MAE 4341/5340: Innovative Product Design via Digital Manufacturing

Team 2 PDS

Jin Bae, Ludia Cho, Mehali Desai, Brandon Feraud-Solorzano,
Xavier Figueroa, Andrew Lin, Iyana McGirt, Noon "Stellar" Son

December 2024

Prof. Robert Shepherd, Prof. Sirietta Simoncini

Table of Contents:

1. **Product Description Executive Summary [Ludia, Andrew, Stellar, Mehali]**
   a. **Team Name and Summary of Participants [Stellar]**
   Team name: Team 2 / Locked-In
   Team Members: Jin Bae, Ludia Cho, Mehali Desai, Brandon Feraud-Solorzano, Xavier Figueroa, Andrew Lin, Iyana McGirt, Noon "Stellar" Son
   b. **Product Name [Stellar]**
   Clippy
   c. **Problem you are solving [Stellar]**
   How might we design a product that fuels efficiency for the everyday small struggles for college students that create a lot of stress?
   d. **Basic Functions of Product to solve problem**
   The product clamps onto the lecture desk and provides an extended surface that students can use. The extended surface can hold objects or provide left-handed students with the same convenience of using the lecture desks as right-handed students.
   e. **Special Features of Product beyond the core problem solution**
   There is "potential" space for switching out the table aspect for other components like a cup and pencil holder. The clamp should be designed to be versatile so Clippy can be attached to multiple different surfaces like an armrest to create a table surface for seats without desks.
   f. **Picture of highest level product refinement (CAD or physical) [Andrew]**

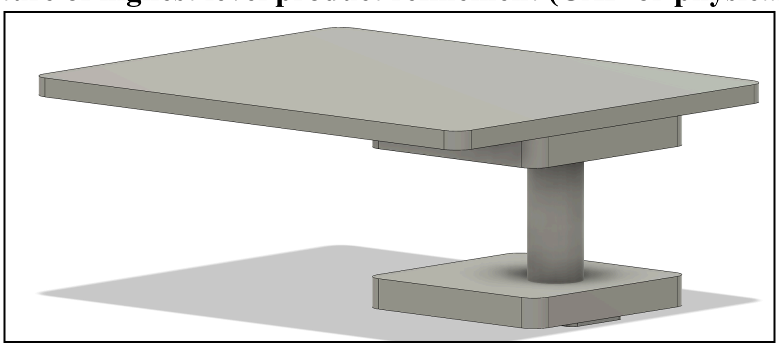


Figure 1: Andrew's Cardboard Prototype CAD

This is a preliminary CAD model of one of our cardboard prototypes. This model was extremely rough as the cardboard was very flimsy, which became confusing for some of the use testers. Some of this confusion arose from the clamping mechanism and desk as the cardboard material did not provide enough structural support to grip onto the lecture desk or hold up school supplies. However, the general purpose of the product was able to be communicated through the screw-on clamp and the desk platform seen in the prototypes.

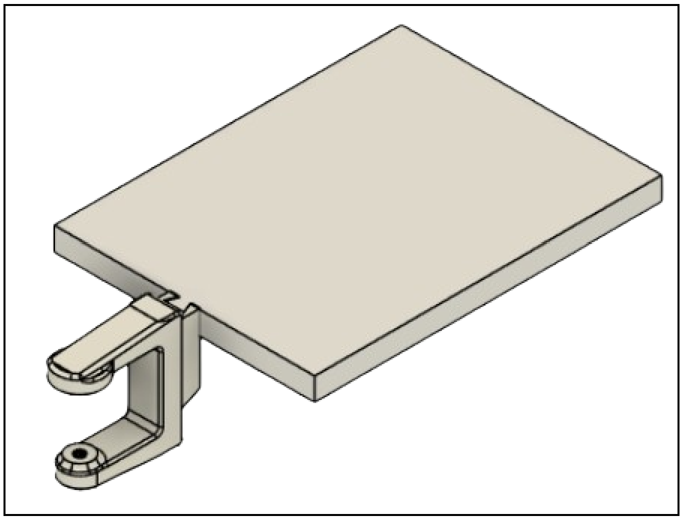


Figure 2: Jin's Prototype CAD

Combining our Design 0, testing results, and conjoint analysis, design one seen in Figure 2 was created which features a screw clamping mechanism and a detachable table component. The screw is meant to only require a couple of rotations before contacting the lecture desk. Many students expressed that they wanted a quick way to attach and detach Clippy. To reach a wider audience the dovetail joint is implemented so the table could be swapped out with other components that some students could find useful. These components include a water bottle holder, a desk extension, and a pencil holder. A flaw in this design is that the clamp is quite large relative to a lecture desk, and the clamp goes on top of the desk. This means that while Clippy allows for an extension, it also takes up space on the lecture desk, making it an inefficient product. In addition, the sharp corners of a dovetail joint can lead to large stress concentration, resulting in the joint snapping off from the table if enough force is applied at the end of the table.

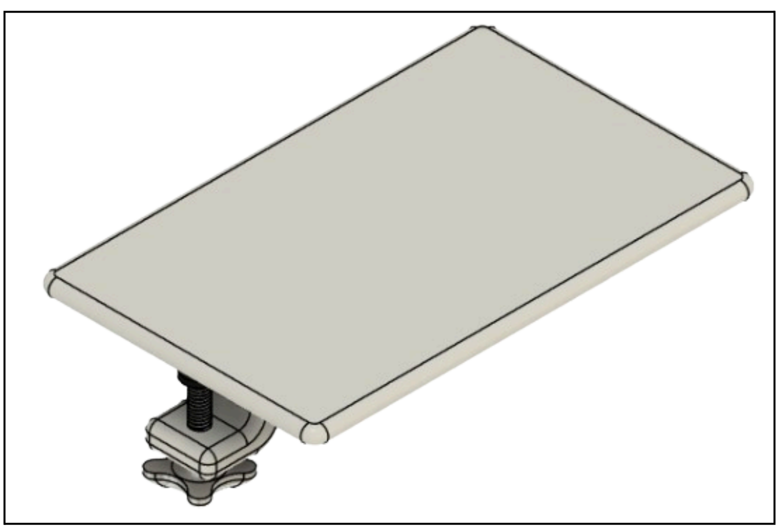


Figure 3: Mehali's Prototype CAD

Figure 3 is an alternative design that features a clamp that goes under the lecture desk. The design has a custom screw to help with ergonomics and also requires a few rotations before making contact with the lecture desk. The flaw of this design is that the table extension will rest on the lecture desk, thus, taking up space on the lecture desk. However, this design was created such that the surface lying on the lecture desk is rectangular, so students can still use it as a surface to place their belongings. Another flaw of this design is that it removes the ability to switch the table out for other components. However, this makes the manufacturing process easier as it can be completed in one print instead of multiple components. The design appears to fail at the point where the clamp is connected to the table if enough force is applied at the end of the table.

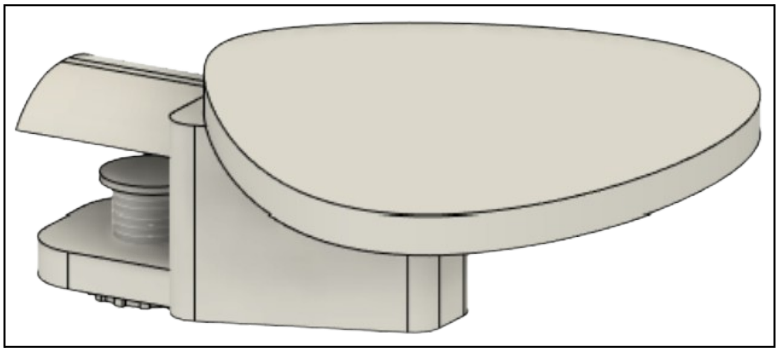


Figure 4: Xavier's Prototype CAD 1

Here is another design iteration of Clippy after Design 0. The product above demonstrates an emphasis on a large clamping mechanism and the utility of modularity in the future. After further research, we chose not to use this design because the large clamp was bulky and uncomfortable to use for the user. From this design, we learned it was important to have a strong clamp that is not overbearing.

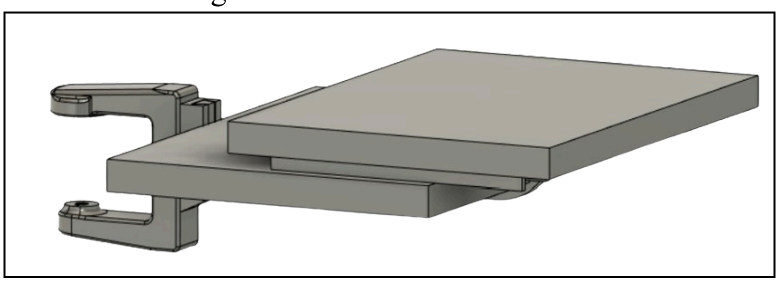


Figure 5: Xavier's Prototype CAD 2

This is one of the modular components that could be incorporated into Clippy using the base design of Figure 3, which features a slidable desk attachment that further extends the lecture desk and Clippy for those who want it to stretch across the width of the lecture seat.

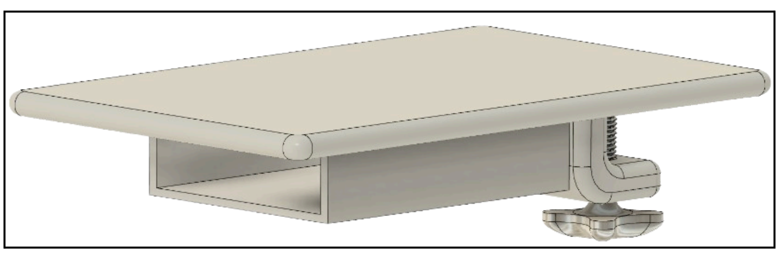


Figure 6: Andrew's Prototype CAD Design

Another component that can be incorporated into Clippy is a drawer, which allows students to store electronics, books, and other school supplies. It can also be used as a storage compartment in student's dorms since Clippy can attach to any flat surface and items can be stored in it. However, we decided to not include this idea for the scope of this project, but it could be implemented further in the future.

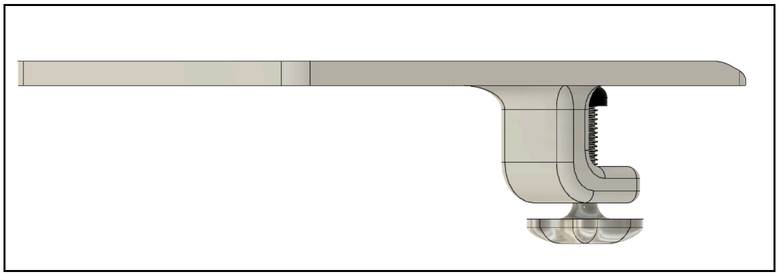


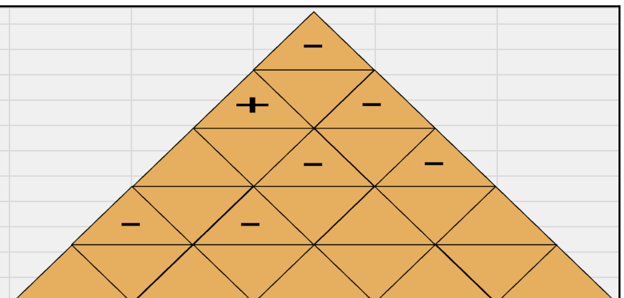
Figure 7: 3D Printed Iteration 2

Figure 7 shows an iteration of Clippy has a ramp near the point of attachment, allowing for a smoother transition from the flat lecture desk to Clippy. It is a redesign of Figure 3. The design has a custom screw to help with ergonomics, requiring a few rotations before contacting the lecture desk. This design shares similar flaws as previous designs as it cannot switch the table out for other components. This does make the manufacturing process easier as it can be completed in one 3D print instead of multiple components. Like the previous design, it will fail at the point where the clamp is connected to the table if enough force is applied at the end of the table. Therefore, the main change of this iteration is allowing the user to transition from the lecture desk to Clippy.

2. Physical Description [Jin, Ludia, Mehali, Brandon, Andrew, Stellar]

a. House of Quality Level 1 [Mehali, Andrew]

Key	
-	negatively correlated
+	positively correlated



			↑	↓	↓	↑	↓
			Engineering Characteristics				
Requirements	#	%	Material	Cost	#Components	Load-Bearing Capacity	Production
Portability	6	15.00	9	1	9	4	0
Use Case	4	10.00	3	1	8	8	7
Efficiency	9	22.50	4	6	7	3	0
Modularity	7	17.50	0	8	9	2	8
Price	9	22.50	9	9	9	7	9
Aesthetics	5	12.50	4	6	2	1	5
	40	Sum	29	31	44	25	29
	100	%	18.35	19.62	27.85	15.82	18.35

Figure 8: First House of Quality

The first house of quality shows our user requirements to be portability, use case, efficiency, modularity, price, and aesthetics. These requirements correspond with our engineering characteristics of material, cost, number of components, load-bearing capacity, and production. On the right-hand side of the house of quality, it shows how the team rated Clippy relative to some competitors. Clippy has the highest rating in terms of modularity because most products found online were strictly desk attachments, while Clippy allows for other attachment components. Clippy also ranks second best in portability and use case, which shows requirements where Clippy performs well but could be improved. However, Clippy falls in the middle of the pack for efficiency, price, and aesthetics. These are areas in which the team can improve the product to increase Clippy's marketability. Right below the roof, we ranked the engineering characteristics on whether or not we wanted to maximize or minimize them. The roof showcases the correlations between the engineering characteristics.

These correlations seen by the House of Quality are listed below:

- Positive correlation between material and load-bearing capacity
- Negative correlation between material and cost
- Negative correlation for material and cost
- Negative correlation for cost and number of components
- Negative correlation for cost and load-bearing capacity
- Negative correlation for material and production
- Negative correlation for production and cost
- Negative correlation for production and number of components

b. Describe List of Requirements from Customer [Mehali, Andrew]

From our testing of design zero, we categorized our data into 5 subcategories, which are convenience, availability, material/design, interest level, and space.

These 5 subcategories are explained below:

- Convenience: The type of clamping mechanism that is used to install Clippy. For example, does it take a very long time to install the clamp or does it only take a couple turns of a screw? Convenience also relates to the size of Clippy, such that the product is not too big that it is not easily transportable.
- Material/Design: The balance between a material that is lightweight but also strong enough to withstand the weight of different items.
- Space: Clippy provides enough extra space to write on or hold other items, while not being too large such that there is too much weight. Additionally, we do not want Clippy to take up too much space in one's backpack or bag.
- Availability: Clippy has the potential to be available in classrooms instead of being a product that students have to buy and carry around campus.
- Interest level: Some students don't need Clippy as the lecture desk provides sufficient space, or laptops are used to take notes rather than a pencil and paper.

i. Empathy fieldwork

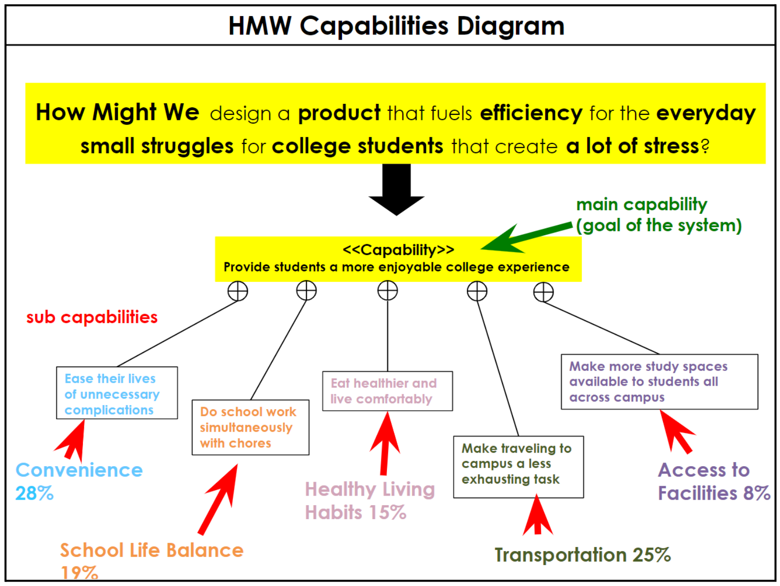


Figure 9: First HWM Capabilities Diagram

The HWM capabilities diagram shows the five categories of our first empathy fieldwork, where the problem addressed is "How might we design a product that fuels efficiency for the everyday small struggles for college students that create a lot of stress?" The 5 categories determined were convenience, school life balance, healthy living habits, transportation, and access to facilities. Convenience has the highest emphasis while access to facilities has the least importance. This is because access facilities deal with card access and the lack of general study spaces across campus, whereas convenience has many aspects the group can address.

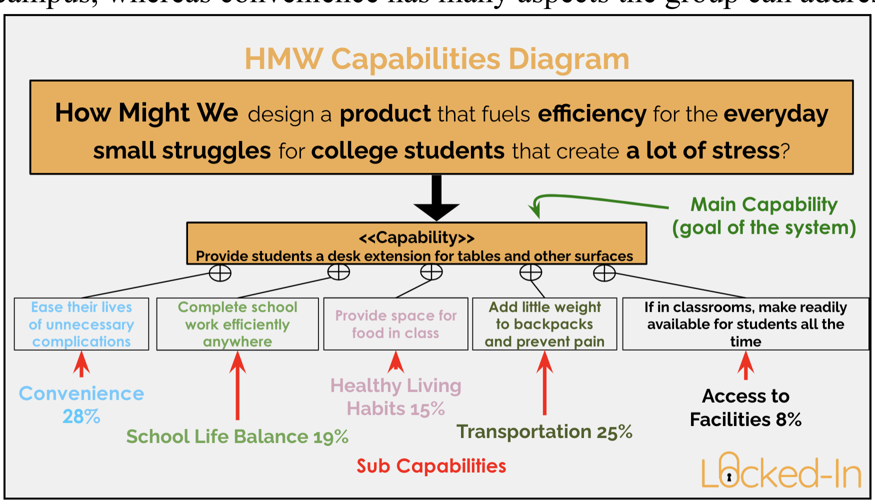


Figure 10: Second HWM Capabilities Diagram

The second HWM Capabilities Diagram has the same five categories as the first diagram and addresses the same problem as our first empathy fieldwork, but the definition of our sub-categories has changed. This time the HWM Capabilities diagram is more catered towards Clippy and how the five categories relate to Clippy.

ii. Analytical Hierarchy Process

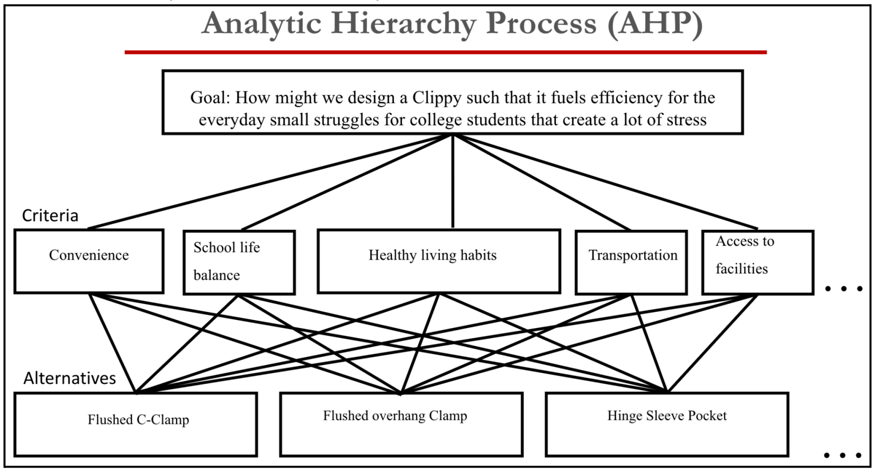


Figure 11: First Analytical Hierarchy Process

The first Analytical Hierarchy Process shows the goal the team is trying to achieve, and the different criteria the team wants to address. The five criteria listed are the same as the ones from the HWM Capabilities Diagram, as these were the main subcategories the team discovered during empathy fieldwork. Some alternative solutions the team has come up with for clamping are a flushed C-clamp, a flushed overhang clamp, and a sleeve pocket. The sleeve pocket was abandoned due to its complexity, inefficiency, and size. Both the flushed C-clamp and flushed overhang clamp were implemented in the design process. However, it was difficult to get a clamp that allows the Clippy to be flushed with the lecture table, so alternative solutions like a ramp were implemented instead.

iii. Conjoint Analysis [Brandon, Mehali, Andrew]

The conjoint analysis allows us to gain a better understanding about how different characteristics of our product correlate to each other. This ultimately helps us understand our product and potential customers better, and we can make more informed decisions about our final prototype.

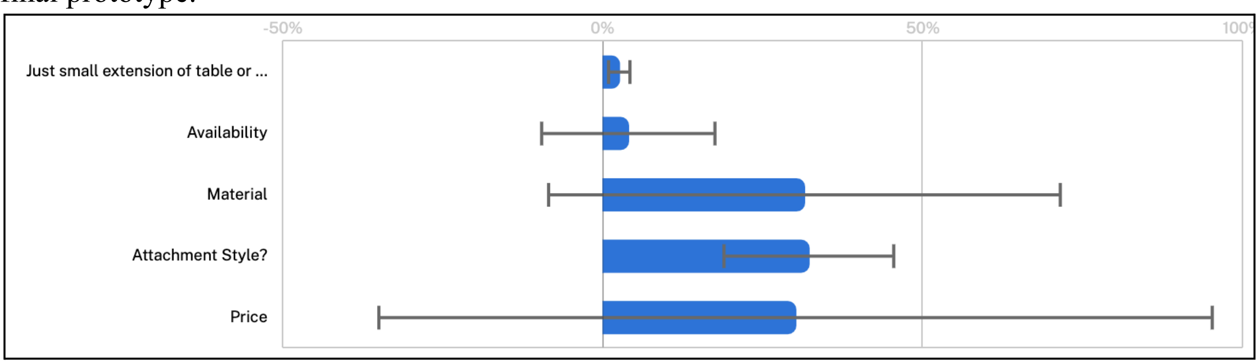


Figure 12: First Conjoint Analysis Results

Our conjoint analysis shows importance on material, attachment style, and price, while less emphasis on availability and the length of the extension. These results were implemented to Design 1 as we aim to reduce cost through using 3D printing, laser cutting, and minimizing the number of components. Note that this conjoint analysis was sent out to multiple students, but it appears that only a few completely filled out the survey. This means that this data might not be a good representation of what the general student body would want in Clippy. Therefore, another conjoint analysis was sent out. In that conjoint analysis, there were four qualities of the product that we wanted to focus on: availability, price, attachments, and surface finish.

We first wanted to identify where we could potentially sell Clippy. Because Clippy is a solution to a school infrastructure problem, we asked users whether they would prefer to keep Clippy as a personal item or to be kept in classrooms. The results showed that users overwhelmingly preferred to have them available in classrooms.

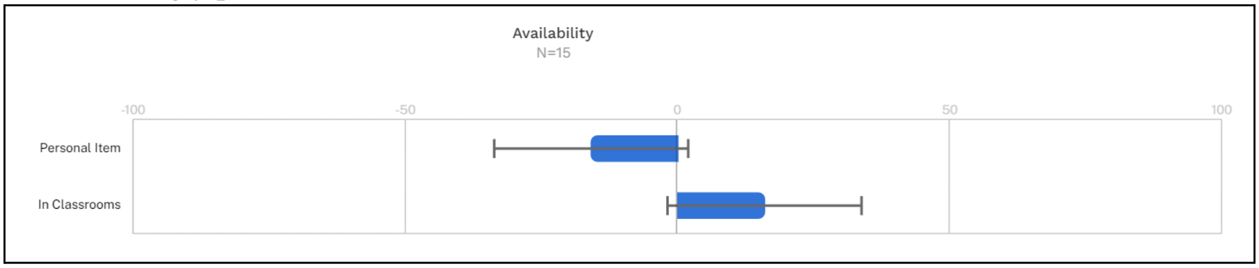


Figure 13: Availability of Clippy

Since our pricing strategy is a factor to our profitability, we also wanted to determine in what price range our customers would be willing to pay for Clippy. Based on the results, it showed that users find the most value out of the product in the ten dollar price range with it decreasing as the price increases. This allows us to target a price range between $10-25 for our customers and constrains the material selection of our design.

