gradually instead of attempting to the full blade height at once. This reduces the peeling force needed which makes the design more accessible than peeling by hand.

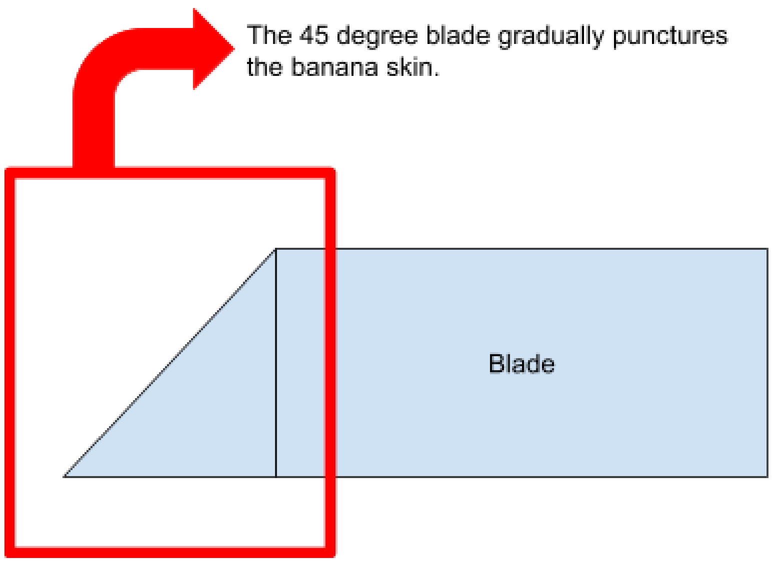



Figure 4.2.1: 45° Blade

Secondly, the tool has 3 stainless steel blades that are 10 mm high. The blades need to be much larger than the average peel thickness of 4 mm because bananas have variable thickness [6]. The larger blades ensure that the skin will come off for thinner and thicker bananas.

Lastly, the width of the tool was 40 mm because the maximum banana thickness is around 43 mm [6]. We decided that it was impractical to attempt to go for all banana sizes, so we cut it off at the nearest pipe size, 40 mm. This also meant the blades could be shorter which means less material use and a smaller torque on the blade, reducing the chance of a blade breaking off.

# 5. Citations

[1] R. P. Kachru, N. Kotwaliwale, and D. Balasubramanian, "Physical and mechanical properties of Green Banana (musa paradisiaca) fruit," Journal of Food Engineering, vol. 26, no. 3, pp. 369–378, Jan. 1995. doi:10.1016/0260-8774(94)00054-d

[2] United Nations, Globally Harmonized System of Classification and Labelling of Chemicals, 10th edition, 2023

[3] "EHEDG: Guideline Catalogue," Ehedg.org, 2025. https://www.ehedg.org/guidelines-working-groups/guidelines/guidelines/guidelines/guidelines/detail/hygienic-design-principles

[4] A. C. Zoeller and Knut Drewing, "A Systematic Comparison of Perceptual Performance in Softness Discrimination with Different Fingers," Attention, Perception, & Psychophysics, vol. 82, no. 7, pp. 3696–3709, Jul. 2020, doi: https://doi.org/10.3758/s13414-020-02100-4.

[5] Human strength - roy mech, https://roymech.org/Useful_Tables/Human/Human_strength.html.

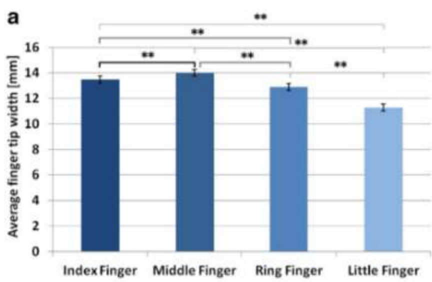
[6] R. P. Kachru, N. Kotwaliwale, and D. Balasubramanian, "Physical and mechanical properties of green banana (Musa paradisiaca) fruit," *Journal of Food Engineering*, vol. 26, no. 3, pp. 369–378, Jan. 1995, doi: https://doi.org/10.1016/0260-8774(94)00054-d. Available: https://www.sciencedirect.com/science/article/abs/pii/026087749400054D

# 6. Source Extracts

[1] *153·39% (db) and 516·41% (db), respectively for Nendran. At these average moisture contents, the average pulp to peel ratios were 1·39 and 2·32, and peel thickness were 3·65 mm and 2·95 mm, respectively. The*

[3] "All easy to clean surfaces must be smooth and free of imperfections (e.g. crevices and cracks) to prevent harbouring of microorganisms and other residues, therefore:
- All internal angles of 135° or less shall have a minimum radius of 3 mm. Sharp corners (
90°) must be avoided."

[4]




[5]

| Sex | Mean (Nm) | S.D (Nm) | Range (Nm) |
| --- | --- | --- | --- |
| Male | 457,22 | 99,37 | 290,65 - 543,61 |
| Female | 314,47 | 136,42 | 215,91 - 500,26 |

[6] Physical and mechanical properties of bananas
The physical and mechanical properties of two varieties of green banana fruit, namely, Dwarf Scavendish and Nendran, were determined. The average pulp and peel moisture content were 264.17% (db) and 666.28% (db), respectively for Dwarf Scavendish and 153.39% (db) and 516.41% (db), respectively for Nendran. At these average moisture contents, the average pulp to peel ratios were 1.39 and 2.32, and peel thickness were 3.65 mm and 2.95 mm, respectively. The maximum diameter of fruit without peel was 23.34 mm and 37.08 mm, and average pulp specific gravity was 0.993 and 1.110, respectively for the two varieties. The maximum effective length and width of the banana pulp resting at its most stable position was observed to be 137.0 mm and 66.5 mm, respectively for Dwarf Scavendish and 194.5 mm and 50.0 mm, respectively for Nendran.

# 7. Appendix

## A. Force Calculations for a Rolling Clip

Assuming a the same amount of force $F_c$ is needed to separate the flesh and the peel, then we can calculate the force needed for the Rolling Clip in a simple manner using a torque arm.

Assuming a quasistatic state, the force balanced is defined by $F_A r_{handle} = F_C r_{clip}$. Since the clip's radius is half that of the handle, half the applied force is needed compared to peeling by hand. This may make it easier to peel the banana.

## B. Diverging Processes

Our group employed various effective CTMFs to diverge ideas. At the very beginning, the 6-3-5 brainstorming method was employed to generate as many new ideas as possible, and during the process being passed around, initial ideas are improved.
SCAMPER helps us further manipulate the ideas generated, providing us with unique perspectives to think from and produce better ideas. For instance, it clearly indicates that we need to consider combining two ideas or eliminating the unnecessary parts of the design.
Members also met offline to brainstorm the existing design, generate possible designs, and record improvement suggestions and new design ideas.

# 8. Original Design Brief