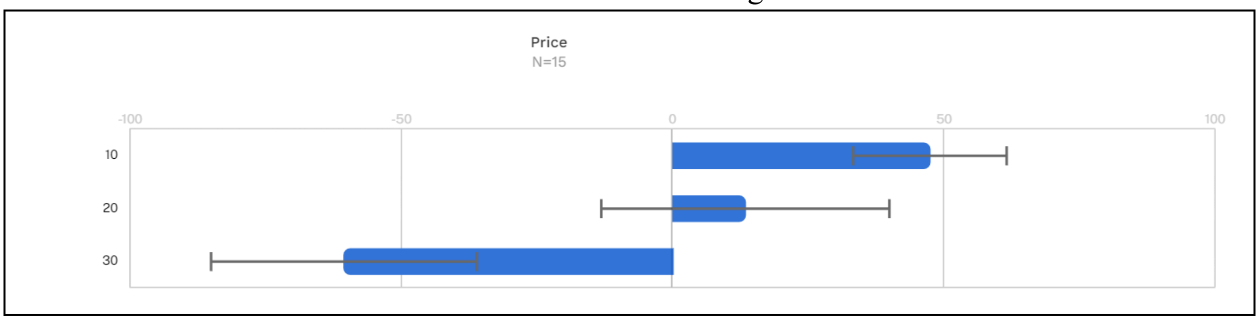


Figure 14: Price of Clippy

The modular aspect of Clippy also allows us to change out our table extender for other attachments. We wanted to determine the viability of different attachments with our users, so we included it in our analysis. The results show that many users preferred a laptop case attachment and did not want a cup holder. This somewhat aligns with our discussions as many people would prefer a multi-functional laptop case during school but is surprising with the cup holder as we believed it could add value to students.

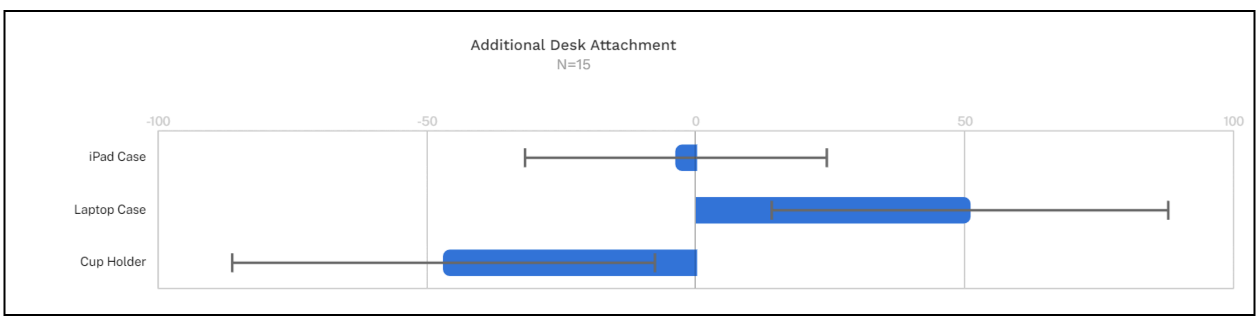


Figure 15: Additional Desk Attachment of Clippy

We also wanted students to feel comfortable using the table attachment for our modular design, and since the writing experience is important to being productive in lecture, we wanted to identify what surface finish our users would prefer to write on. The options were based on surface roughness characteristics with leather representing a premium material, glossy representing the smoothest, and grainy representing the roughest. Users were inclined to a matte surface which is between glossy and grainy in surface roughness. This surface finish selection suggests that users want the surface roughness to grip the items on the desk, but do not want it to interfere with their writing.

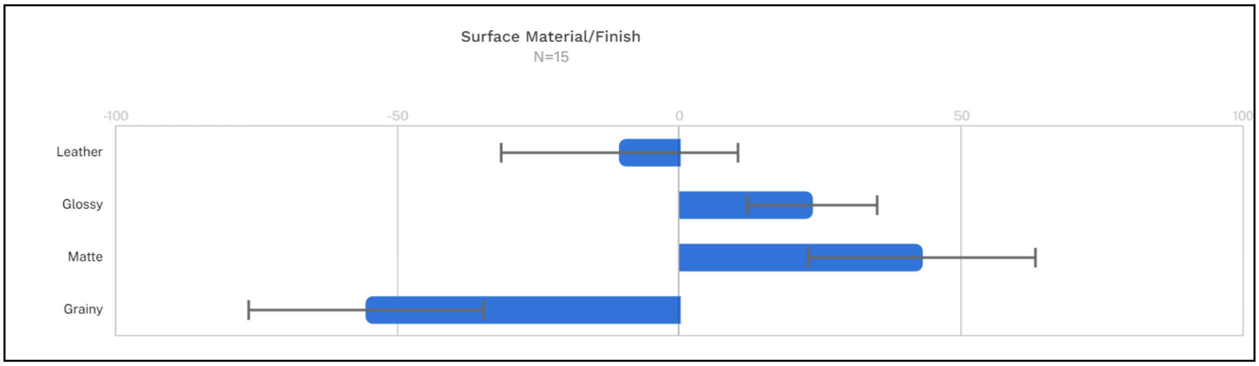


Figure 16: Surface Materials/Finish of Clippy

The attribute importance shows how important each characteristic of our product is to our users. Based on the results, users cared the most about the additional desk attachment seen in Figure 15 followed by the price, surface finish, base material, availability, and attachment style.

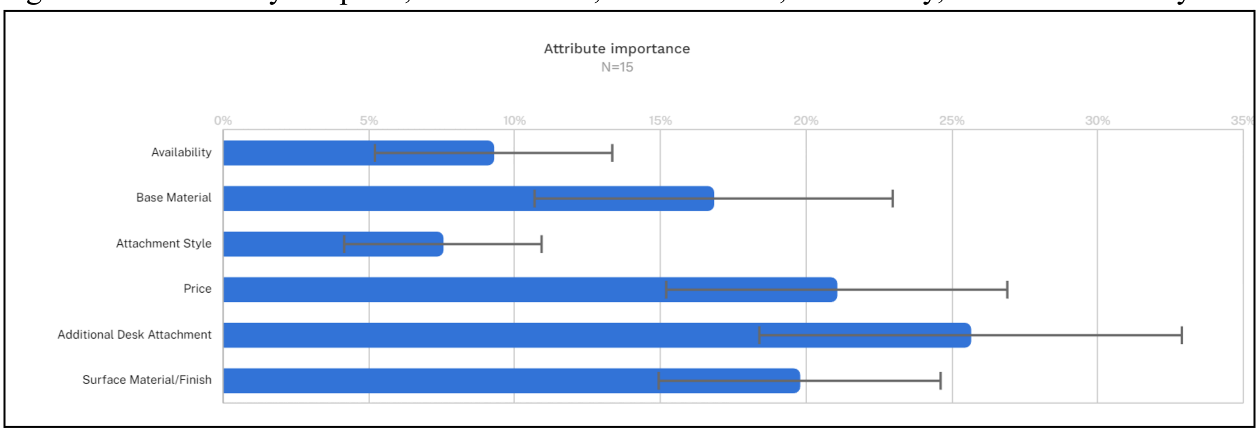


Figure 17: Attribute Importance of Clippy

c. Describe Engineering Characteristics of Concept [Mehali, Andrew]

i. What subsystems output engineering features that address the customer requirements?

Different clamp mechanisms were considered, such as a snap fit, screw, and spring, to best address customer requirements of convenience. The screw-on clamp was picked because it was simplistic to design and integrate with a desk. The clamp was designed such that it only requires a few rotations to make contact with the lecture desk; therefore, students will not have to spend a lot of time installing and removing Clippy. Moreover, customers were concerned about the product's weight as it seemed inconvenient for students to buy a product that would add additional weight and take up space in their book bags. To address this issue, cutouts were made on the bottom of the 3D printed table attachment to reduce weight. The team also found acrylic as a viable option as it was used for Design 1 and was lightweight and sturdy. In addition, the team is looking into different materials the table could be manufactured. The additional room

Clippy provides is approximately 8.5 x 11 inches, which is the size of a loose-leaf paper. This ensures that Clippy will fit in backpacks while allowing enough table space for typical iPad, paper, and small laptops. To increase interest in Clippy, a dovetail joint was made, allowing the table component to be detachable and swapped out with attachments like a cup or pencil holder. This will hopefully also ease the lives of students who do not want a table extension.

1. Units (Nm, kg, W, etc.)

The general units used for this project were grams, millimeters, and Newtons. This is because using the meter dimensions on Fusion 360 outputs a volume of 0 m^3, which is inaccurate, which means smaller units characterized our product more accurately.

Physical			
Mass	230.554 g	Volume	2.175E+5 mm^3
Density	0.001 g / mm^3	Area	63182.305 mm^2
World X,Y,Z	0.00 mm, 0.00 mm, 0.00 mm	Center of Mass	97.217 mm, -112.644 mm, 6.103 mm

Figure 18: Mehali and Andrew's CAD

These were parameters produced from Fusion 360 from a version of Clippy, assuming that Clippy is made out of only ABS. Using the mass of Clippy and assuming gravity to be $9.81\ \frac{m}{s^2}$, the weight of Clippy is approximately $2.26173474\ N$.

Physical			
Mass	728.519 g	Volume	6.873E+5 mm^3
Density	0.001 g / mm^3	Area	1.631E+5 mm^2
World X,Y,Z	0.00 mm, 0.00 mm, 0.00 mm	Center of Mass	85.535 mm, 3.602 mm, -79.264 mm

Figure 19: Jin's CAD

These were parameters produced from Fusion 360 for another version of Clippy, assuming that Clippy is made out of only ABS. Using the mass of Clippy and assuming gravity to be $9.81\ \frac{m}{s^2}$, the weight of Clippy is approximately $7.14677139\ N$.

2. Subsystem interactions (++, --, +, -,)

- Positive correlation between material and load-bearing capacity
- Negative correlation between material and cost
- Negative correlation for material and cost
- Negative correlation for cost and number of components
- Negative correlation for cost and load-bearing capacity
- Negative correlation for material and production
- Negative correlation for production and cost
- Negative correlation for production and number of components

d. Use of TRIZ throughout iterations [Mehali, Andrew]

	Weight	Length	Volume	Force	Stress	Stability	Strength	Durability	Reliability	Adaptivity
Weight		10, 1, 29, 35	5, 35, 14, 2	8, 10, 19, 35	13, 29, 10, 18	26, 39, 1, 40	28, 2, 10, 27	2, 27, 19, 6	10, 28, 8, 3	19, 15, 29
Length	35, 28, 40, 29		35, 8, 2, 14	28, 10	1, 14, 35	39, 37, 35	15, 14, 28, 26	1, 10, 35	15, 29, 28	1, 35,
Volume	35, 10, 19, 14	No Solution		2, 18, 37	24, 35	34, 28, 35, 40	9, 14, 17, 15	35, 34, 38	2, 35, 16	No Solution
Force	18, 13, 1, 28	28, 10	2, 36, 18, 37		18, 21, 11	35, 10, 21	35, 10, 14, 27	no solution	3, 35, 13, 21	15, 17, 18, 20
Stress	13, 29, 10, 18	35, 1, 14, 16	35, 24	36, 35, 21		35, 33, 2, 40	9, 18 3, 40	no solution	10, 13, 19, 35	35
Stability	26, 39, 1, 40	37	34, 28, 35, 40	10, 35, 21, 16	2, 35, 40		17, 9, 15	39, 3, 35, 23	No Solution	35, 30, 34, 2
Strength	40, 26, 27, 1	15, 14, 28, 26	9, 14, 17, 15	10, 18, 3, 14	10, 3, 18, 40	13, 17, 35		no solution	11, 3	15, 3, 32
Durability	40, 26, 27, 1	1, 40, 35	35, 34, 38	No Solution	no solution	39, 3, 35, 23	No Solution		34, 27, 6, 40	2
Reliability	3, 10, 8, 28	15, 29, 28, 11	2, 35, 24	8, 28, 10, 3	10, 24, 35, 19	no solution	11, 28	34, 27, 6, 40		13, 35, 8, 24
Adaptivity or Versatility	19, 15, 29 ,16	1, 35, 16	No Solution	15, 17, 20	35, 16	35, 30, 14	35, 3, 32, 6	2, 16	35, 13, 8, 24	

Figure 20: TRIZ Matrix

This TRIZ[1] matrix has a vertical column showing the features to improve and a horizontal row showing features that get worse. Each of the numbers within the cells is correlated to 40 different solutions suggested by TRIZ 40. Not all 39 features from TRIZ 40 were implemented into our matrix because some aspects did not relate to our product such as temperature. Many of the same solutions were repeated throughout the TRIZ matrix which makes it easier to combat these contradictions. TRIZ allows the team to see potential drawbacks in improving one aspect while allowing another to worsen. Then, by using the suggested solutions, the team could mitigate the results of the feature getting worse.

1. Functional Decomposition [Mehali, Andrew]

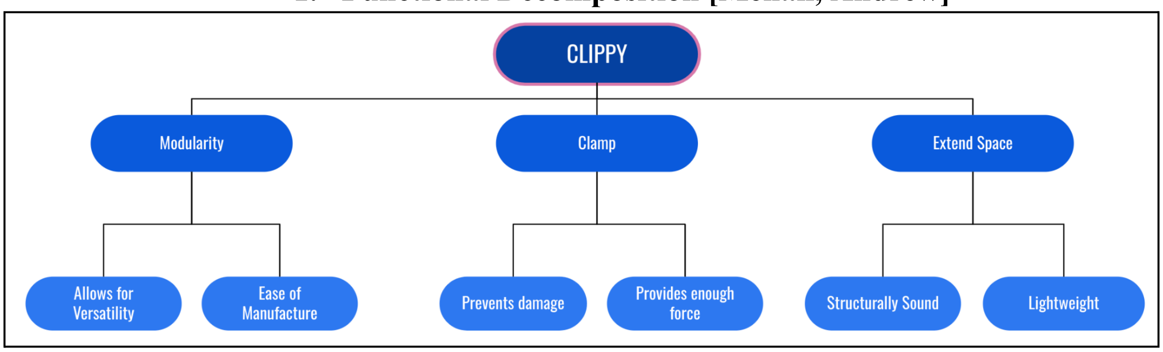


Figure 21: Functional Decomposition

The functional decomposition chart shows three essential design considerations of Clippy, which are modularity, clamp, and extended space. The modularity aspect has both drawbacks and benefits as it can allow for versatility in the product but can make the manufacturing process more complex or expensive. The clamp must not damage the surface when attaching to surfaces but also be able to apply enough force to stay attached. In terms of extended space, it must be lightweight as students have expressed that a heavy product might not be worth carrying around. In addition, it has to support the force of the student's arm and the weight of the product they put on Clippy. To anticipate extreme loads, we provided some analysis in later sections that simulate Clippy under at least half of an average person's body weight.

ii. What engineering contradictions are you solving for? [Mehali, Andrew]

After completing the functional decomposition, the team noticed many contradictions within our product. For instance, we want to allow for modularity within our product without complicating the manufacturing process or adding significant weight to the product. Clippy

[1] https://www.triz40.com/aff_Matrix_TRIZ.php

should also ensure the overall size is large enough to fit either a piece of loose leaf paper or a tablet without overstepping other people's boundaries.

iii. What are the historical solutions? [Mehali, Andrew]

Many of our problems with creating Clippy were incorporating modularity, ensuring size was right, and limiting weight. Historically, some solutions to combat these problems include adding pin-in-hole joints, reducing the overall length, and decreasing the thickness of the device. However, the pin-in-hole joint strategy added more weight and volume to the product, especially if the device was segmented into two different components. The pin that would be attached to the table would replace a flat board that can easily be packed in a backpack, causing a hindrance due to the protrusion. Reducing the overall length of the product would help keep the desk attachment from getting in the way of other students while ensuring lightweight characteristics. Decreasing the thickness of the device would reduce the weight, but it also introduced vulnerability to weakened strength and susceptibility to fracture.

iv. What is your proposed solution? [Mehali, Andrew, Jin]

Based on trends seen by TRIZ 40, the most repeated solutions are parameter change and preliminary action. Parameter change suggests that changing the flexibility of the product is a solution. Therefore, changing the material of which the table component is flexible can allow for it to bend a bit before fracture or, in other other words, allow for a graceful failure. In addition, the flexibility will allow the user to identify that they are applying too much force on Clippy. Preliminary action suggests that failure modes should be identified before manufacturing and addressed in the design. This could be achieved by using Ansys simulations or 3D printing of multiple prototypes and applying different stress tests to them. Then, after visualizing where failure occurs, a different design or support could be implemented in the redesign of the component. To combat reducing weight while ensuring strength, one of our proposed solutions is adding rib structures to the table attachment of Clippy. Ribs can be used to stiffen a plane-shaped sheet of plastic against bending and fracture in-plane without adding excessive weight. For attachment style, a dovetail joint can be used. Dovetail joints are easy to assemble and disassemble while providing enough joint strength. Another feature is moving the connection point between the table and the Clamp slightly closer to the middle of the table. This helps reduce the moment arm of torque while also minimizing the inconvenience of having an uneven writing surface. Overall, these solutions are meant to assist with improving user experience and migrating potential structural failures.

e. What is the embodiment of your solution? [Mehali, Andrew]

The embodiment of the solution the team chose is using ABS material to create the table component instead of the original material of acrylic. Acrylic is too stiff, so it will fracture or break in half when it fails. Whereas, ABS will deform a little and bend when too much force is applied. This will allow for some flexibility and bending in the product before failure. Seen in later sections of the document, there are simulations completed on Clippy to evaluate where stress will occur under certain loading. These simulations along with physical testing were used to make changes to Clippy design. One change was the orientation of how Clippy's clamp is printed as certain orientations provide more resistance to pulling force. Other changes are changing the overall design of the clamp like introducing more fillets to reduce the amount of sharp corners on a Clippy preventing stress concentration. The grid underneath Clippy is meant to reduce weight while maintaining structural stability. An iteration of Clippy's desk was a rectangle made out of ABS, and the team realized that it was adding unnecessary weight to the product. In addition, the joint was changed so that it is not directly on the edge to mitigate the disturbance to the user because Clippy is not flushed with the lecture desk. This also reduces the moment arm when a force is applied at the end of the table, reducing torque and increasing durability. These solutions are seen throughout the prototype as the final design has the ramp, rounded corners, and the grid.

i. Static Renderings [Andrew]

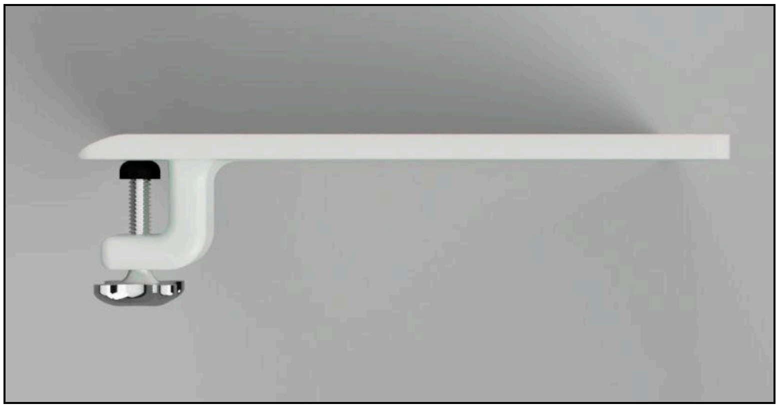


Figure 22: Static Rendering of Final Non-Modular Clippy 1

Figure 23: Static Rendering of Final Non-Modular Clippy 1

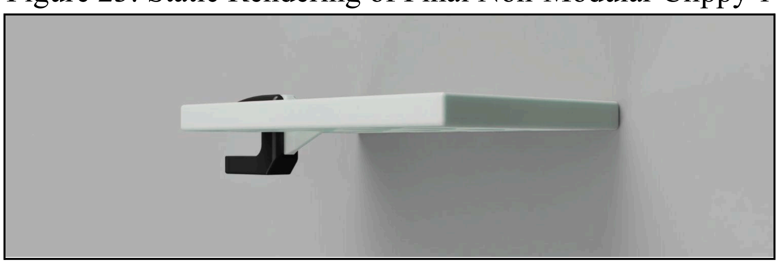


Figure 24: Static Rendering of Final Modular Clippy

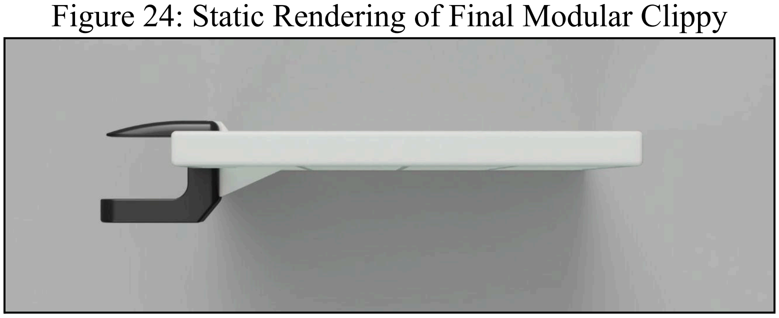


Figure 25: Static Rendering of Final Modular Clippy

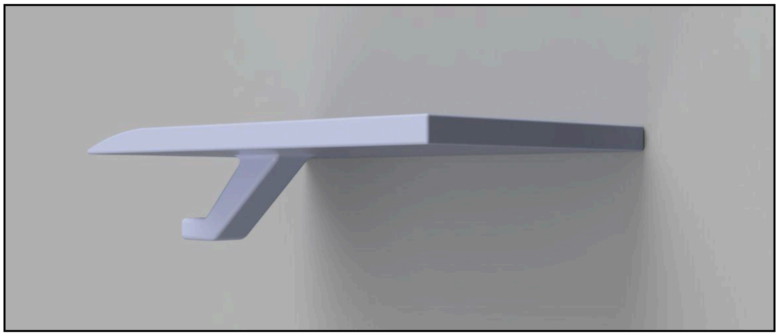


Figure 26: Static Rendering of Final Non-Modular Clippy 2

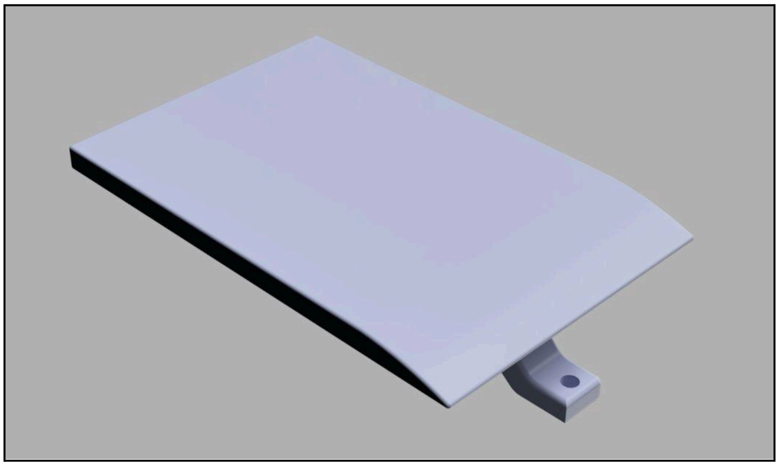


Figure 27: Static Rendering of Final Non-Modular Clippy 2

ii. **Link to dynamic renderings [Brandon, Stellar]**

- Motion study video of the second prototype
- Motion study video of the final modular prototype

iii. **Pictures of physical prototype Iterations [Everyone]**

Figure 28: First Prototype with Cup Holder

Figure 29: First Prototype with Desk Extender

Figure 30: User Testing with First Prototype

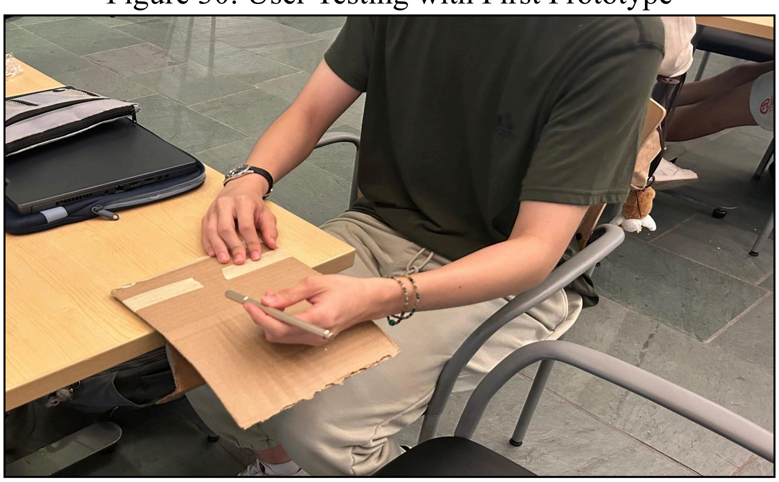


Figure 31: User Testing with First Prototype

Figure 32: User Testing with Second Prototype

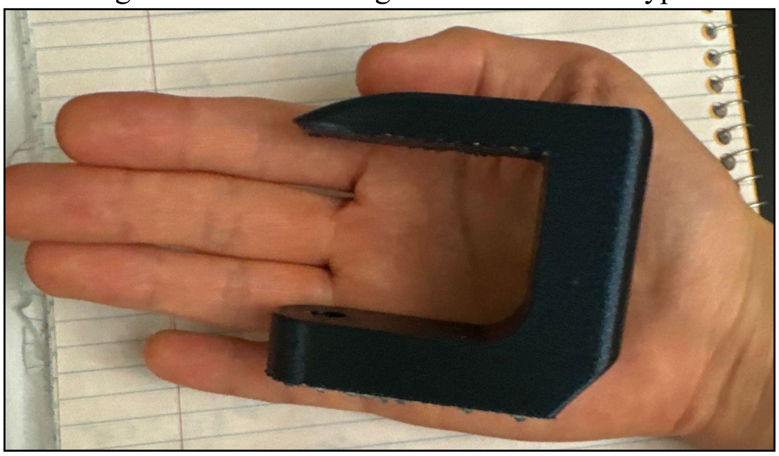


Figure 33: Final Modular Clippy Desk Clamp

Figure 34: Final Modular Clippy Desk Clamp Attached to Table

Figure 35: Final Modular Clippy Desk Clamp and Desk Extender Attached to Table

iv. Final Works Like Prototype [Brandon, Stellar]

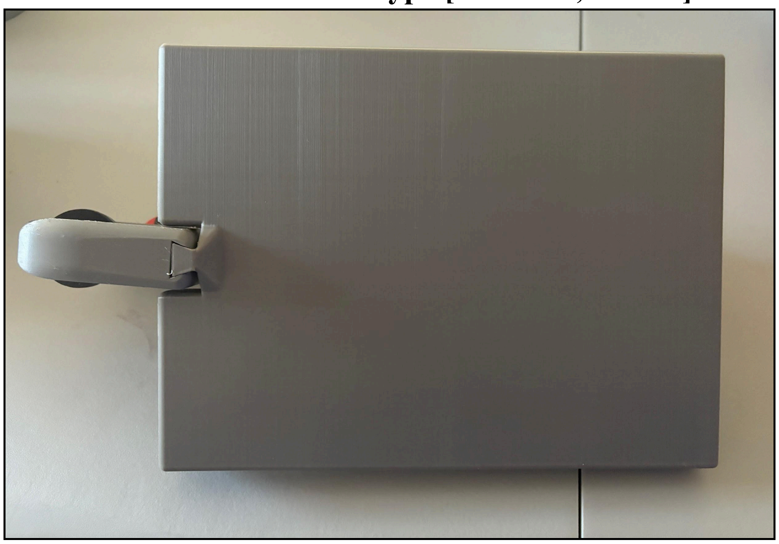


Figure 36: Final Modular Clippy

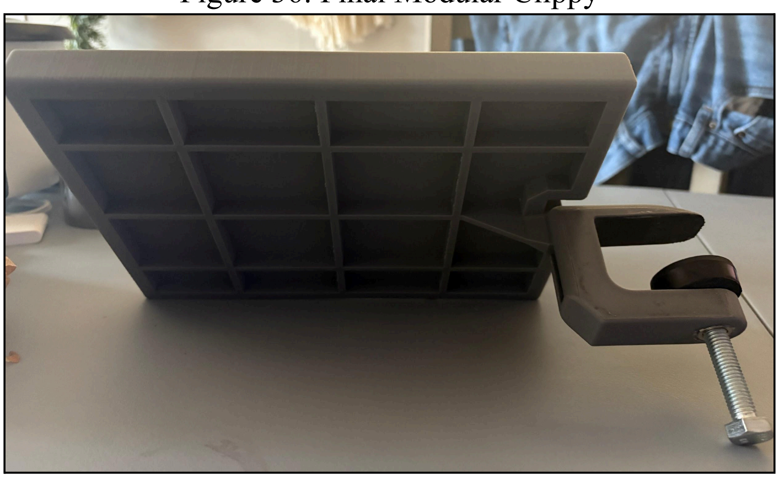


Figure 37: Final Modular Clippy (Bottom View)

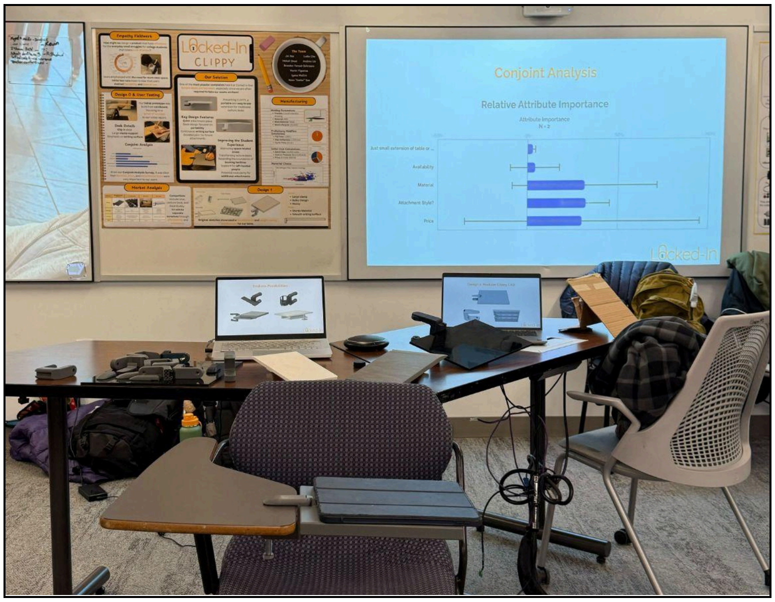


Figure 38: Design 0 (Cardboard Prototype) to Final Designs

f. Mechanical Analysis [Jin, Mehali, Andrew, Stellar]

i. Analytical [Jin, Stellar]

In order to carry out an effective mechanical analysis for Clippy, it is essential to identify possible loading conditions during its usage. The first model we look at is the modular version of Clippy, where there are three main components - lecture desk, clamp, and extension desk.

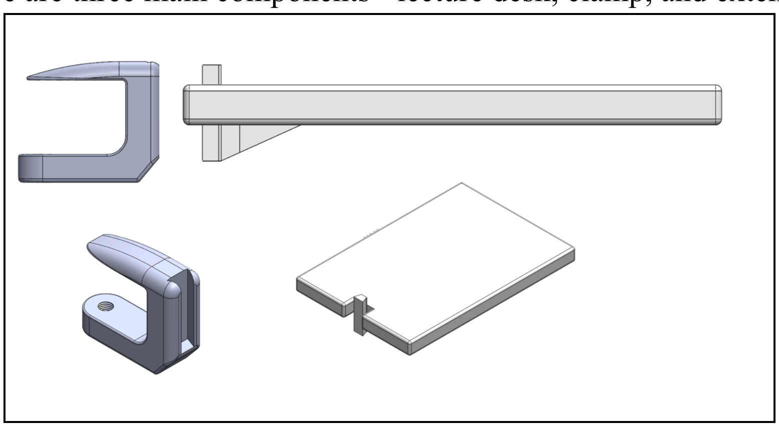


Figure 39: Parts of Final Modular Clippy

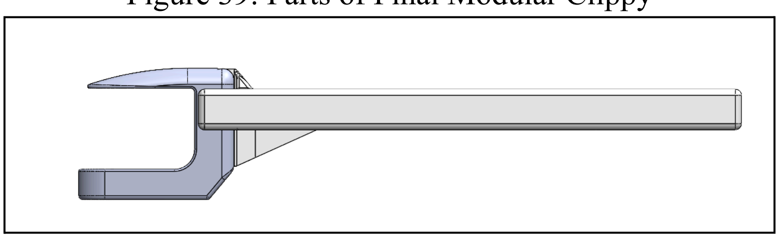


Figure 40: Assembled Final Modular Clippy

The second model we look at is a non-modular version of Clippy.

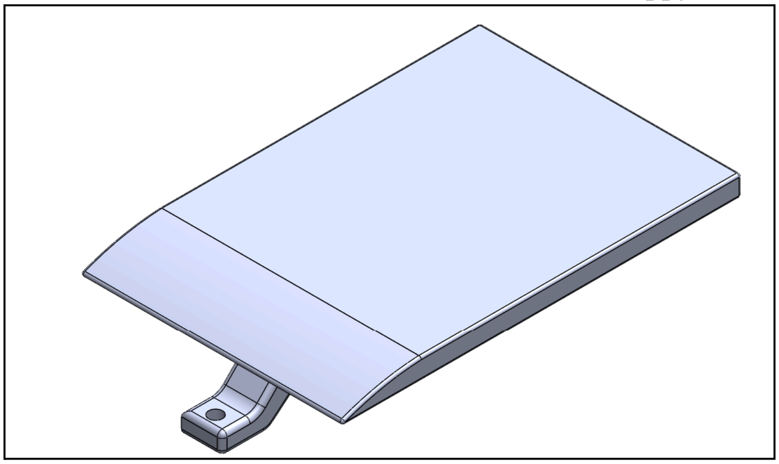


Figure 41: Final Non-Modular Clippy

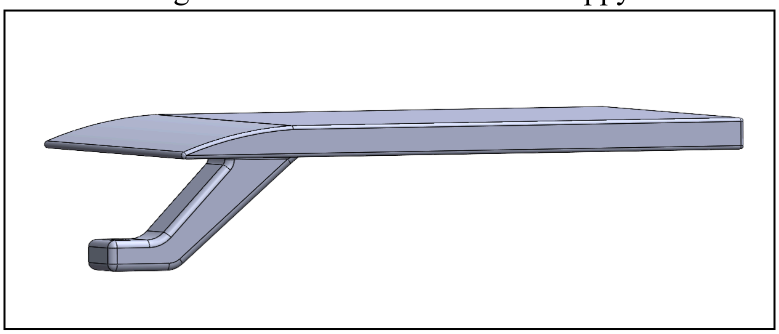


Figure 42: Final Non-Modular Clippy

Let us analyze the modular version first. Assume that Clippy is attached to a fixed lecture desk. The image below shows the initial condition of Clippy.

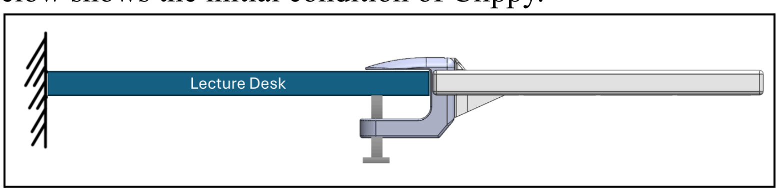


Figure 43: Final Modular Clippy Attached to Lecture Desk

Let us now introduce a load. For the sake of simplicity in deriving an analytical solution, we will assume a point load from a realistic, distributed load of a user. We will also assume that our dovetail joint connection is a rigid one.

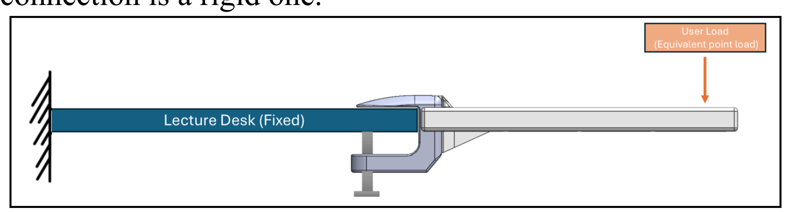


Figure 44: Simulation of Final Modular Clippy Attached to Lecture Desk with User Load

Then, we can draw a free body diagram based on the components of Clippy and the desk.

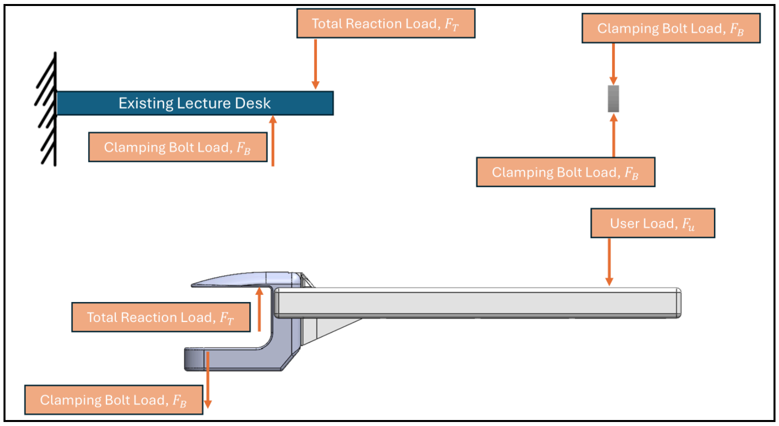


Figure 45: Force Applied on Lecture Desk and Clippy

Now knowing the forces and their directions,

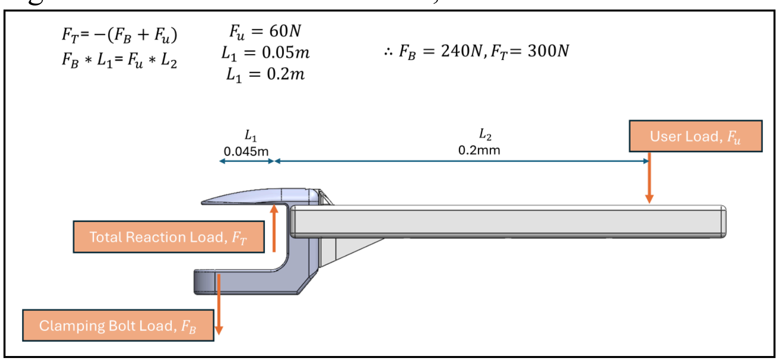


Figure 46: Clamping Bolt Load Calculation on Clippy

The resulting values seem large. However, remember that this case assumes zero bending where materials are fully rigid and that there is no force applied in x direction to counteract the thickness.

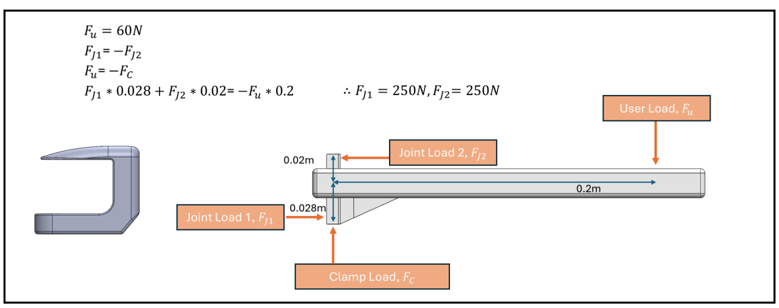


Figure 47: Joint Loads Calculation on Clippy

We also analyze the joint here. In the worst case scenario, we assume the joints to take 250N of force. This, again, assumes materials to be rigid and there are point bar, linkage, and force application assumptions made. The second version of Clippy has a different structure without modularity requirements. In this version, Clippy is attached directly to the desk without a joint.

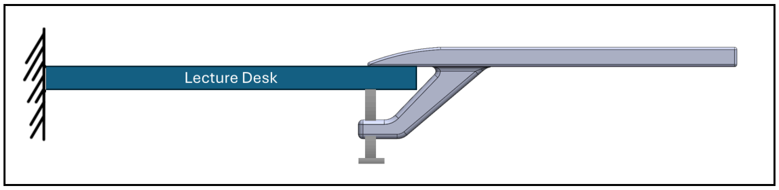


Figure 48: Final Non-Modular Clippy Attached to Lecture Desk

A similar analysis shows the following results.

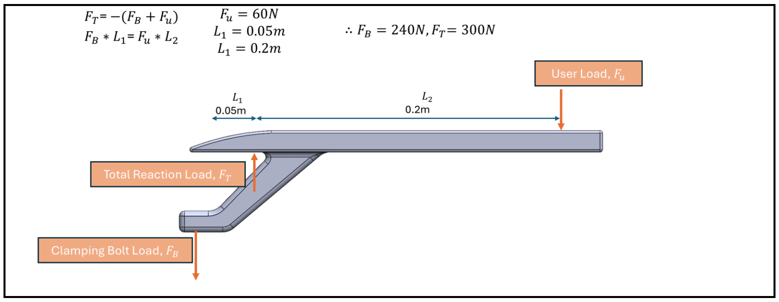


Figure 49: Clamping Bolt Load Calculation on Clippy

ii. FEA

1. Static [Jin, Andrew]

For the modular Clippy, a static analysis under the above conditions looks as follows. A non-uniform force application has been applied to match the loading conditions for both User Load and Clamping Load. To build some conservative simulations, I have increased the load on the clamp to 300N.

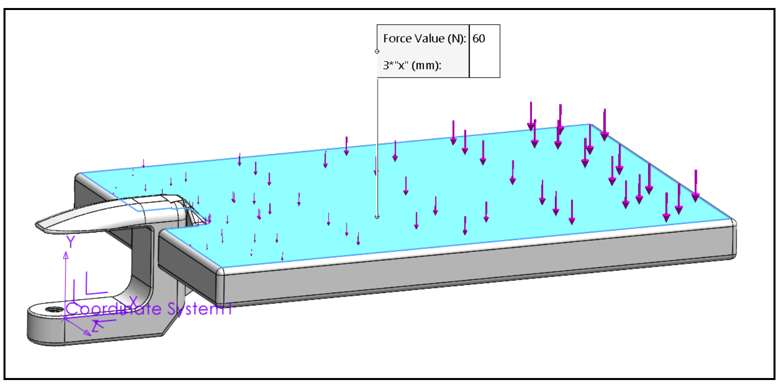


Figure 50: Force Applications of Clippy

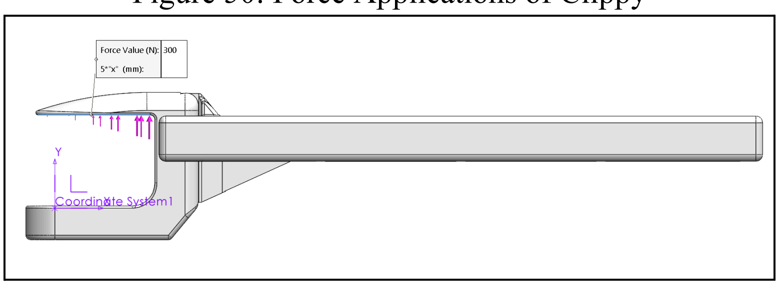


Figure 51: Force Applications of Clippy

Figure 52: Force Applications of Clippy

The deflection is shown in this FEA.

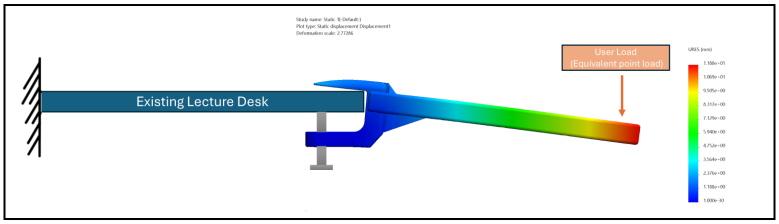


Figure 53: FEA Deflection Analysis of Clippy Attached to the Lecture Desk

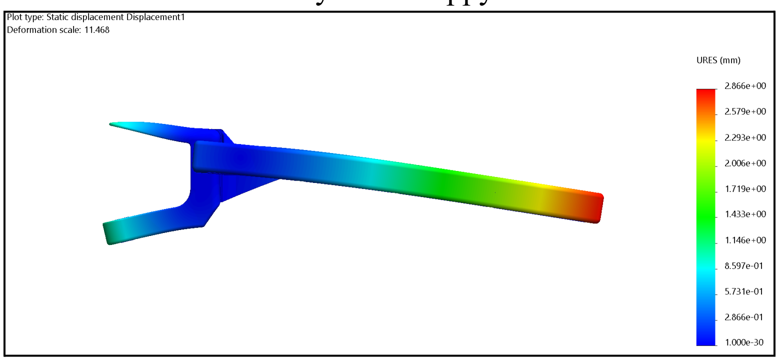


Figure 54: FEA Deflection Analysis of Clippy (without Bolt)

Von Mises Stress shown in FEA below.

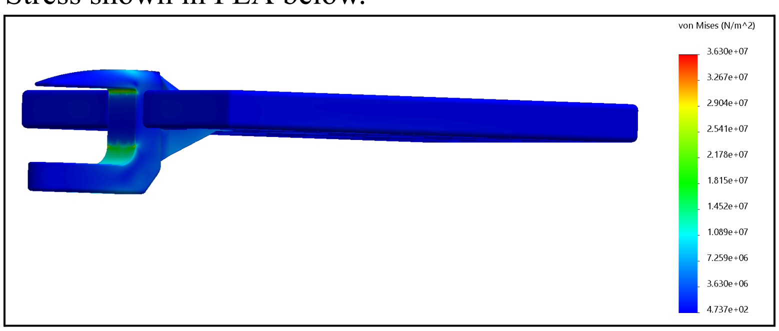


Figure 55: Von Mises Stress Analysis of Clippy

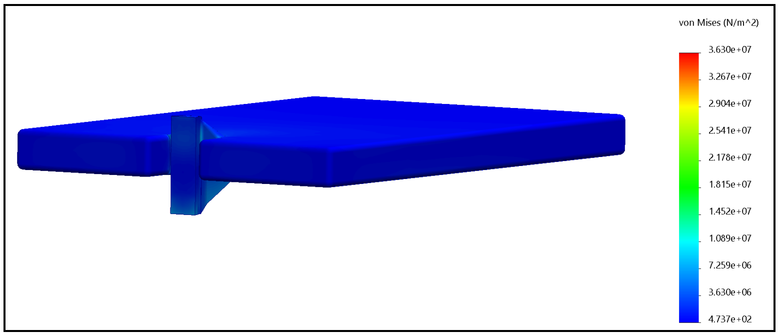


Figure 56: Von Mises Stress Analysis of Desk Extender Part of Clippy

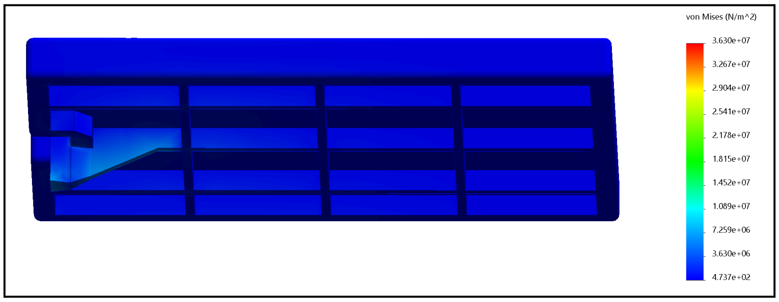


Figure 57: Von Mises Stress Analysis of Desk Extender Part of Clippy (Bottom View)

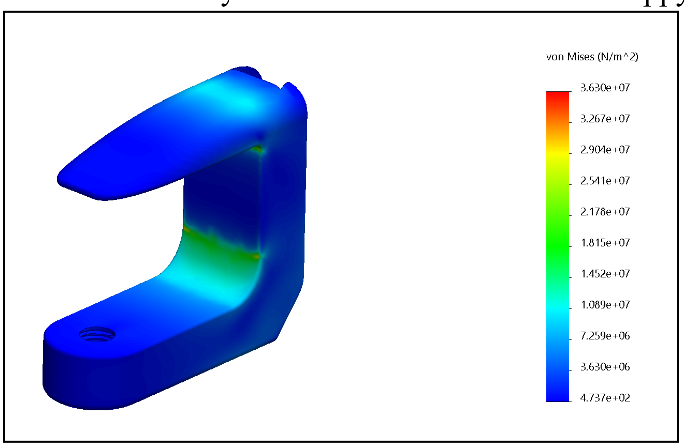


Figure 58: Von Mises Stress Analysis of Clamp Part of Clippy

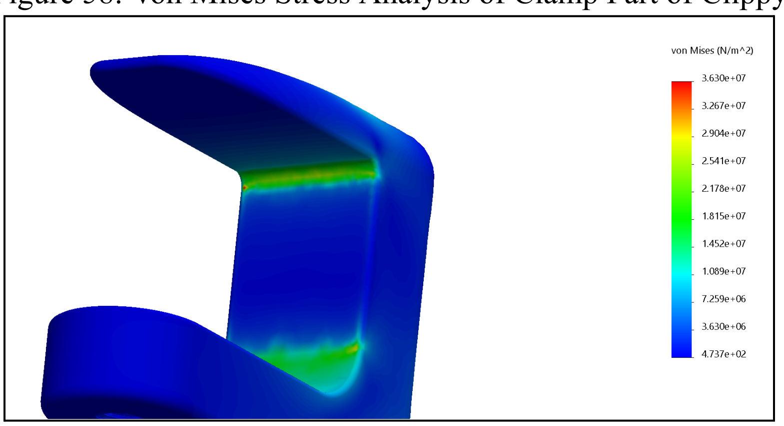


Figure 59: Von Mises Stress Analysis of Clamp Part of Clippy

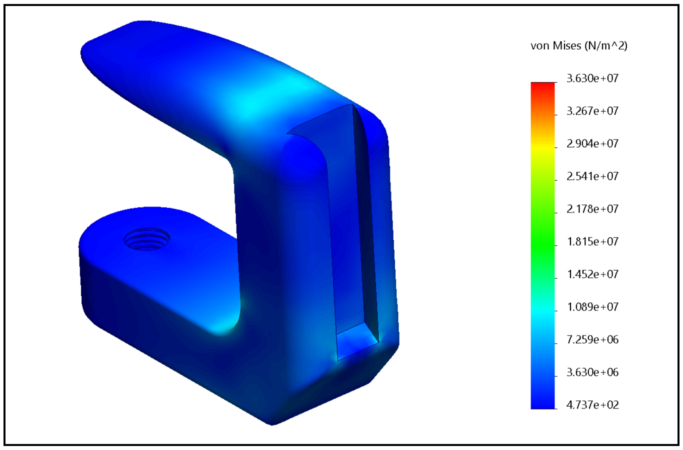


Figure 60: Von Mises Stress Analysis of Clamp Part of Clippy

The results of this FEA are promising. Although the maximum VM-Stress appears around 36.5MPa, most of the part stays at or below 30MPa. The maximum stress of 36.5MPa may be due to meshing conditions. Further analysis is required with a more sophisticated simulation using ANSYS for more verification.

Below are the results of non-modular Clippy.

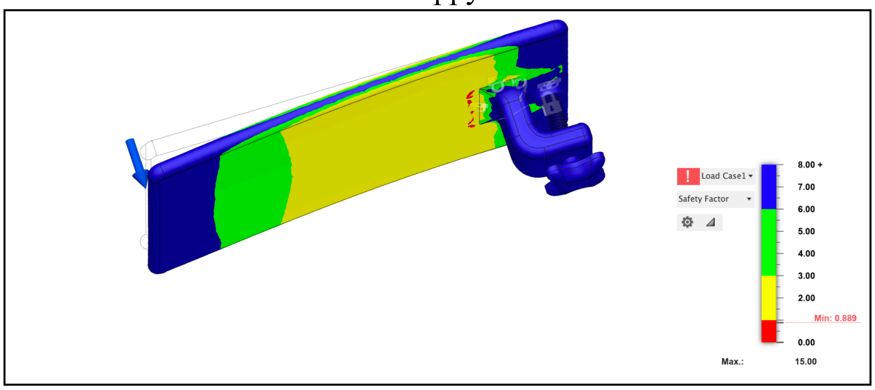


Figure 61: FEA Deflection Analysis of Non-Modular Clippy

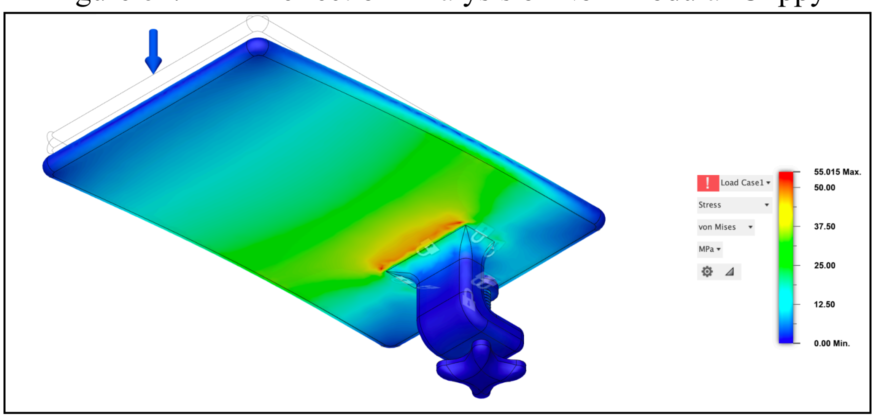


Figure 62: Von Mises Stress Analysis of Non-Modular Clippy

The parameters for simulation in Figure 61 and Figure 62 are that the joint between the clamp and the table and the end of the screw where a rubber stopper is located are considered fixed supports. This is because when Clippy is in use these parts of Clippy are expected to be fixed. Then a force of 320 Newtons is applied to the end of the table to resemble the weight student or their school supplies can supply. These simulations show the safety factor and stress throughout the product, under a force of 320 Newtons near the end of the table. A value of 320 Newton force was used for the simulation because it is approximately half the average human's body weight. The simulation shows the lowest safety factor occurs near the attachment point of the clamp to the board. Since a lower safety factor means there is a chance for failure to occur at that point. This is also reflected through the stress simulation where the highest stress concentration of 55.015 MPA occurs near the attachment point of the clamp to the table. The analysis also shows deformation of the table when the force is applied, which is expected since Clippy faces an issue of a moment applied at the end that will cause it to break off near the clamp.

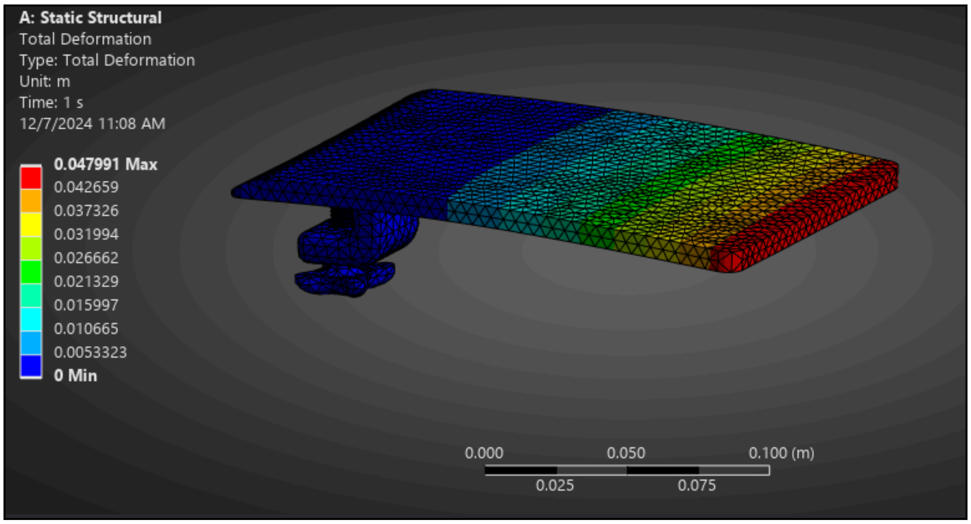


Figure 63: Total Deformation Results

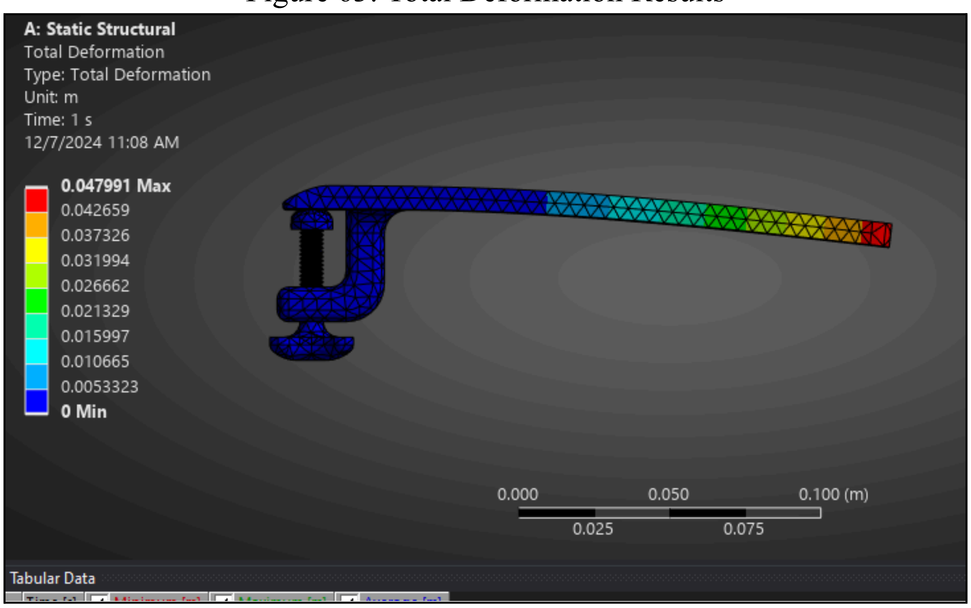


Figure 64: Total Deformation Results

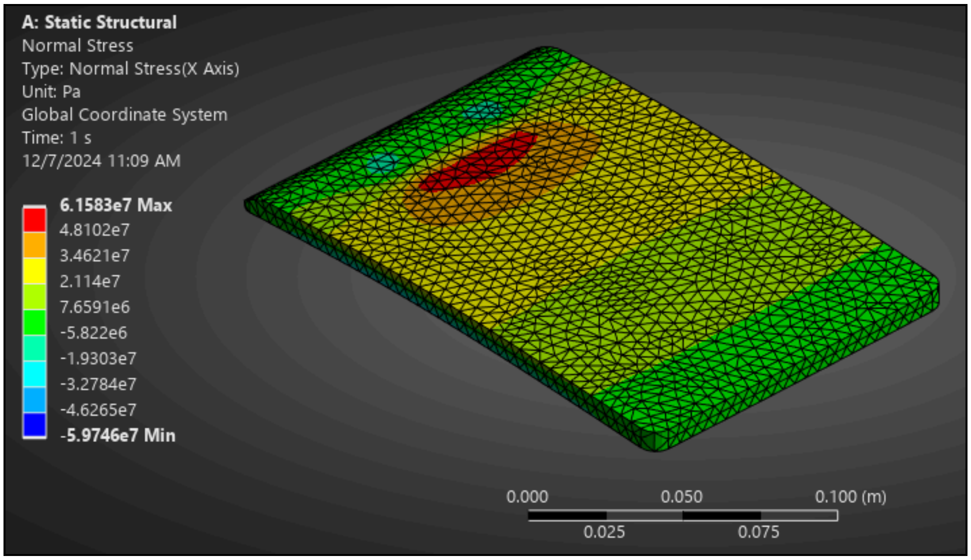


Figure 65: Normal Stress Results

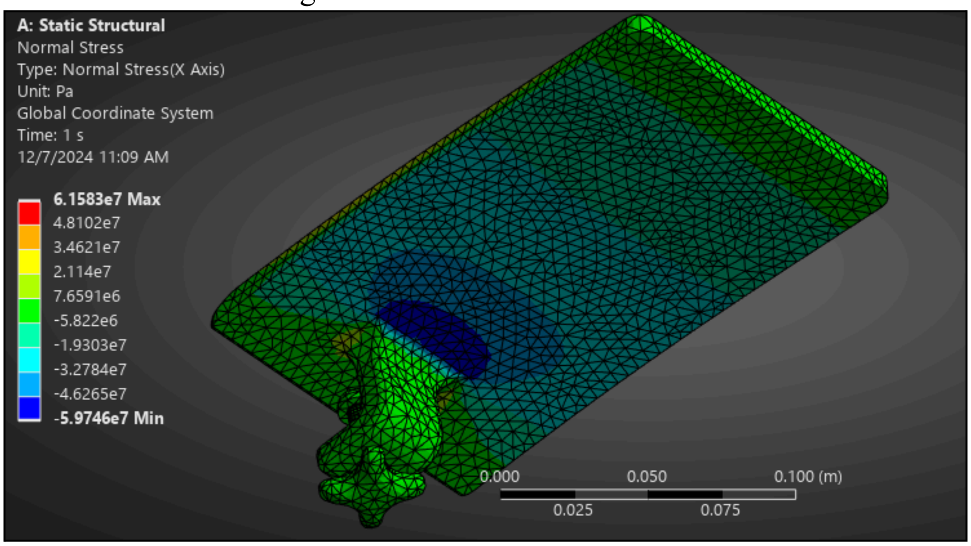


Figure 66: Normal Stress Results

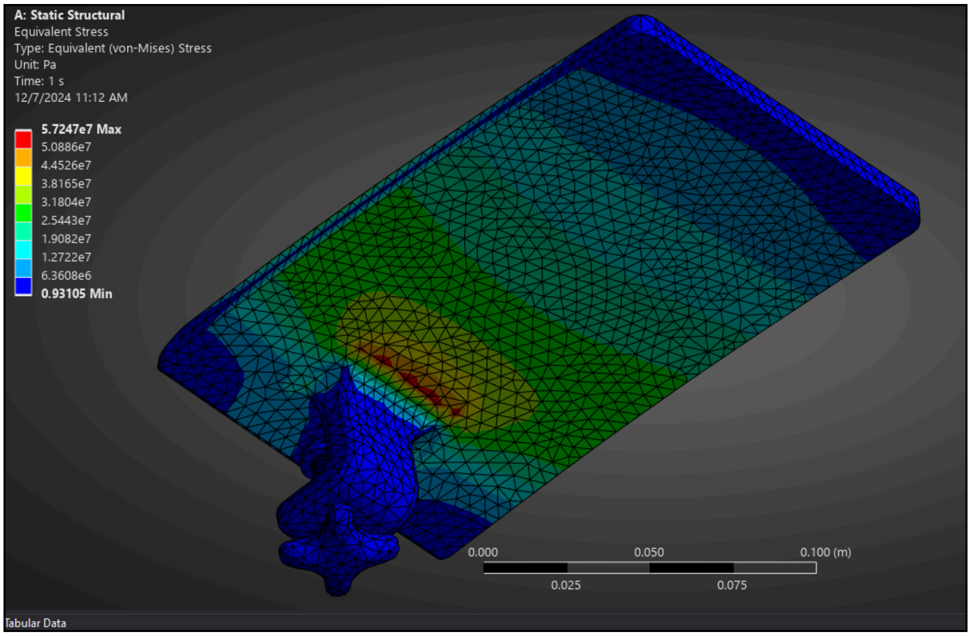


Figure 67: Von-Mises Stress Results

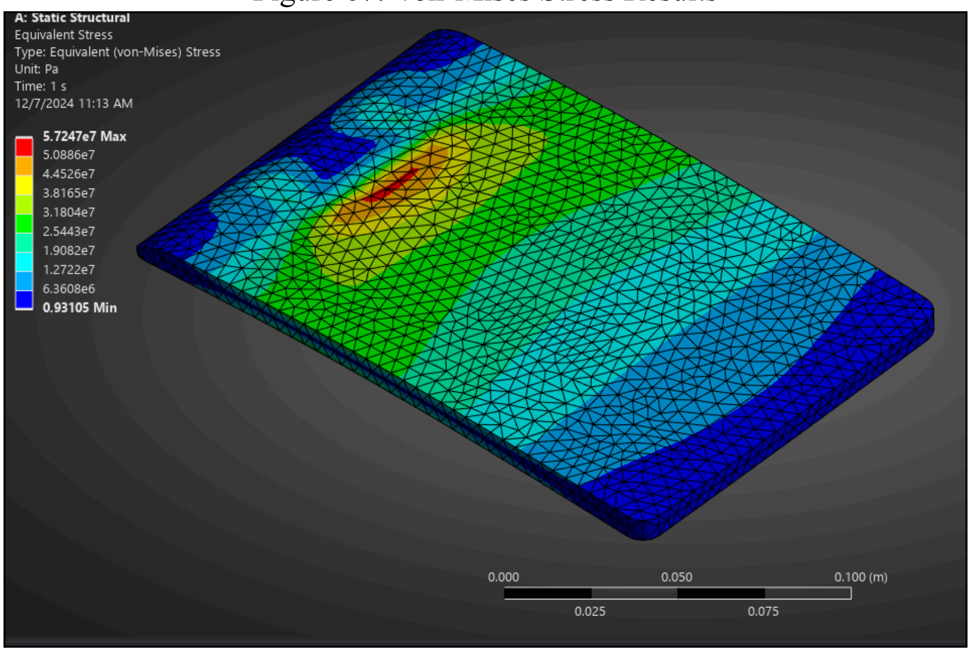


Figure 68: Von-Mises Stress Results

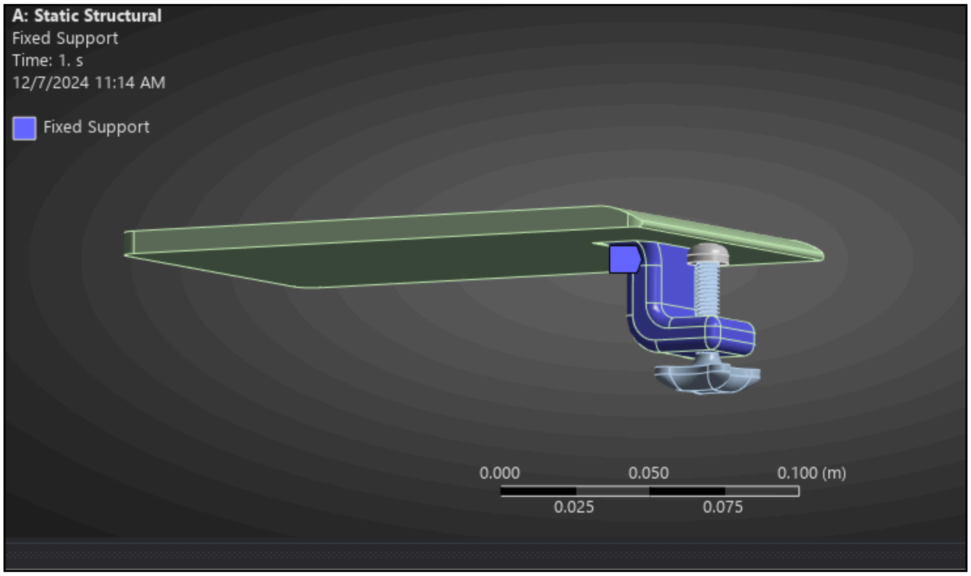


Figure 69: Support Conditions on Clippy

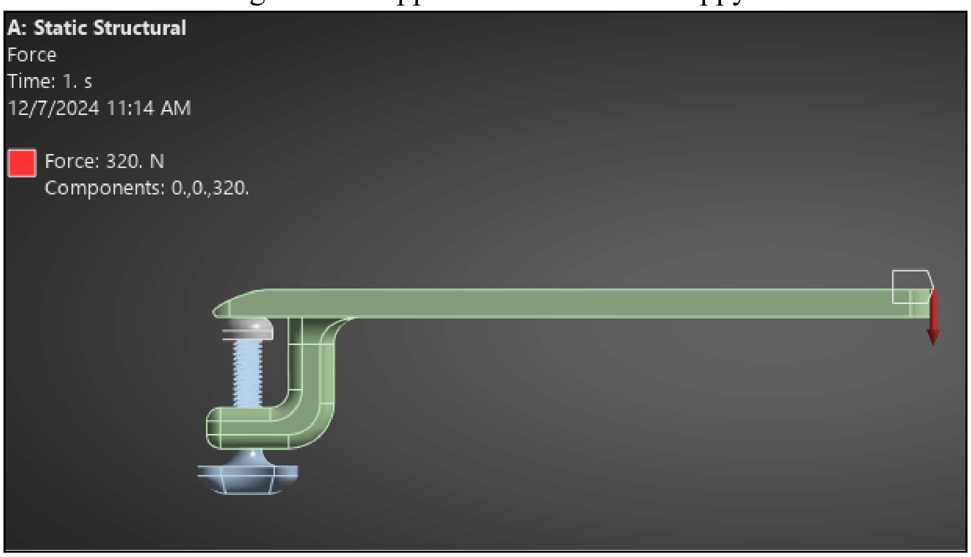


Figure 70: Force Conditions on Clippy

Figure 69 and Figure 70 show the support and force applied to the product when completing Ansys Simulations. The overall clamp that extends out of the desk is treated as a fixed support, and a 320 N force is applied at the very end of the table where it will result in the largest torque. These parameters were chosen because when a user utilizes Clippy, it is expected that the clamp provides firm support. The most amount of force is expected to be applied near the end of the table where students could be leaning on the table extension or items placed near the end. Note that these figures use the default scale set by Ansys, which is 0.26. Also, a force of 320 N might be an overestimate because that is about 71.9389 pound-force. Still, in terms of engineering, it would be better to overestimate the force than underestimate it. The total deformation analysis shows that a great deflection occurs where the force is applied with a maximum deflection of .047991 meters, and the minimum deflection of 0 meters occurs farthest from the applied force. These results tell the team that either a new material that deflects less could be implemented, or a support system could be installed near the end of the table to mitigate deformation. Looking at the normal stress results, it shows that the highest stress occurs near the top surface of Clippy and close to where the Clamp is joined with the table, while the minimum stress is on the opposite surface. The maximum normal stress is 6.158e-7 Pascals, and the maximum normal stress is -5.9746e-7 Pascals. These results imply that there is stress concentration near the top surface of Clippy, so a solution to distribute this stress could be implemented. These solutions could involve fixing the transition from the clamp to the desk or separating them into two parts instead of one 3D print. The Von-Mises stress simulations show that maximum stress occurs near the transition point of the clamp and Clippy and on the opposite surface. The maximum stress is about 5.7247e-7 Pascals, and the minimum is 0.93105 Pascals. These Ansys results show the team where areas of improvement could be implemented. However, if Clippy is to pursue further down the line, a more in-depth Ansys simulation should be considered and advice from industry leaders should be implemented.

2. Cyclic Loading [Jin]

To determine the lifespan of our product we have decided to run a basic fatigue life study. However, it is difficult to come up with an S-N curve without knowing the exact conditions of plastic and its application scenarios such as temperature. Furthermore, plastics generally have higher material variability and have complex stress-strain behaviour depending on strain rate, loading frequency, and other factors. Hence, unlike metals, we could not find a reliable source of S-N curve to perform an accurate cyclic loading analysis. With the understanding that this is not possible unless we do meticulous testing of the exact material over the range of cycles, we chose to take the data from a paper - Investigation of Fatigue Behavior of ABS and PC-ABS Polymers at Different Temperatures: Materials (Basel). 2018 Sep 25;11(10):1818. doi: 10.3390/ma11101818. Here is a picture of the S-N curve we used. We took the 52.7MPA line based on 22 degree celsius room temperature.

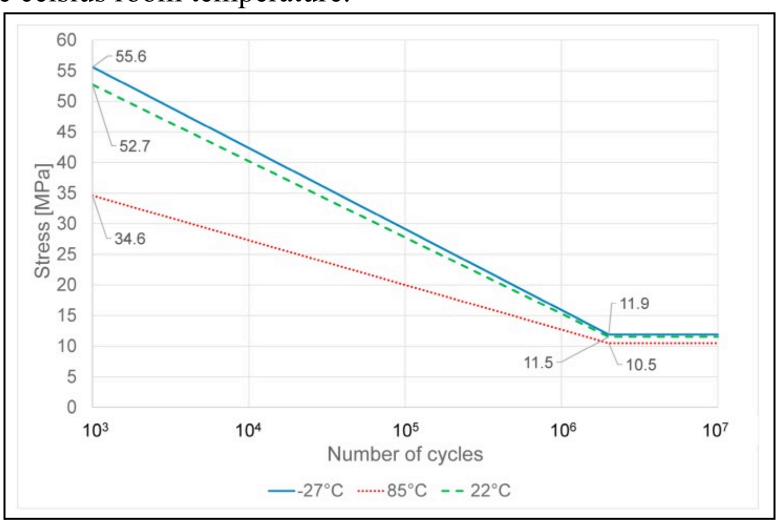


Figure 71: S-N Curve from source

Under the 60N load case with clamp loads of 200N on each end, we obtained the following.

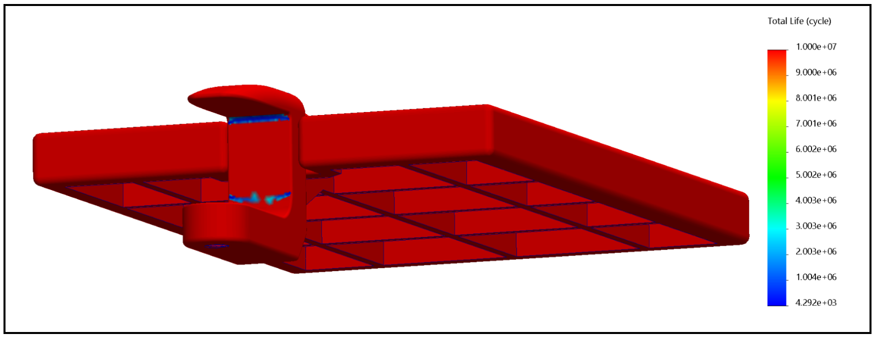


Figure 72: Total Life Cycle of Modular Clippy (Side Bottom View)

As predicted by our static analysis, the clamp region fails first due to higher stress in that region. This is predicted to happen at around 4,300 cycles of loading. As visible, this set of S-N curve data does not give us a high definition in our study of cyclic loading. Hence, another method was used to obtain another (not experiment-based) set of S-N curves that was extrapolated from Solidworks by using Young's modulus ratio. Again, keep in mind that this S-N curve is likely much less accurate than the one based on an experimental set of data, as you cannot simply extrapolate an S-N curve of a plastic based on a ratio of young's modulus between plastic and metal.However, we decided to include this data to show the region of failures and for higher definition.

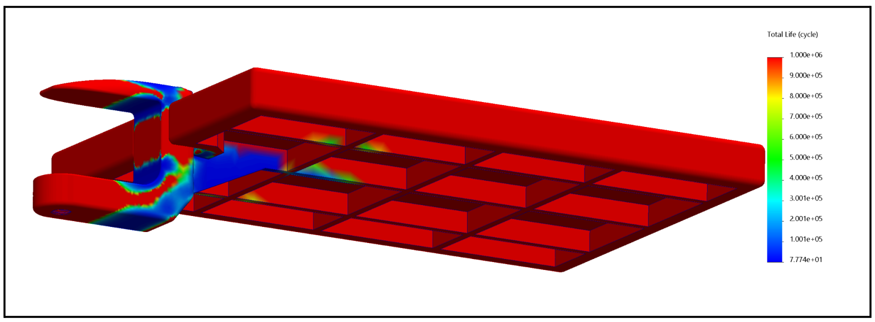


Figure 73: Total Life Cycle of Modular Clippy (Bottom View)

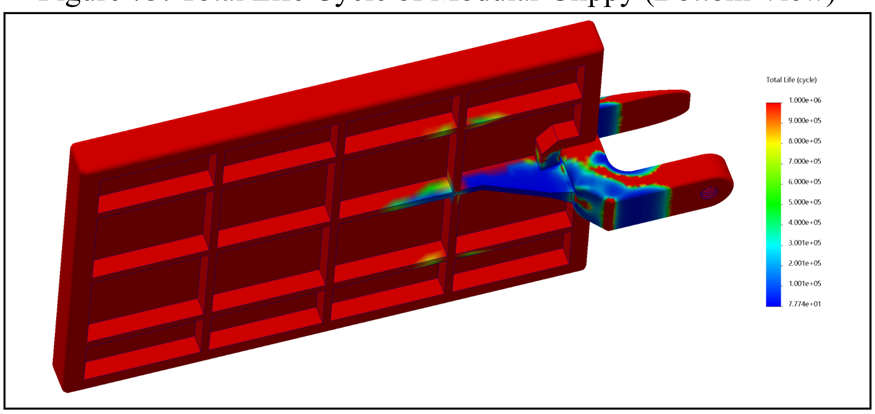


Figure 74: Total Life Cycle of Modular Clippy (Bottom View)

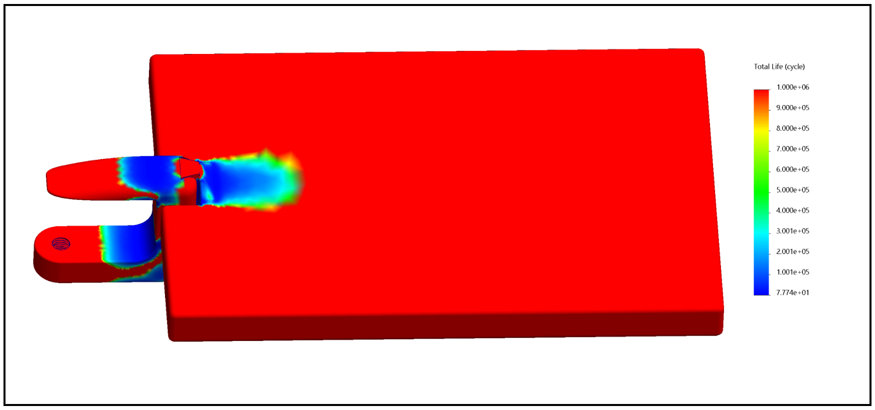


Figure 75: Total Life Cycle of Modular Clippy (Top View)

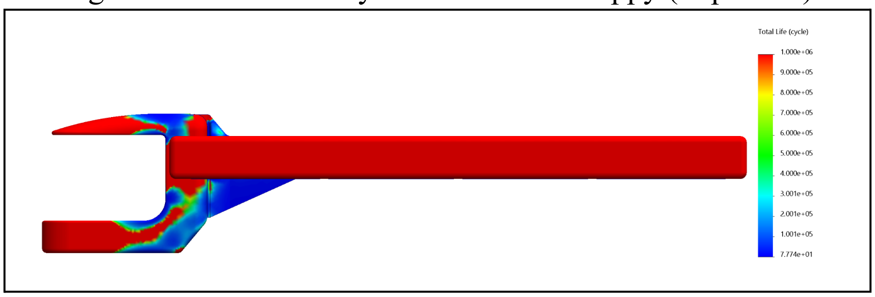


Figure 76: Total Life Cycle of Modular Clippy (Side View)

As predicted, the failure points occur in the clamp and the joint regions of Clippy. Disregarding the total life cycles (due to inaccurate S-N curve), this is still a good visualization in confirming that the joint itself (dovetail) will not fail but the surrounding area will. From these two results, we can generalize that under the worst loading and material conditions, Clippy will last more than 4,000 cycles, and that it will break at the clamp region. We believe that we can improve this life cycle by a factor of magnitude or two at the minimum by using a filled ABS that has better material properties than a simple ABS-PC used in the simulation.

3. ANSYS Polyflow [Mehali, Brandon, Jin]

The team did not end up pursuing manufacturing simulation using Polyflow due to its complexity, and Professor Rajesh Bhaskaran suggested that Moldflow might be a better alternative and software for this application. Therefore, Moldflow was pursued through help from employees of Autodesk and YouTube videos. Also, the simulations in the figures below were based on the default settings built into Autodesk.

Moldflow Simulations from Autodesk were done on some of the final products of Clippy. The main criteria were fill time, deflection, and confidence of fill. Injection sites were placed on the flat parts of the table component where balanced flow is likely to occur. Due to the asymmetric nature of the desk component, some unbalanced flow is expected as seen in Figures [fill time 1] and [fill time 2] under the fill time simulation. Fill time simulations show that the red areas are the last places to be filled in a mold, and the blue areas are the first places to be filled in a mold. Due to the complex underside of the Clippy version in Figure 81, fill time is about 2 seconds longer than the simpler, monolithic version of Clippy.

Deflection, all effects is a result that combines the temperature variations, shrinkage, and orientation effects to showcase the total deflection of the product. Deflection shows how far the nodes of the product moved from its original location. In Figure 78, most of the deflection occurs at the far edge of the table component. In Figure 82, most of the deflections concentrate at all four edges of the table component. Deflection would occur from changes in shape during or after cooling time. Shrinkage should be anticipated as the density of the material changes as the mold cools from hot injection fluid. Figure 82 minimizes the deflection that should occur after cooling occurs, meaning there should be no cause for concern compared to Figure 78.

The confidence of fill estimates how well the injection molding process will lead to favorable results. Red areas mean that the product will most likely not be filled or will not have good quality. Yellow areas mean that the product might have difficulties being filled or may not have good quality. Green areas suggest that the product should not have any issues being filled. As seen in Figure 79, this version of Clippy predicts a good-quality fill. Figure 83 also shows that this version of Clippy will result in a good-quality fill.

The last criterion analyzed using the Moldflow simulations was cycle time. A longer cycle time means that the part takes longer to be filled, cooled, and replaced with the next shot. As seen in Figure 80, we can see that this version of Clippy takes 222 seconds for an entire cycle. This is longer than the combined cycle time of the modular version of Clippy which is 187 seconds. This is probably due to the thickness of the first version and its monolithic design.

Overall, both designs will take a relatively quick time to fill. However, there are benefits and drawbacks to both. The first prototype will experience more deflection or shrinkage during the cooling process and will experience a longer cycle time. The second prototype requires more part to manufacture because of the modularity aspect. While the second prototype is better fitted for the needs of the Clippy, such as the modularity aspect, the design can be reformed to better fit the needs of injection molding to and reduce the cycle time.

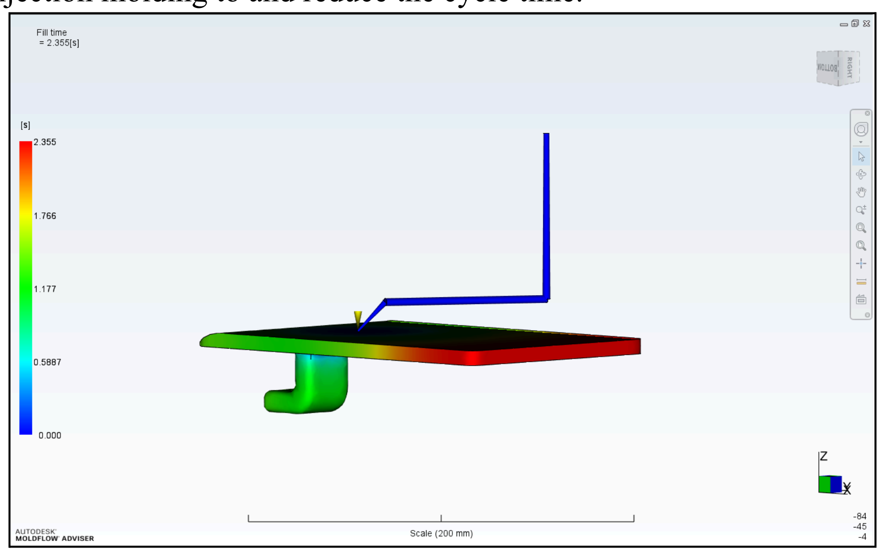


Figure 77: Fill Time

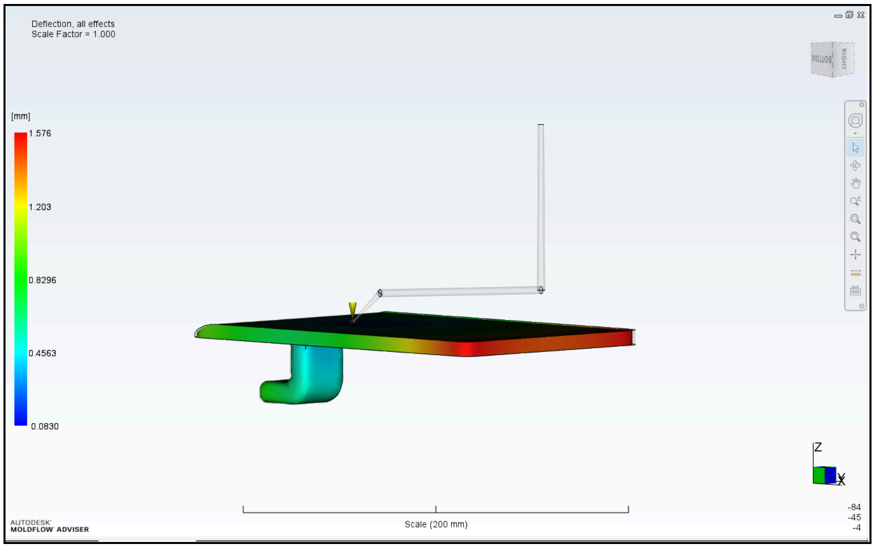


Figure 78: Deflection Effects

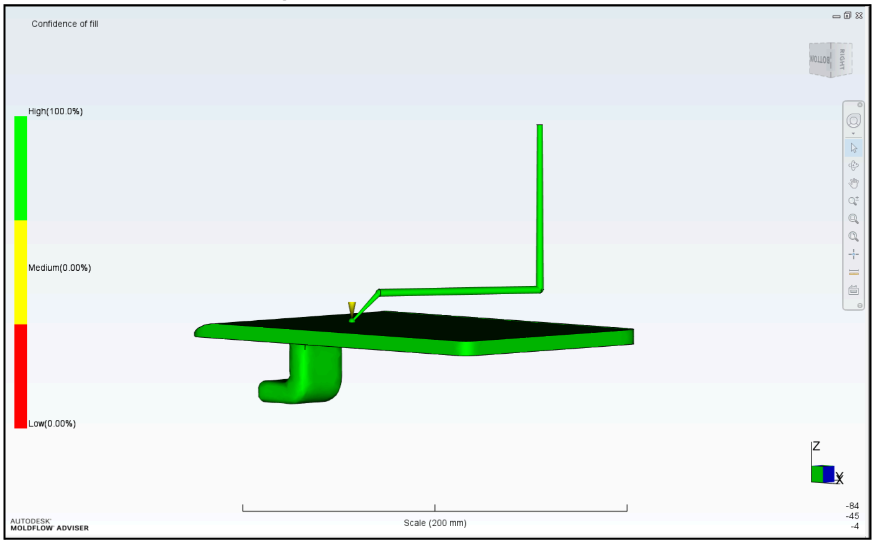


Figure 79: Confidence of Fill

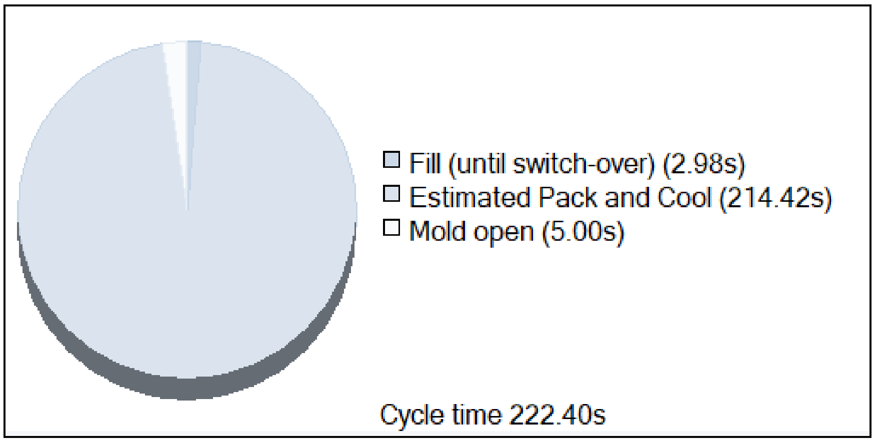


Figure 80: Non-Modular Clippy Cycle Time

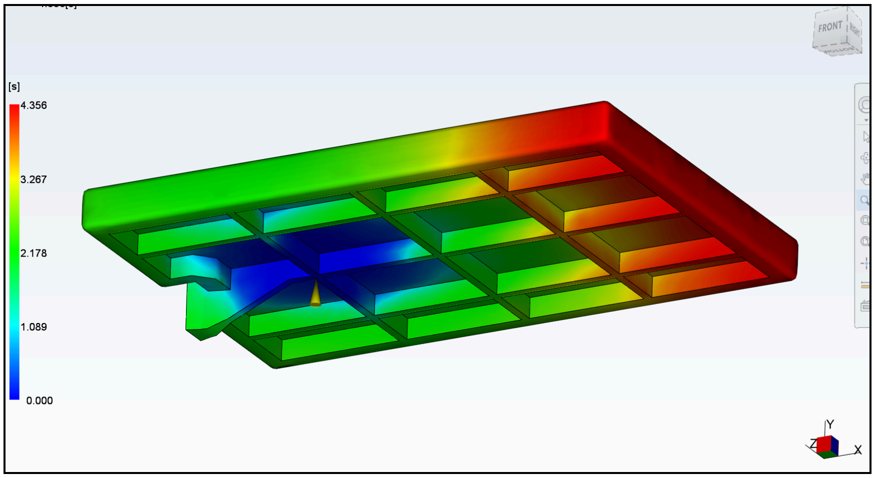


Figure 81: Fill Time

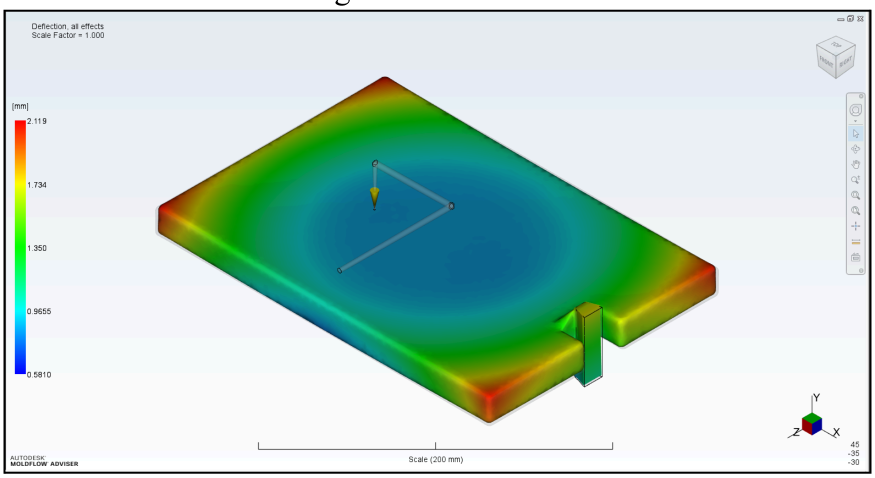


Figure 82: Deflection Effects

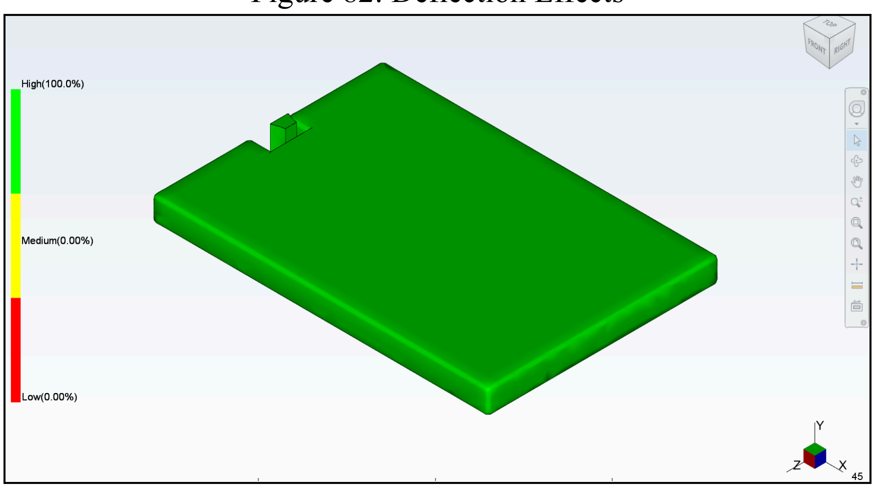


Figure 83: Confidence of Fill

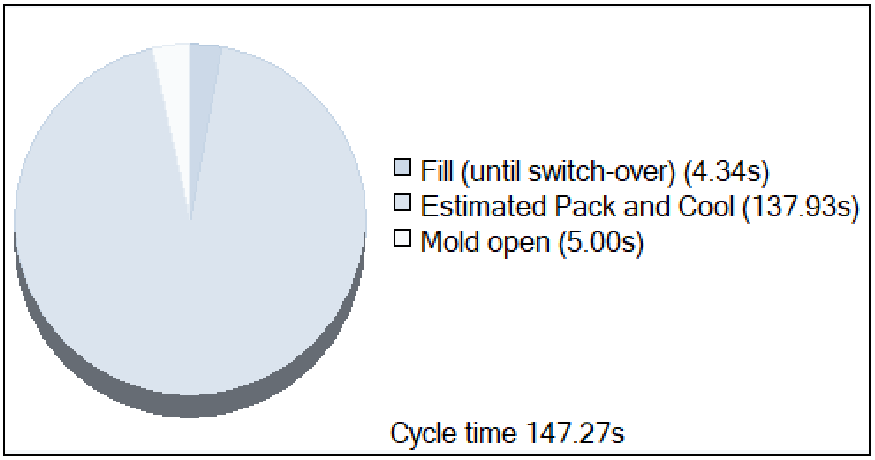


Figure 84: Modular Clippy Cycle Time

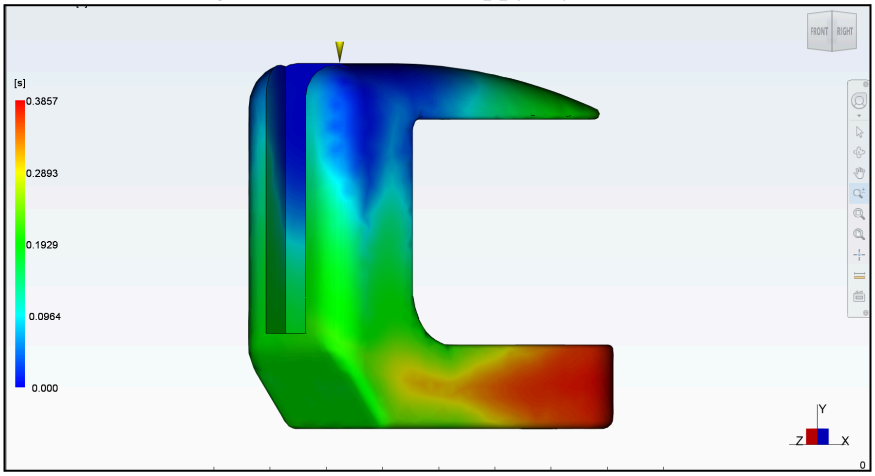


Figure 85: Clamp Fill Time

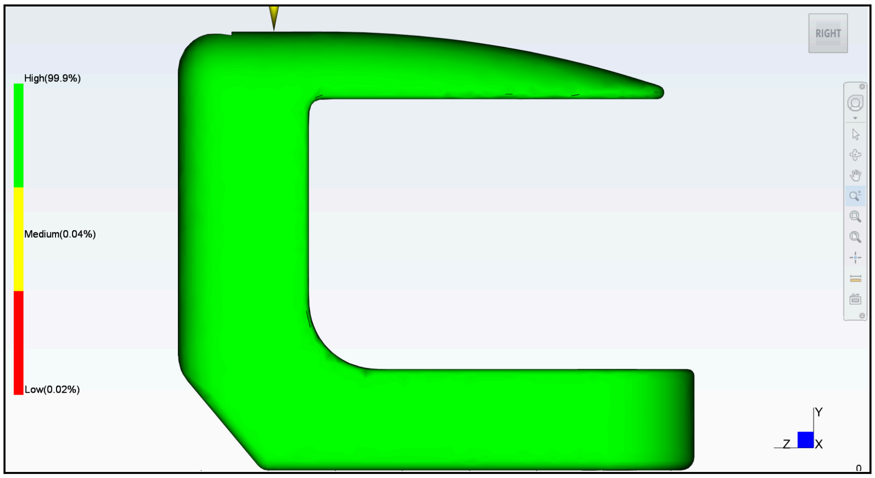


Figure 86: Clamp Confidence of Fill

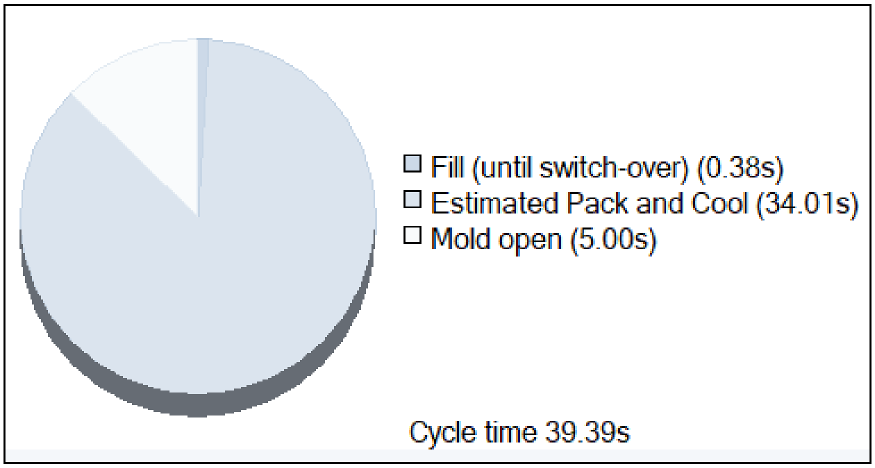


Figure 87: Clamp Cycle Time

g. Project Deadlines [Ludia]

i. GANTT chart

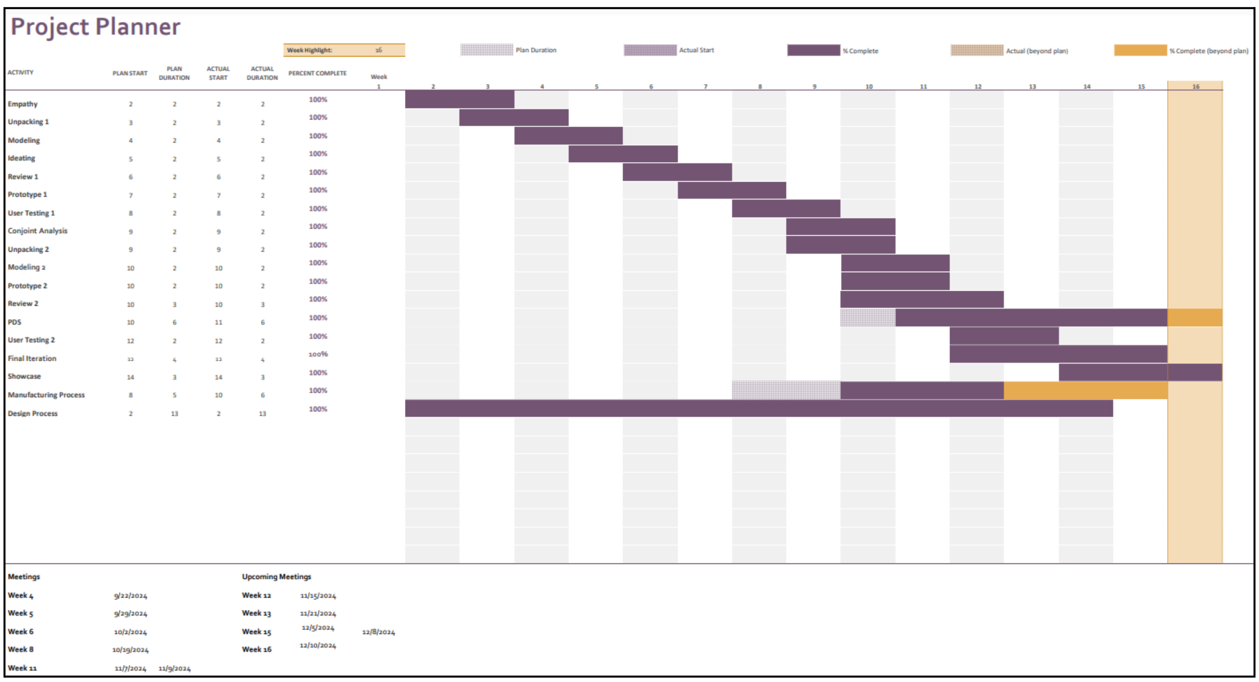


Figure 88: GANTT Chart

The GANTT chart was created based on the timeline given in the class Canvas page. We were able to set meetings based on this GANTT chart to meet certain deadlines. We also monitored our design and manufacturing process using the GANTT chart and kept track of how our product evolved over time.

ii. Highlight Gate Review Dates

Table 1: Gate Review Dates

STAGE	ACTION
Scoping	Empathy
	Unpacking 1
	Modeling
	Ideating
	Review 1
GATE 1: 10/11/2024	**[Determination of Product]**
Development 1	Prototype 1
GATE 2: 10/19/2024	**[Completion of First Prototype]**
Testing 1	User Testing 1
	Conjoint Analysis
	Unpacking 2
	Modeling 2
GATE 3: 10/31/2024	**[Completed Research for Second Prototype]**
Development 2	Prototype 2
	Review 2
GATE 4: 11/13/2024	**[Completion of Second Prototype]**
Testing 2	User testing 2
	Final Iteration
GATE 5: 11/26/2024	**[Completion of Final Product]**
LAUNCH: Showcase 12/9/2024	

We set five gates for our project, as shown in Table 1, Gate 1 was the determination of our product from our initial product ideas, which included Clippy, Washy, and Wavey. After passing through Gate 1, we worked on the first prototype of our chosen product, Clippy. Gate 2 was the completion of the first prototype of Clippy, as then we were able to move onto user testing and analysis. Gate 3 was the finished research and analysis of the first prototype so that we could continue onto our second prototype. With this research, we were able to start the second prototype, and we were only able to pass Gate 4 after completing the second prototype. After the second prototype was completed, we did a round of user testing and created the final iteration of the product. We were able to pass Gate 5 after finishing the final iteration of the product so that we can showcase it during the launch, or showcase.

3. **Market Identification [Jin, Ludia, Brandon, Andrew, Stellar]**
   a. **Target Market [Jin]**

The target market are college students looking to extend the typical lecture desk. Therefore, we want to create a product that is affordable and portable. Let us do a market size estimation first to determine if this is a market that is worth going into.

i. **Market Size – IBISworld/other market reports**

According to US News, there are about 4,000 universities and colleges in the US. Within these universities, let us further assume that there are, on average, about 15 big lecture halls in each university. Further, let us assume that there are about 100 seats per lecture hall. Further, let us assume that about half of these lecture halls have desk sizes small enough to justify and accommodate Clippy. This gives us:

- Total Number of Lecture Halls: 4,000 universities * 15 lecture halls/university = 60,000 lecture halls
- Total Number of Seats: 60,000 lecture halls * 100 seats/hall = 6,000,000 seats
- Total Number of Desks that may require Clippy: 6,000,000 seats * 0.5 desk/seat = 3,000,000 desks

Following our logic of this estimation problem, we can hypothesize that there are about 3 million potential lecture desks that may benefit from Clippy (we assume the actual data to be within a magnitude of this estimation). Furthermore, the National Center for Education Statistics (NCES) quotes that there are approximately 13.5 million students enrolled in 4-year higher education in the US. Assume that one out of fifty students are serious about academics, goes to class, cares enough in that class to buy Clippy, then we have a target market population of 2,700,000 students.

b. **Consumer Behavior [Brandon]**

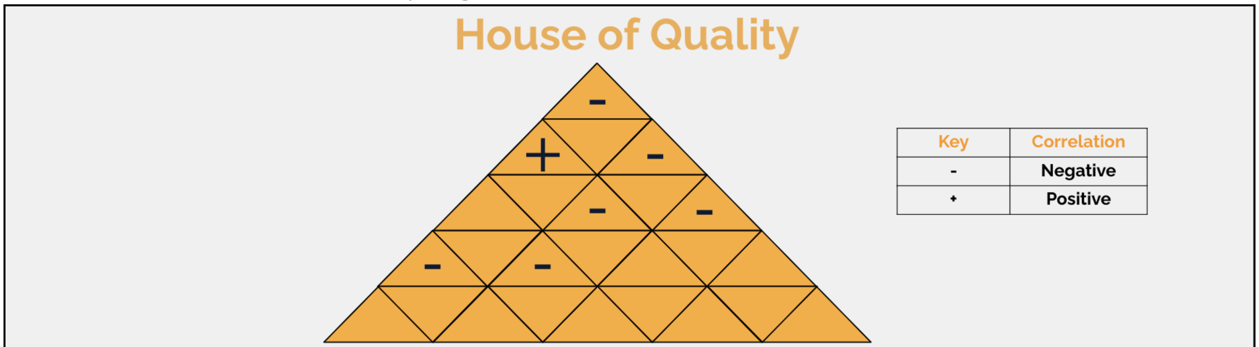
i. **Sociological research**

Until the mid-1800s, lecture desks were large enough to accommodate students' needs. However, as school class sizes grew, due to desegregation and the post-war baby boom in the 1940s-60s, they had to shrink the size of the desks to accommodate the influx of students. The result was more cramped classrooms and smaller desks. This need for capacity carried over into college lecture desk size and design with traditional lecture classrooms. It also no longer represented the estimated 10% of the left-handed population at the time since they had to standardize desk design for the remaining 90% of right-handed students.

ii. **Historical solutions to stated problem**

As left-handed students became more common, lecture halls started including special desks on the left side of the rows for left-handed students. Additionally, as the population growth returned to normal, schools have been able to focus on more collaborative desks that can provide more space. The need for more flexible classroom setups and lower budgets, however, still restricts the current size of desks.

c. House of Quality (again) [Mehali, Andrew]

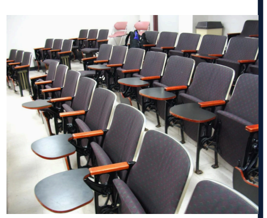
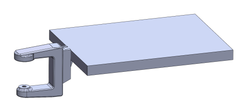


Requirements	#	%	Material	Cost	#Components	Load-Bearing Capacity	Production	Clippy	Desk Buddy	Lecture Desk	Vivo
			↑	↓	↓	↑	↓				
			Engineering Characteristics								
Portability	6	15.00	9	1	9	4	0	6	7	0	3
Use Case	4	10.00	3	1	8	8	7	7	5	1	8
Efficiency	9	22.50	4	6	7	3	0	5	8	7	2
Modularity	7	17.50	0	8	9	2	8	9	0	0	1
Price	9	22.50	9	9	9	7	9	5	5	9	3
Aesthetics	5	12.50	4	6	2	1	5	6	7	3	6
	40	Sum	29	31	44	25	29				
	100	%	18.35	19.62	27.85	15.82	18.35				

Figure 89: Second House of Quality

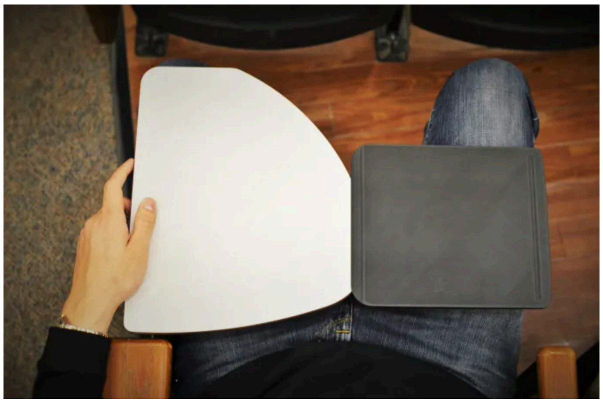
i. Focus on Competitor Analysis [Andrew, Ludia]

Table 2: First Competitor Analysis

Comparisons	Vivo Clamp on Desk Extension	In-Lecture Desk	Desk Buddy	Our Product
Picture				
Advantages	Large desk area Sturdy Flushed with table	Free* Available in majority of classes	Simplistic/efficient Affordable Not disruptive Portable	Simplistic Lightweight Detachable Easy setup
Drawbacks	High price Undetachable Long setup	Limited left handed seats Small surface area	Not Modular Limited table space	Not flushed with surface Table and clamp can snap off easily
Price	$45.99	$0.00*	$25.00	$15

Some of our competitors are Vivo, Lecture Desk, and Desk Buddy. We want our product to be the most affordable besides the lecture desk. This is because our target customers are college students who might not want to spend a substantial amount of money on a desk attachment. In addition, we want our product to be portable allowing college students to take them from their dorms to lecture halls with ease. Looking at the competitors can help the team find ways to make Clippy more unique or implement other ideas into Clippy. This will hopefully increase the marketability of Clippy. The competitor analysis also allows the team to gauge where we fall in the market in terms of our advantages and drawbacks. Then by using this information, the team can redesign Clippy to address our drawbacks while building upon the advantages.

Table 3: Desk Buddy Analysis

 **Top View** - Not much bigger than the desk, smaller in comparison - Looks mostly flat, cross shape on underside to support weight on top better - Maybe we should consider different lecture hall table shape and thickness into account - Smooth texture top	 **Side View** - Same kind of c clamp design as our (current) design - Smaller clamp, ours looks bulkier in comparison - Clamp is attached to surface, not two different parts - Only use one clamp

We also focused part of our analysis on the Desk Buddy, as its design and manufacturing process seemed the most similar to our product. Some aspects we could do differently than the Desk Buddy is having a bigger surface area, having a different texture for the surface, making our product multifunctional, and considering the convenience for left-handed people.

4. **Financial Requirements [Jin, Ludia, Mehali, Brandon, Xavier, Andrew, Stellar]**
    a. **Financial Executive Summary [Jin, Ludia, Brandon]**
        i. **Price [Ludia, Brandon]**

We aim to have the price be roughly double what it costs to make. As a result, the price should be in the $15.00-$25.00 range. We aim to make our product less than $25.00, as Desk Buddy sold their product for $25 and their crowdfunding was not able to make the product come to market. Using the moldflow models for the two designs of Clippy, we determined the price of the non-modular Clippy to be $14.99 and the modular Clippy to be $19.99. Both of these prices fall into the original $15.00-$25.00 range that we aimed for and is less than the cost of the Desk Buddy.

ii. Expected sales [Jin, Brandon]

As there is currently only one competitor in the market of lecture desk attachments, we can expect to penetrate the market through effective marketing and brand awareness. Initially, we intend to capture 10% of the market share during the launch and work up to be a cost leader and capture 50% of the market. Additionally, because Clippy is the only product being marketed to students, this would allow this sharp increase. Based on the market demand and initial market share expectation, we should be producing 270,000 units of Clippy. Due to the unknown market conditions, however, we will take a conservative approach and expect a total of 10,000 initial target sales of Clippy.

iii. Cost [Brandon, Ludia]

There are both fixed and variable costs associated with the manufacturing of Clippy. For the injection molding machines, tooling, and warehouse space, these costs are fixed regardless of the units that are sold. Averaging these costs over five years is estimated to be around $400,000. The variable cost is the amount that must be spent to produce every unit of our product. This includes the cost of the materials, the cost of the mold, the energy and labor from the molding process, and the packaging of the unit. Since we have two designs, the variable cost for each product differs. The variable cost per unit is broken down into the components shown below.

Table 4: Cost Per Part to Produce Modular Clippy and Non-Modular Clippy

	Modular Clippy	Non-Modular Clippy
Material Cost	$1.78	$0.55
Mold Cost	$4.34	$2.26
Molding Cost	$2.78	$2.81
Post-Processing Cost	$5.30	$4.91
Total Cost per Part:	$14.20	$10.53

iv. Net Present Value over 5 years of sales [Ludia, Brandon]

Using the formula $NPV = C_0 + \sum_{i=1}^{5} \frac{C_i}{(1+r)^i}$, where i is the number of years after the product is introduced to the market, we will be able to calculate the net present value over 5 years of sales.

Table 5: Modular Clippy NPV Calculation

Modular	r	0.1077
i	C_i:	Total:
0	-2000000	-2000000
1	57900	52270.47034
2	289500	235941.4568
3	579000	426002.4498
4	1447500	961457.1856
5	2895000	1735952.308
	NPV	1411623.87

Table 6: Non-Modular Clippy NPV Calculation

Non-Modular	r	0.1077
i	C_i:	Total:
0	-2000000	-2000000
1	44600	40263.60928
2	223000	181744.1964
3	446000	328146.9648
4	1115000	740604.326
5	2230000	1337192.969
	NPV	627952.0658

Assuming that r = 0.1077 and our total startup cost over the five years is $2,000,000, we estimated our NPV Present Value over 5 years to be a total of $1,411,623.87 for modular Clippy and $627,952.07 for non-modular Clippy.

1. Fixed cost to produce (tooling, etc) [Brandon, Xavier]

The cost to produce one unit of our product will be the sum of the tooling costs, the machine setup cost, facility costs, and quality assurance and testing divided by the total units produced. If the mold costs $15,000, the setup costs $5,000, and the facility costs $10,000 for 10,000 units, the fixed cost per unit will be $3.00. According to a preliminary cost estimate by custompartnet.com, it will cost $76,349 dollars to produce 10,000 units of Clippy, or $7.635 per unit. Using custompartnet.com, we input the proper parameters, specified ABS as our material of choice, and proposed that our surface roughness and tolerance were not critical to our design. custompartnet.com then broke down our costs into $41,766 for materials, $15,098 for production, and $19,484 for tooling. An industry quote from ICOMold resulted in similar pricing for Clippy, with an estimated cost of $12,459 in tooling costs and $7.49 dollars per unit. A more in depth look into final production costs can be found under our production costs section of the report.

2. Annual net profit: (price-cost)*quantity [Ludia]

Table 7: Annual Net Profit Over Five Years for Modular Clippy

Modular			
Price	Cost	Quantity	Annual Net Profit
19.99	14.2	10000	57900
19.99	14.2	50000	289500
19.99	14.2	100000	579000
19.99	14.2	250000	1447500
19.99	14.2	500000	2895000

Table 8: Annual Net Profit Over Five Years for Non-Modular Clippy

Non-Modular			
Price ($)	Cost ($)	Quantity	Annual Net Profit ($)
14.99	10.53	10000	44600
14.99	10.53	50000	223000
14.99	10.53	100000	446000
14.99	10.53	250000	1115000
14.99	10.53	500000	2230000

3. Estimated Weighted Average Cost of Capital [Brandon, Ludia]

Using the formula for weighted average cost of capital $WACC = (E/V \times Re) + (\frac{D}{V} \times Rd \times (1 - T))$, where E is the market value of the company's equity, D is the market value of the company's debt, V is the total value of capital, Re is the cost of equity, Rd is the cost of debt, and T is the tax rate, we will be able to calculate the estimated weighted average cost of capital. Since we are not officially a company, we do not have a market capitalization and will have to estimate the following values. We will assume the company to have an equity of 8 million, debt of 2 million, and a total value of 10 million.

Using the CAPM pricing model $CAPM = RFR + \beta(MR - RFR)$, where RFR is the risk free rate from treasury bonds, MR is the market return, and β is the risk relative to the market, we can calculate the cost of equity. We will assume an RFR of 4.23%, a market return of 10%, and a higher risk of 1.3. With these numbers we can calculate the cost of equity (Re) to be $CAPM = (4.23) + (1.3)(10 - 4.23) \Rightarrow Re = 11.73\%$.

To calculate the cost of debt, we can use historical data to predict the APR of business loans. The most recent data found online shows a bank business loan can reach up to 8.75% APR. Along with a 21% tax rate, we can calculate our WACC.

$$WACC = (\frac{8}{10} \cdot 0.1173) + (\frac{2}{10} \cdot 0.0875 \cdot (1 - 0.21)) \Rightarrow WACC = 10.77\%$$

4. Compounded annually [Ludia]

Table 9: Net Present Value Compounded Annually for Modular Clippy

Modular	r	0.1077
t	A	P
1	57900	52270.47
2	289500	235941.46
3	579000	426002.45
4	1447500	961457.19
5	2895000	1735952.31

Table 10: Net Present Value Compounded Annually for Non-Modular Clippy

Non-Modular	r	0.1077
t	A	P
1	44600	40263.61
2	223000	181744.20
3	446000	328146.96
4	1115000	740604.33
5	2230000	1337192.97

Using the formula for compound interest when compounded annually $A = P(1 + r)^t$, where A is the final balance after interest has been calculated, P is the principal amount, r is the annual interest rate, and t is the time in years. Through this, we are able to calculate the net present value compounded annually for both modular and non-modular Clippy. Since we are solving for our principal amount of money, the formula becomes rearranged to $P = \frac{A}{(1+r)^t}$.

b. Pricing Policy [Mehali, Brandon]

i. Derived from Conjoint and other observations

Based on the Conjoint Analysis, potential customers are willing to pay no more than $30 for our product made with its current selection of material combinations. One of our competitors, the VIVO Clamp-on Desk Extender, prices the desk at a much higher price at $49.99. Additionally, a startup on Indiegogo.com, a crowdfunding website that helps people raise money for their projects, called Desk Buddy priced their product at $25 but the product was never delivered.

Marketwise, we are more favorable to interested consumers. Since there are a few competitors out on the market that are similar to Clippy, we want to use a value-based pricing policy. Seeing that a few people wanted to purchase Desk Buddy at $25, we want to be a cost leader and increase volume at a lower price to make a profit. Additionally, the other competitor VIVO, is marketed towards consumers with stationary home setups. Based on this information, to make a profit with the intended student demographic, Clippy should be priced at $15 to appeal to customers without undercutting valuable attributes that the competition does not offer. Through mass production and partnerships with other companies with similar products, the cost of Clippy can be cheaper. Using tools, such as injection molding, would produce large quantities of our product without the need for many workers, increasing our profit margin.

Figure 90: Conjoint Analysis on Price

c. **Production Costs [Xavier]**

i. **What manufacturing process will you use based on:**

1. **Economic Batch Size**

Since our end goal is for Clippy to be available across most universities, our economic batch size will be large. However, at our stage in development it would be helpful to order a prototype run, which should keep our economic batch size at 10,000 units. Having smaller runs during our initial production will allow us to test the market before scaling up. This will help Locked-In maximize its profits while minimizing its risk. Once we can prove that our initial batch size is successful, we can then scale up to larger batch sizes, which could potentially serve schools worldwide. Therefore, plastic injection molding would be our best option. Although the initial molds are an investment, the same molding process can produce a much larger batch size once we choose to scale up production.

2. **Surface Roughness**

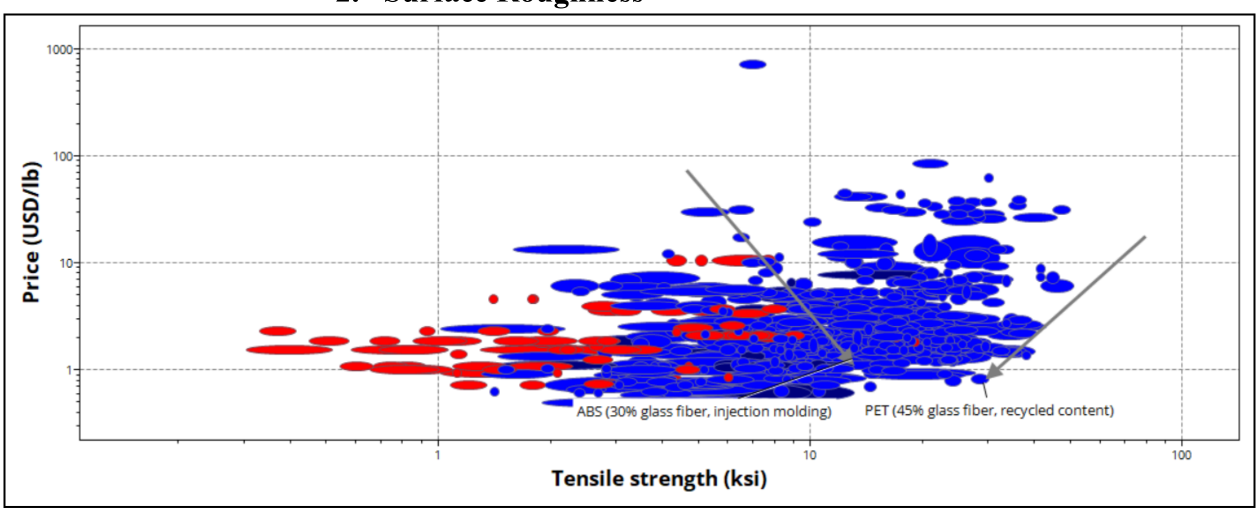


Figure 91: GrantaPack Tensile Strength vs Price

Our product, Clippy is intended to be used in classrooms as an additional writing surface for the students. Therefore, our goal is to make our surface smooth and resilient, similar to the finish on the already provided lecture desks. Since we are aiming to have a smooth surface while also staying lightweight and portable, plastics like ABS and PET would be great solutions. Looking at the graph from ANSYS Granta, ABS and PET also have relatively high tensile strength to price ratio, which is excellent for our intended use case. Since most plastic would work for a smooth surface finish, it is important to take into consideration the price and strength of these materials, as seen in the figure above. As a manufacturing process, plastic injection molding would be most beneficial in this scenario, especially if we are using plastics like ABS and PET. Plastic injection molding would allow us to create the smooth surface finish we are looking for. Additionally, we could create molds that would create indents on the surface to hold different items such as pencils or phones. Plastic injection molding would also optimize the use of plastics, which in the case of ABS and PET, have a very high tensile strength while keeping the price under one dollar per pound. Having a smooth surface in our production might also decrease our manufacturing costs, and aid in the recyclability of our product.

3. Part Architecture

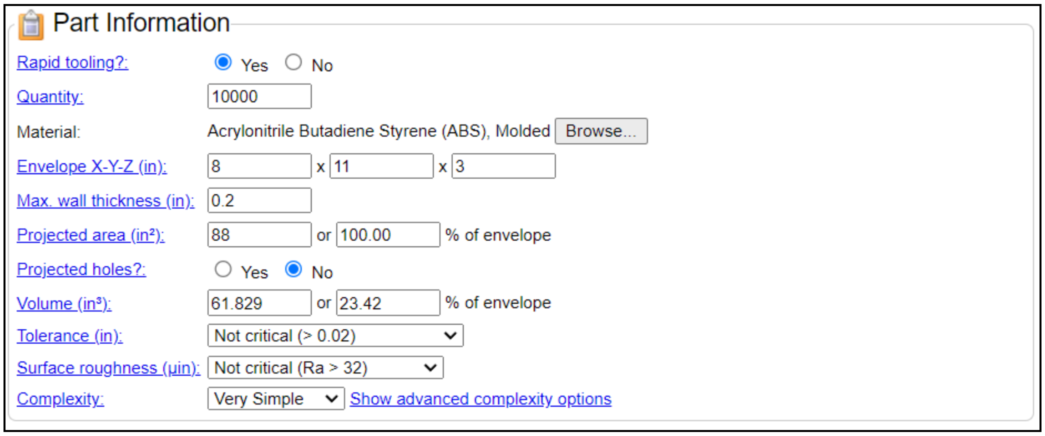
Clippy consists of a table and an attachment component that 'clip' together via a dovetail joint. Our table has strategic extrusions on the underside to keep our weight down while still preserving structural integrity of the product. Our clipping mechanism was chosen so that there may be different attachments in the future, such as a coffee cup holder instead of a full desk. However, there is a second version of clippy that is non-modular, which combines our clip and table into one solid product. The non-modular version of clippy makes the most sense financially, since it keeps our production and shipping costs down, whicll still preserving functionality. On the other hand, the modular version of Clippy emphasizes different use cases, which was important to our users. Overall, Clippy maintains simple product architectures that we plan to shape out of plastic material such as ABS. Therefore, plastic injection molding would be the best manufacturing option for our design architecture. Having a straightforward geometry is also optimal for plastic injection molding, since the tooling costs for the molds will go down.

ii. Tooling parameters and costs for the selected process

1. Custompartnet.com

Physical	
Mass	280.557 ouncemass
Volume	61.829 in^3
Density	4.538 ouncemass / in^3
Area	381.748 in^2

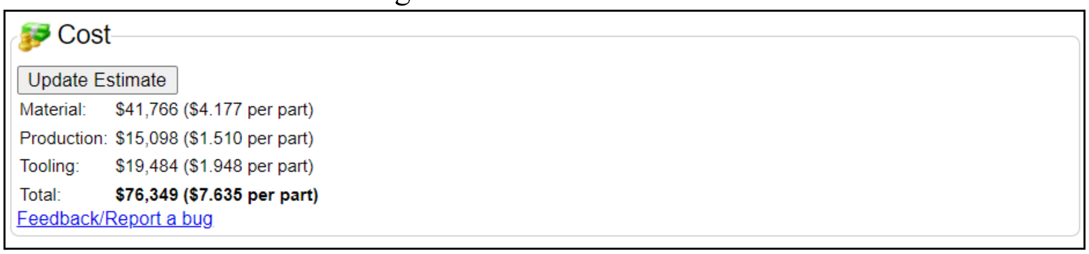
Figure 92: Properties of CAD model



Part Information

Rapid tooling?:	(•) Yes ( ) No
Quantity:	10000
Material:	Acrylonitrile Butadiene Styrene (ABS), Molded Browse...
Envelope X-Y-Z (in):	8 x 11 x 3
Max. wall thickness (in):	0.2
Projected area (in²):	88 or 100.00 % of envelope
Projected holes?:	( ) Yes (•) No
Volume (in³):	61.829 or 23.42 % of envelope
Tolerance (in):	Not critical (> 0.02)
Surface roughness (μin):	Not critical (Ra > 32)
Complexity:	Very Simple Show advanced complexity options

Figure 93: Part information



Cost

Update Estimate

Material:	$41,766 ($4.177 per part)
Production:	$15,098 ($1.510 per part)
Tooling:	$19,484 ($1.948 per part)
Total:	**$76,349 ($7.635 per part)**

Feedback/Report a bug

Figure 94: Preliminary Cost Estimate

Based on our initial CAD design, we calculated accurate values for our area and volume, and used additional tools to gain insight into the dimensions of our product. Custompartnet.com required many different parameters, and the most straightforward way to measure these requirements was by looking at our CAD model. Using Custompartnet.com, we specified all the necessary dimensions of our product which we calculated from our CAD model. We also maintained a wall thickness of 0.2inches and opted for no projected holes in our final product. Since our geometry is simple and meant to fit a variety of different desk sizes, we believe that our tolerance is not critical for the production of our product. Additionally, since we want a smooth surface for the top of our desk, our Surface roughness is also not critical to our design. At a batch size of 10,000 units our price per unit would be $7.365, putting our total price at $76,349. This is assuming we use ABS, molded material. There are cheaper options available, but these materials might sacrifice the durability of our product and don't have a competitive strength to price ratio. Custompartnet.com also breaks down our cost into 3 separate categories: Material, Production, and Tooling. For Clippy, it is estimated that we will invest $4.177 in material per unit, $1.510 in production per unit, and $1.95 in Tooling. At $7.365 per unit, pricing our product at $15 would give us a reasonable profit margin while still undercutting competing brands.

2. **Quotes from manufacturer – simple product architectures, and manufacturing heavy team**

ICOMold by FATHOM

Quote: U-241208154426
Date: 12/08/2024

Xavier Figueroa

111 Osmun Place
Ithaca, New York 14850 United States
phone:5512256416

Brian Enneper
ICO Mold, LLC
1050 Walnut Ridge Dr
Hartland, WI 53029
phone:419-205-9384

Tooling

Item	Part Description	Material	Color	Surface Finish	Tooling Config.	Tooling Life	Lead Time	Sample Quantity	Tooling Price	Snap Shot
1	Part1.stp	ABS+30%GF LG LUPOS GP2300	NATURAL COLOR	SPI-C1 low polish	1	Production Mold	15 Business Days	5	$12,459	

Parts

Item	Part Description	Part Size	Part Weight	Part Qty	Price Ea.	Estimated Price Ea. w/Air Shipping	Estimated Price Ea. w/Ocean Shipping		
1	Part1.stp	250.0×60.3×160.0mm	0.6440kg	10000	$7.49	$20.63	$10.60		

Customer's Additional Notes:
The goal is to have an initial economic batch size of 10,000 units. We want to use

Quote Engineer's Additional Notes:

Tax and shipping calculated at time of shipment. If shipping is quoted, rates are subject to change based on time of shipment. Quote is valid for 30 days.

Unless explicitly stated in quote description, manufacturing quality and accuracy is based on the expectations defined in
https://fathommfg.com/quality-and-accuracy-standards

Payment terms for molds are 50% due upon receipt and 50% due at T0 sample shipment.

There is a setup fee of $150 per mold, per part run.

THIS OFFER IS CONDITIONED ON, AND LIMITED TO, BUYER'S ACCEPTANCE OF FATHOM'S TERMS AND CONDITIONS OF SALE LOCATED AT:
https://fathommfg.com/terms-and-conditions

Figure 95: ICOMold Preliminary Quote for Non-modular Design (https://icomold.com/)

ICOMold by FATHOM

Quote: U-241208171001
Date: 12/08/2024

Xavier Figueroa
111 Osmun Place
Ithaca, New York 14850 United States
phone:5512256416

Brian Enneper
ICO Mold, LLC
1050 Walnut Ridge Dr
Hartland, WI 53029
phone:419-205-9384

Tooling

Item	Part Description	Material	Color	Surface Finish	Tooling Config.	Tooling Life	Lead Time	Sample Quantity	Tooling Price	Snap Shot
1	Att_modular.stp	ABS+30%GF LG LUPOS GP2300	NATURAL COLOR	Standard No Machine Mark	1	Production Mold	15 Business Days	5	$6,873	
2	Table_Modular.stp	ABS+30%GF LG LUPOS GP2300	NATURAL COLOR	Standard No Machine Mark	1	Production Mold	15 Business Days	5	$9,408	

Parts

Item	Part Description	Part Size	Part Weight	Part Qty	Price Ea.	Estimated Price Ea. w/Air Shipping	Estimated Price Ea. w/Ocean Shipping		
1	Att_modular.stp	77.0×65.0×26.0mm	0.0685kg	10000	$0.95	$2.36	$1.30		
2	Table_Modular.stp	269.0×185.0×48.0mm	0.8100kg	10000	$10.11	$26.82	$13.71		

Customer's Additional Notes:

Quote Engineer's Additional Notes:

Tax and shipping calculated at time of shipment. If shipping is quoted, rates are subject to change based on time of shipment. Quote is valid for 30 days.

Unless explicitly stated in quote description, manufacturing quality and accuracy is based on the expectations defined in
https://fathommfg.com/quality-and-accuracy-standards

Payment terms for molds are 50% due upon receipt and 50% due at T0 sample shipment.

Figure 96: ICOMold Preliminary Quote for Modular Design (https://icomold.com/)

We chose ICOMold as a preliminary manufacturer, since they specialize in plastic injection molding are are trusted by companies such as Honeywell, Panasonic, Kawasaki, and many more. ICOMold is also excellent with quick turnaround time, competitive pricing, and the ability to request an online quote. The first quote that was requested was for the non-modular version of Clippy, which would only require one mold, as seen above. The material choice was ABS (30% Glass Fiber), with a natural color and a SPC-C1 low polish finish. ABS (30% Glass Fiber) has a high tensile strength to price ratio and is also readily available, making it a great option for our product. Based on the .stp file we submitted, our part size is 250x60.3x160mm and weighs a total of 0.6440 kg. It was also specified that our economic batch size was 10,000 units. We received a quote of $7.49 per part before shipping, which is very close to the $7.63 that was predicted by custompartnet.com in our tooling parameters and costs section. This confirms the fidelity of our preliminary estimations. However, the quote we received from ICOMold makes it clear that we will have additional to make additional investments into tooling and shipping costs. If we were to utilize ocean shipping, our total price per part would be closer to $10.60 cents. It is possible to manufacture our parts locally, but that would increase our production costs even further. In order to have a reasonable profit margin, Clippy would have to be priced at double the production costs, meaning our final price would be closer to $21.20. This price is too high to significantly set us apart from our competitors, so we will need to research ways to bring down our price in the future.

The second quote we received was for the modular version of Clippy, meaning that the attachment mechanism and the table would be separate and therefore require separate molds in manufacturing. When requesting the quote for the modular version of Clippy, we specified ABS (30% Glass Fiber) to keep the material constant between versions of Clippy, but we opted for a standard no machine mark finish in order to keep the costs down as much as possible. Our modular clip has a part size of 77.0x65.0x26.0mm and a part weight of 0.0685 kg. Our Modular table has a part size 269.0x185.0x48.0mm and a part weight of 0.81 kg. At a specified economic batch size of 10,000 units, the price per unit for our clip and table comes out to $0.95 cents and $10.11, respectively. The total cost then becomes $11.06 per unit before shipping. Utilizing ocean shipping, our total costs become $15.01, which means Clippy would have to be priced at closer to $30 dollars in order to have a reasonable profit margin. This would make the modular version of Clippy too expensive to pursue if we want to undercut our competitors. From a financial perspective, it would benefit us to focus our efforts on the non-modular version of Clippy. While this sacrifices some functionality, it keeps our price becomes much more reasonable, which is extremely important to our customer based on our conjoint analysis.

Additionally, we have to take into consideration tooling costs, which are exceptionally high since we are utilizing plastic injection modling. For the modular version of Clippy the tooling cost fot our clip and table are $6,873 and $9,408, respectively. This brings us to a total tooling cost of $16,281. For the non-modular version of Clippy, our total tooling decrease to $12,459. Again, the non-modular version of Clippy makes the most sense financially. However, Custompartnet.com gave us a total tooling cost estimate of $19,484. While this is within the same magnitude of cost, it could point to erroneous inputs of area and volume. ICOMold's manufacturing quote inspires more trust and reliability, since they utilze the .stp files to make a calculations rather than manual inputs from the user. Additionally, their estimates are reviewed by engineers, a functionality that Customparnet.com is lacking. It is important to note that while tooling costs are relatively high, it would only be a sunk cost during our first year of manufacturing, since we can continue to utilize the same molds and process as we scale up production.

d. Cost of Goods Sold [Andrew]

i. Bill of Materials (BOM)

The current BOM is based on our prototyping costs. Thus, the cost per unit of Clippy is significantly higher than the cost of our production unit estimate. In addition, this BOM assumes 3D printing is free as it is accessible through the RPL, however, this is not true in a manufacturing setting as employees must be hired to monitor the 3D prints.

Table 11: Bill of Materials

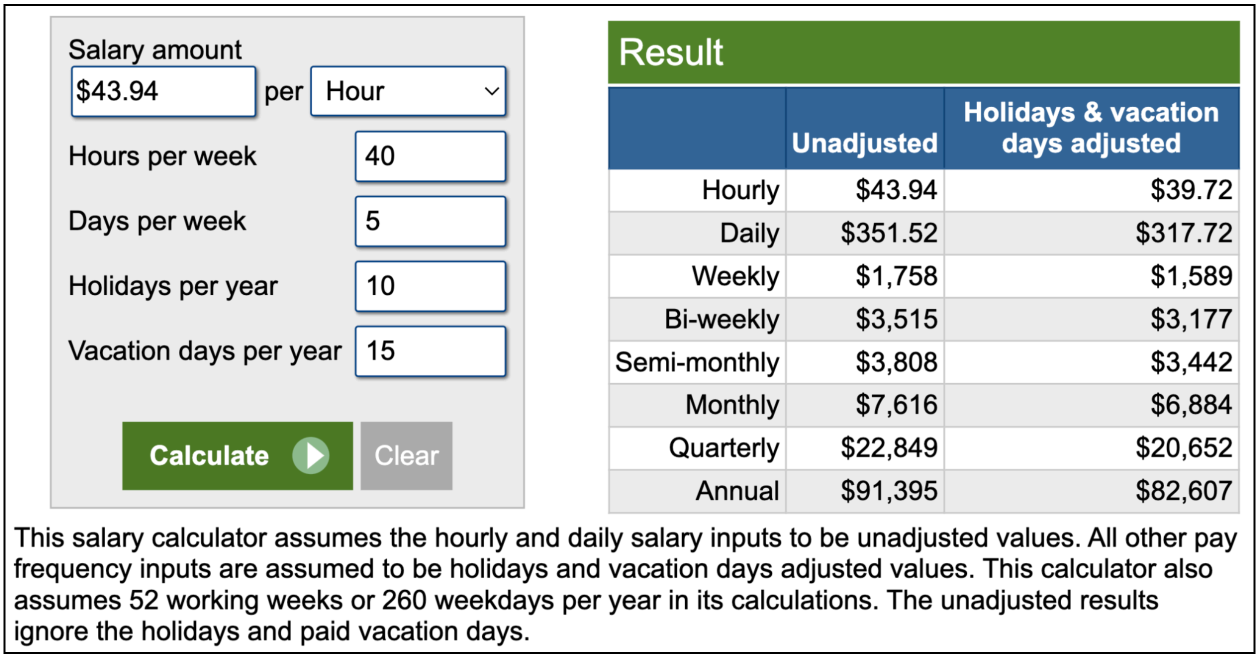
Purpose	Item	Quantity	Cost	Manufacturability	Link
Table Platform of Clippy	Cast Acrylic Sheet 12" x 12" x 1/8"	1	$9.65	Laser Cut Injection molding for mass production	https://www.mcmaster.com/8505K741-8505K116/
Clamping Mechanism of Clippy	N/A	1	Free	3D printed for prototype Injection molding for mass production	
Screw for the Clamp	Stainless Steel Flanged Hex Head Screw M10 x 1.5 mm Thread, 50 mm Long	1	$10.47	Brought	https://www.mcmaster.com/90166A164/
Heat Inserts	18-8 Stainless Steel Tapered Heat-Set Insert for Plastic M10 x 1.5 mm Thread Size, 15.88 mm Installed Length	1	$4.01	Brought	https://www.mcmaster.com/97163A128/
Rubber stopper	Free	1	$0.00	Brought	Found in Upson

The total cost of items that can be brought from McMaster Carr for Clippy is approximately $24.13. However, this cost includes the acrylic table, but the team has pivoted to a 3D printed table, so the cost would be about $14.48. Note that these calculations do not include the cost of a 3D printed table or clamp.

ii. Labor

The Bureau of Labor Statistics[2], claims that for private industries the average cost for a worker including benefits is $43.94 per hour. Therefore, assuming an average work day of 8 hours, the daily salary is $351.52.

[2] https://www.bls.gov/news.release/pdf/ecec.pdf



	Unadjusted	Holidays & vacation days adjusted
Hourly	$43.94	$39.72
Daily	$351.52	$317.72
Weekly	$1,758	$1,589
Bi-weekly	$3,515	$3,177
Semi-monthly	$3,808	$3,442
Monthly	$7,616	$6,884
Quarterly	$22,849	$20,652
Annual	$91,395	$82,607

Figure 97: Labor Cost

This tool calculates an annual employee salary of $91,395 excluding holidays and $82,607 including salary. These values are underestimated as it does not include potential overtime that employees have worked. Assuming the team size remains at 8 people, the total cost of employee per year is $660,856. This means that Clippy as a company will require substantial capital not only towards employees but also the product itself.

e. Capital Investment Required [Mehali, Xavier]

i. How will you raise money for manufacturing equipment or afford to outsource? [Xavier]

Since our product is in the early stages of development, a viable option for funding is crowdfunding, which is possible through 3rd party avenues such as Kickstarter. This method of raising funds relies on strong marketing of our product and relies on public support in order to meet our objective. However, it is the quickest and most feasible way for us to meet our goal, especially when social media platforms are an accessible form of gaining traction for our product. Since this product is marketed towards college students, our target audience is already best reached through social media and online forums. Additionally, starting a crowdfunding campaign will allow us to garner funds from friends and family who are willing to help our cause.

Our first step towards our crowdfunding campaign would be to focus on our personal community and build our own email list to garner interest. Concurrently, we also need to develop our pre-launch landing page, which will serve as a website where people may explore our product and mission. These strategies would target our early adopters who are passionate about the product. Additionally, hands-on demos at local colleges would garner further interest from students. Once we have a substantial following from email lists, social media, and in-person demos, our next step will be to launch our Kickstarter campaign. While Kickstarter is a great way to raise awareness and funds, we will have to combine our Kickstarter campaign with additional outreach efforts to fully fund our production.

ii. How will you raise money to pay employees to scale up production? [Mehali]

It is important to identify the funding needed first and how it will be distributed. Getting a rough estimate of the additional staff or production equipment needed for future production capabilities would help us keep our goals in mind for our business. If the company can afford and meet the requirements, Locked-In can take out a bank loan for additional capital. Bank loans often fund the growth and development of companies to improve production and facilities. Locked-In would have to consider their annual revenue, potential business plan, collateral, etc. first before opting for a bank loan. Reaching out to industry experts to advertise our products and services could build valuable connections with potential investors. Investments from other companies or organizations can help with paying employees and improve production. Another way to access funds is by acquiring competitors to our company. As mentioned before, there are prototypes of our same concept out there that lack the modularity and competitive edge that we have. Being able to form alliances could bolster Locked-In and give us access to significant funds for the growth of our company. There could also be sacrifices made by the founders, where they do not pay themselves a salary for years, and the product does not make a profit. In addition, they will have to pour their funding into the company to help scale up production or accommodate for losses experienced throughout the project.

5. **Legal Requirements [Mehali, Xavier, Iyana, Stellar]**
   a. **Safety & Environmental Regulations for your product's manufacturing [Stellar]**

To ensure Clippy is manufactured responsibly and adheres to U.S. and international standards, we will comply with the following regulations:

- Worker Safety – All manufacturing facilities will adhere to OSHA (Occupational Safety and Health Administration) standards and guidelines to ensure a safe production environment. This includes maintaining and inspecting machinery, providing workers with protective equipment such as eyewear and gloves, and offering appropriate clothing and safety training to prevent workplace accidents proactively.
- Material Compliance – All materials used in Clippy's production will comply with the TSCA (Toxic Substances Control Act) to eliminate harmful chemicals. For international markets, Clippy will also meet RoHS (Restriction of Hazardous Substances) and REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) regulations to ensure environmental and health safety. Additionally, we are committed to using sustainable materials that reduce environmental impact, reinforcing our dedication to responsible manufacturing.
- Manufacturing Processes – Clippy's production will adhere to ISO 14001 Environmental Management standards to minimize waste and improve resource efficiency. Compliance with EPA (Environmental Protection Agency) regulations, including the CAA (Clean Air Act) and CWA (Clean Water Act), will ensure control of emissions and proper wastewater management. To further minimize the environmental harm, we will prioritize energy-efficient processes and equipment to reduce energy consumption.

   b. **Safety & Environmental Regulations for your product's use [Stellar]**

Clippy will be designed to prioritize user safety and environmental sustainability by following these principles:

- Durability and Maintenance – Clippy will be manufactured using high-quality materials that resist wear and tear to ensure long-term usability. Maintenance guidelines, including instructions for tightening screws and cleaning surfaces, will be provided to extend the product's lifespan and enhance user experience.
- Load and Stability Testing – Clippy will undergo rigorous load-bearing and stability testing based on ASTM International standards. These tests will confirm that the product can safely support its intended weight without failure. Clear warnings regarding maximum load capacity and desk compatibility will be displayed in multiple languages to prevent misuse.
- Material Safety – All materials used in Clippy will comply with TSCA and REACH regulations to ensure the absence of harmful substances. Clippy will also be manufactured with non-flammable materials and feature smooth, rounded edges to minimize the risk of injury.
- Recycling and Environmental Responsibility – Clippy will be manufactured with recyclable materials to reduce environmental impact. Recycling symbols will be included on the product, along with recycling instructions in the packaging to encourage responsible disposal at the end of its life.
- User Instructions and Warnings – Comprehensive assembly instructions, including clear diagrams and step-by-step guidance, will be included to ensure proper usage. Safety warnings, such as maximum load capacity, desk compatibility, and maintenance recommendations, will be clearly outlined in multiple languages to support accessibility for a global user.

c. Potential Liability Issues for use [Mehali]

i. Prediction of Misuse Cases

There are two components to the overall assembly of Clippy where misuse could occur. Analyzing Figure 98, the product could experience failure modes in the clamp and the table attachment. One possible misuse case of the clamp is overusing the rubber stopper, causing general wear and tear. This could cause damage to the surface that Clippy is being attached to and potentially reduce the clamping force provided by the handle. Another misuse case is overusing the handle and causing the threads to break. This would also reduce the clamping force. Another misuse case would be trying to attach the clamp to a table with a thickness greater than the allowable tolerance built into the system. If forced upon the device, the clamp will most likely fracture at the inner corner of the clamp as predicted through finite element analysis. Another misuse case is screwing the handle too far up without attaching the clamp to another surface. The force from the handle onto the inner face of the clamp will cause the top of the clamp to deflect and eventually break at that inner corner. If the top of the clamp is approximated to be a cantilever beam, the base of the beam will experience the most bending moment and the most stress.

When analyzing the table attachment component, there are a few misuse cases. One possible misuse case is placing a load that is heavier than the ultimate load that the device can withstand. This would damage the dovetail attachment on the clamp and the table attachment. Additionally, under heavy loads, the table component would deflect the most at points farthest from the dovetail joint. Without a flush surface, the user's surface might slip off the table, undermining the overall use of the device.

1. Failure Mode and Effect Analysis

1. Identify		2. Classify										
Item (component, part, assembly)	Function	Requirements	Failure mode	Effect(s) of potential failure	Severity	Classification	Potential causes of failure	Current design controls (prevention)	Occurrence likelihood	Current design controls (detection)	Effectiveness of best method of detection control	RPN (Risk priority no.)
Clamp	Clips onto lecture desk or any desk	Device should have enough clamping force to stay on the desk	The rubber stopper gets damaged, reducing grip/friction on surface	Device is unable to stay on lecture desk, ruining device's	8	Major	Repeated use, wear and tear	Using a high strength, elastic material for durability, make rubber stopper	5	Visible wear and tear	6	240
			The threads from clamp break, releasing the tension between the parts that provide clamping	Device is unable to stay on lecture desk, ruining device's	7	Significant	Repeated use, wear and tear	Using a threaded heat-insert; metal has higher yield strength compared to ABS plastic	1	Visible wear and tear, resistance to screwing motion	4	28
		Device should remain flush on a surface	The clamp is being attached to a table with thickness greater than clearance.	The clamp will deflect and fracture at the inner corner.	5	Significant	Table thickness is greater than clearance	Visual inspection of clearance	6	Deflection on upper ledge of clamp	5	150
			Handle is screwed all the way up, putting pressure on the inside of the clamp.	The clamp will deflect and fracture at the inner corner.	4	Low risk	Over-screwing handle	Visual inspection of clearance, yield strength threshold of ABS plastic	5	Deflection on upper ledge of clamp	5	100
Table Attachment	Acts as a desk extension to previous lecture desk	Device should be able to hold user's belongings (at least half of average body weight)	The table attachment deflects under high loads.	User's belongings might fall off table attachment	5	Significant	Loads applied exceed maximum load capacity	Grid underneath table adds stability	6	Visible deflection	9	270
		Device should be able to be secured to clamp through dovetail attachment	Dovetail attachment fractures	Device in unable to attach to the clamp	7	Significant	Loads applied exceed maximum load capacity; user mishandles dovetail attachmen	Borders installed around dovetail joint	4	Visible fracture	9	252

Figure 98: Failure Mode and Effect Analysis Chart

d. Intellectual Property Considerations? [Xavier, Iyana]

i. Pursue Utility, Design patents? Why?

When evaluating the uniqueness and integrity of one's design, the creator often needs to make a decision concerning the protection of how their design looks, or its novelty. As Locked-In evaluated Clippy, we analyzed the features unique to our product, as well as competing products on the market and the implications of pursuing a patent. Locked-In has concluded that it would not be viable to pursue any patents for Clippy. Our product would fall under the category of a utility patent, which protects a new or improved product, process, or machine, however; it would not be feasible to go through the entire process of applying for a patent considering application costs, similar products on the market, and our uncertainty concerning Clippy's design.

ii. Trade secrets? Why?

Trade Secrets are important to our company because they give LockedIn a competitive advantage by protecting proprietary information that might not yet be patented. A product such as Clippy makes keeping Trade Secrets difficult, since its relatively simple design would allow users to recreate similar designs. However, our trade secrets could come in the form of manufacturing processes and materials used. One of our goals is to create an affordable product for students, and the manufacturing stage of production will contribute the most to the price per unit of Clippy. As a result, it is important to keep our manufacturing process a trade secret, so that competitors are not able to create a product at a similar price point. Having a trade secret is more cost-effective than filing a patent, which requires a plethora of registration fees in the long run. Additionally, retaining trade secrets avoids the disclosure of our innovations that comes with filing for a patent. On the other hand, trade secrets rely on confidentiality, so we must have a plan in place to implement them. The first step we can take would be to have current and new employees sign a non-disclosure agreement before they have access to sensitive information. It is also important to limit the amount of people that have access to our trade secrets. Finally, LockedIn must have strong digital security to prevent unauthorized activity.

iii. Trademark? Describe

1. Team name and logo

Our Team name is Locked-In. The following image displays our official logo, which contains a lock as the centerpiece of our design. Our products will carry the lock as our logo, which will make our company recognizable across all classrooms.

Figure 99: Team Name Logo

2. Steps Towards obtaining a patent

Firstly, we have confirmed that a trademark is appropriate for our team. A trademark protects brand names and logos used on goods and services. Our next step would be to research our logo and decide whether our mark is registrable. In addition, it is important to analyze how difficult it will be to protect our mark based on the strength of the mark selected. Our next step would be to identify our mark format, which will most likely be a standard character mark, as opposed to a stylized/design mark or a sound mark. Next, we would identify the goods and services for which the mark will apply, and research similar goods to ensure our trademark is not yet claimed. We then have to decide on our filing basis, either a use-in-commerce basis or an intent-to-use basis. Before filing our claim, we must consider whether we might benefit from a trademark attorney. Finally, we must set up a USPTO.gov account to access the Trademark Electronic Application System (TEAS) and pay the applicable fees. We continue to monitor our application and standby for an acceptance or rejection. The entire process can take anywhere from 12 to 18 months.

3. Other trademark opportunities?

There is the opportunity to trademark our brand logo, which will be engraved into every LockedIn product. Clippy must be associated with our brand name, LockedIn. This gives us the exclusive right to use our logo, eliminating the threat of competitors using a similar design. A trademark would also protect the integrity of our brand by preventing confusion with similar products. It is imperative to obtain a trademark that is immediately recognizable across all products, to protect our companies assets and integrity.

Figure 100: Team Logo

6. Environmental Targets [Xavier, Iyana]

a. How will the products reduce environmental impact on production?

We plan to produce a market of Clippy products using injection molding. Through this process, plastic is injected into a ready-made mold. This mode of production produces minimal waste by using a certain, limited number of molds for hundreds, potentially thousands of our desired products, as well as using the exact amount of plastic needed for each product. Furthermore, if we decide to use a modern plastic injection molding machine, we will be utilizing a machine that is more energy efficient and results in a lower cost of production. Using modern machines could mean focusing on electric machines instead of hydraulics, which use oil and are not energy efficient. Using modern electric options can also reduce our operational costs and reduce the price per unit of our product. As a company, we can also prioritize energy efficiency through small changes such as switching to LED lighting and being mindful of our energy usage. It is also important to have a strict track of our energy usage across facilities to ensure that we are meeting our environmental targets. Additional ways of reducing our environmental impact is standardizing components and designing parts for ease of fabrication.

b. How will the products reduce environmental impact upon end of life?

Through injection molding, our products will be manufactured out of a plastic material. While plastic is unique in its strength-to-weight ratio, it unfortunately contributes to one of the world's biggest waste problems. Therefore, Locked-In is focused on reducing its environmental impact through systematic plans and ideals. Firstly, we will avoid plastic products that cannot be recycled. Using recyclable plastic ensures that faulty molds can be repurposed into raw materials, and the user can easily recycle end-of-life products. This process is called closed-loop recycling, which is a method of disposing of a used product by turning it into a new one. This connects our cycle of production and re-usage, greatly limiting the amount of waste that is disposed of in a landfill. Therefore, we need to use recyclable plastics such as PET or biodegradable plastics. Additionally, it is important for us to simplify our components and avoid mixing materials that are difficult to separate before recycling. We can also place more emphasis on sustainable packaging, making use of recycled cardboard.

7. **Future timeline [Brandon, Xavier, Andrew, Iyana]**
    a. **What are your team's actual future plans?**
        i. **Formation of an LLC?**

We have not discussed forming an LLC, however, we have agreed to not take the product further as the market is not sustainable long-term if they are only sold to universities and schools.

ii. **Crowdfunding? [Brandon]**

We believe that crowdfunding would not be enough to get our product to market as there are high fixed costs associated with the production of Clippy. For example, the permanent molds for the injection molding machine require costly, high-precision machining.

iii. **Pitch Competitions? [Iyana]**

Due to their nature, we believe that Clippy would gain considerable interest in pitch competitions. Pitching Clippy to our target group of college students, we believe that our audience will immediately relate to having inadequate and uncomfortable writing facilities provided to them in lecture halls and classrooms designed for a large groups of students. Presenting Clippy as a temporary, modular solution to a widespread university infrastructure problem would likely attract a lot of interest to see it implemented in classrooms. We also believe Clippy would gain interest if pitched to university boards and professors. Those with authority in universities are also aware of the challenges students face when learning in lecture halls, but it is difficult to find solutions that don't involve majorly expensive reconstruction projects of their facilities. Purchasing Clippy in bulk order for lecture halls and classrooms provides them with a temporary, non-invasive addition to their universities.

iv. **Abandon product [Andrew]**

We will most likely abandon the product because of its high startup cost and undefined and unproven market. There are still questions about whether it would be marketed to universities and schools or students, and the business models are not sustainable. This is further supported by the total cost of 8 employees is $660,856 per year, which means that the capital required to pursue Clippy is quite high as there are other costs such as material and manufacturing costs. In addition, many products similar to Clippy have been made by other companies. These companies might have better financial backing, such that they can afford to either match the price of Clippy or go lower.

8. **Sources [Everyone]**
    a. **Bibliography**

Section 2d: Use of TRIZ throughout iterations
https://www.triz40.com/aff_Matrix_TRIZ.php

Section 3a1: Desk Buddy Analysis
https://www.indiegogo.com/projects/desk-buddy-expand-your-workspace#/

Section 4aIII: Injection Molding Cost
https://formlabs.com/blog/injection-molding-cost/?srsltid%3DAfmBOoqdt1EBmJIZmZnsd4AuJQaI-6FdLkclLhcLXq6Okk42jWUDiVqJ&sa=D&source=docs&ust=1733853307721504&usg=AOvVaw3JmCXrKuQSOAR6sWKPg9q-

Section 4e: Kickstarter guide to crowdfunding
https://formlabs.com/blog/injection-molding-cost/?srsltid%3DAfmBOoqdt1EBmJIZmZnsd4AuJQaI-6FdLkclLhcLXq6Okk42jWUDiVqJ&sa=D&source=docs&ust=1733853307721504&usg=AOvVaw3JmCXrKuQSOAR6sWKPg9q-

Section 4aIV: Net Present Value Formula
https://www.fool.com/terms/n/net-present-value/

Section 4aIII: Weighted Average Cost of Capital Formula
https://www.investopedia.com/terms/w/wacc.asp

Section 4aIV4: Compound annually formula
https://byjus.com/maths/compound-interest/

Section 4b: Pricing Policy
https://www.indeed.com/career-advice/career-development/pricing-policy#:~:text=What%20is%20a%20pricing%20policy,to%20price%20separate%20products%20differently.
https://www.indiegogo.com/projects/desk-buddy-expand-your-workspace#/

Section 4a
https://www.kickstarter.com/articles/how-to-launch-a-product-on-kickstarter-building-your-community
https://www.linkedin.com/pulse/how-can-you-raise-funds-scale-up-your-manufacturing-business-sheoran/
https://wideeffect.com/pages/3-ways-payroll-funding-can-help-you-scale-your-business

Section 4d: Labor
https://www.bls.gov/news.release/pdf/ecec.pdf
https://dol.ny.gov/minimum-wage-0

Section 5c: Potential Liability Issues for use
https://asq.org/quality-resources/fmea?srsltid=AfmBOoqrqluQMs8Jmavw_AFC6UxFjFFA7u7Ur_o7_RVIlOIpP4C620fQ

Section 5d: Trademark details.
https://www.uspto.gov/trademarks/basics/what-tradem

Section 6: Environmental effects of plastic injection molding
https://www.essentracomponents.com/en-gb/news/manufacturing/injection-moulding/is-injection-moulding-environmentally-friendly

Section 6b: Reducing Environmental Impacts at the End of life. https://www.dcceew.gov.au/environment/protection/waste/publications/how-you-can-reduce-plastic-waste-fs#:~:text=Avoid%20plastics%20that%20cannot%20be,keep%20cups%20and%20travel%20cutlery.

b. Appendices

Abandoned Products from Final Brainstorming

Microwave Lunch Box: Wavey

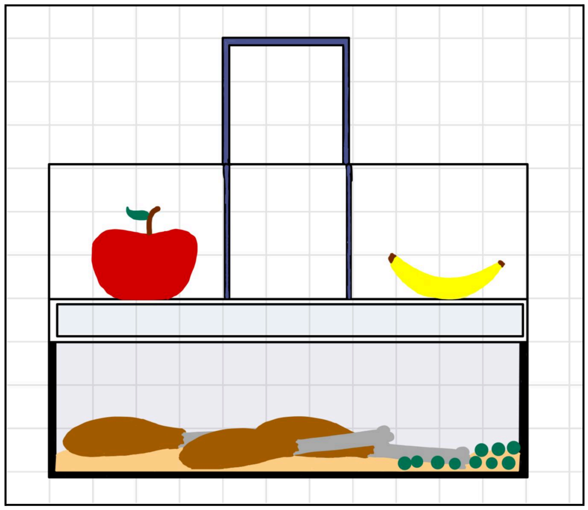


Figure 101: Wavey

Wavey serves as a lunch box that can serve as a potential microwave or a heater. This allows students to heat up their food when there are no microwaves available on campus. This product was scrapped due to a group vote to pursue Clippy.

Portable Laundry Unit: Washy

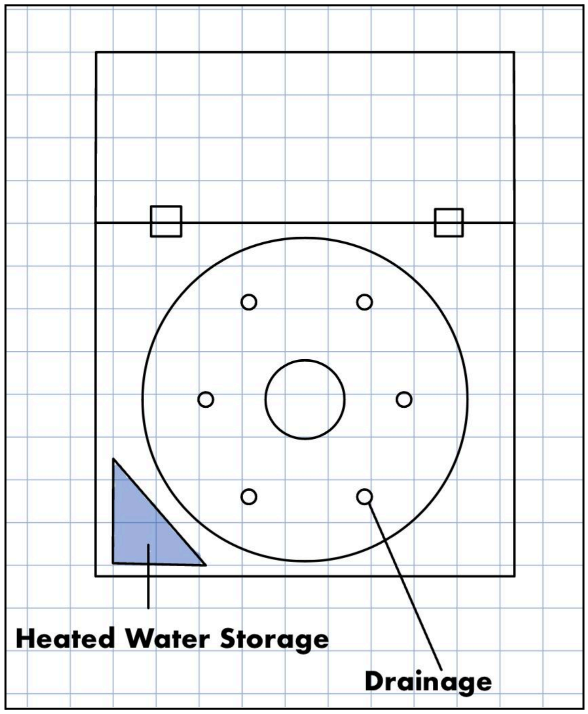


Figure 102: Washy

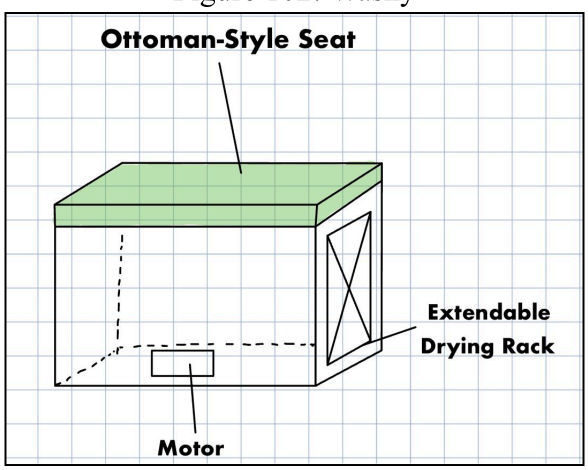


Figure 103: Washy

Washy is a dorm washing machine that allows students to wash laundry while they study. It can also be used as a seat and clothes storage when not being used. This product was scrapped due to a group vote to pursue Clippy.

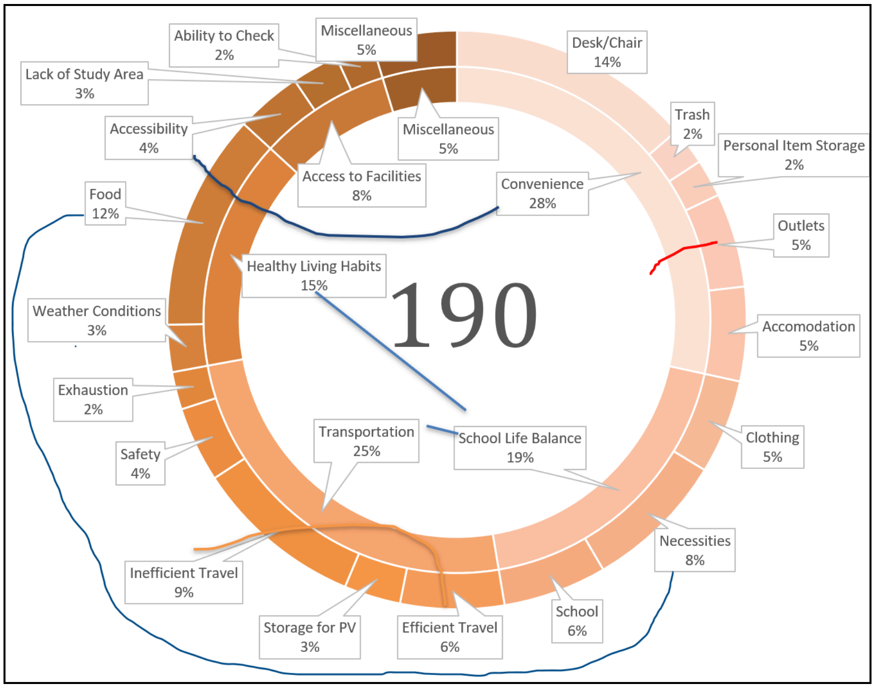


Figure 104: Emotional Donut

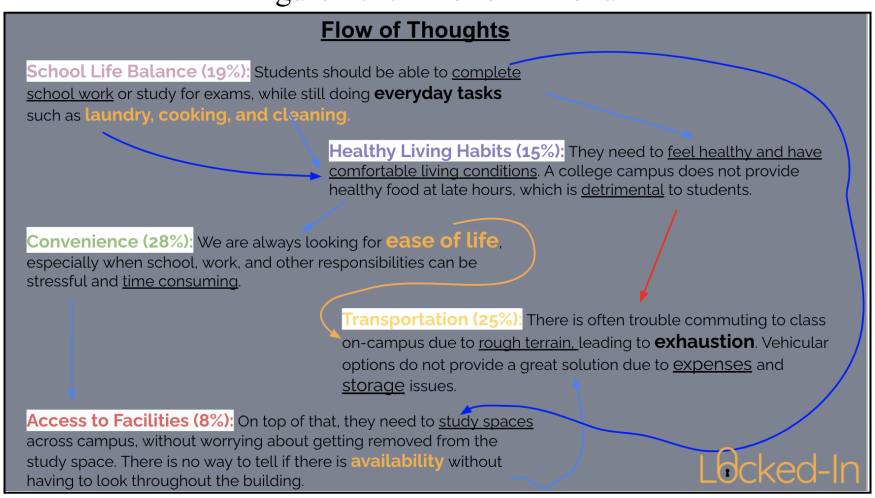


Figure 105: Flow of Thoughts

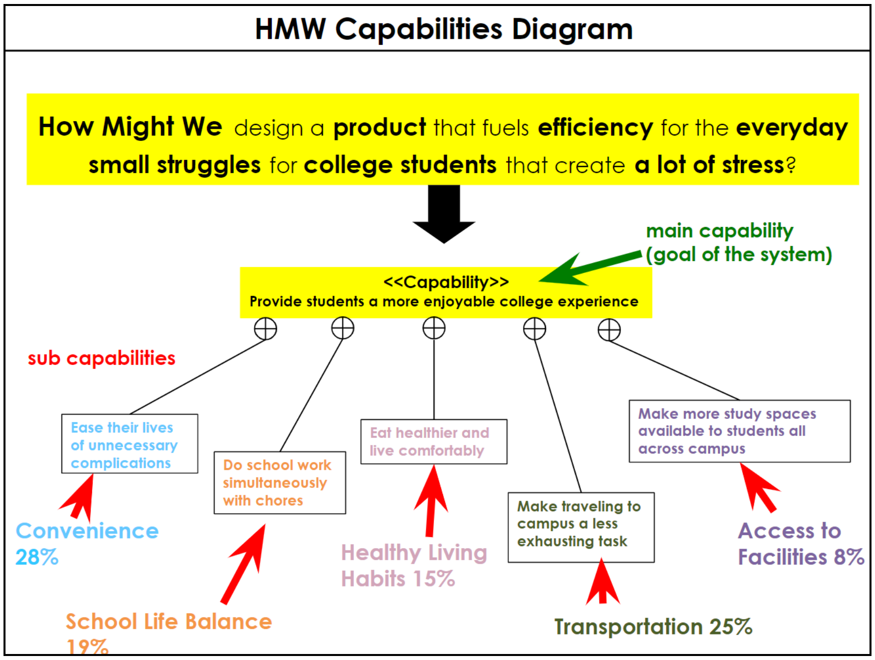


Figure 106: HMW Capabilities Diagram

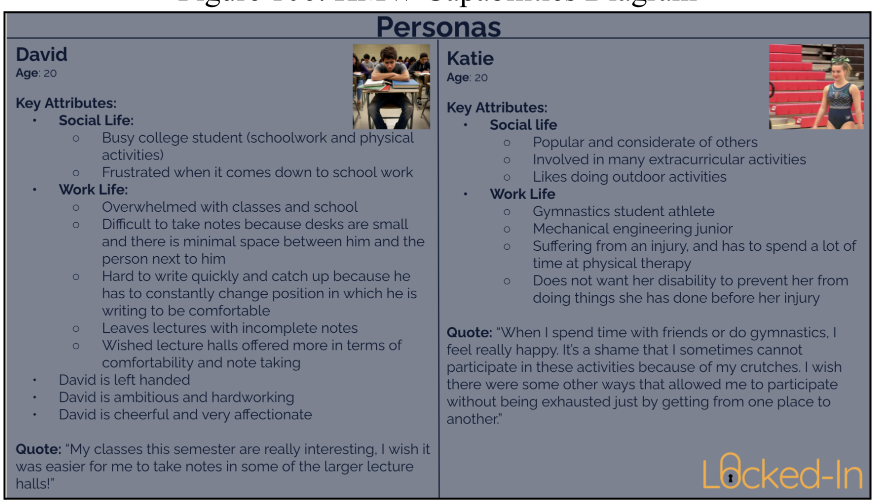


Figure 107: Personas

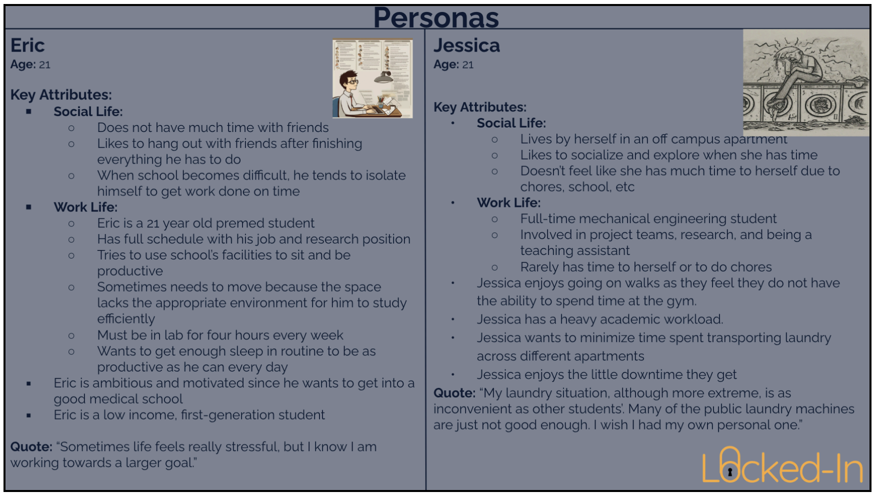


Figure 108: Personas

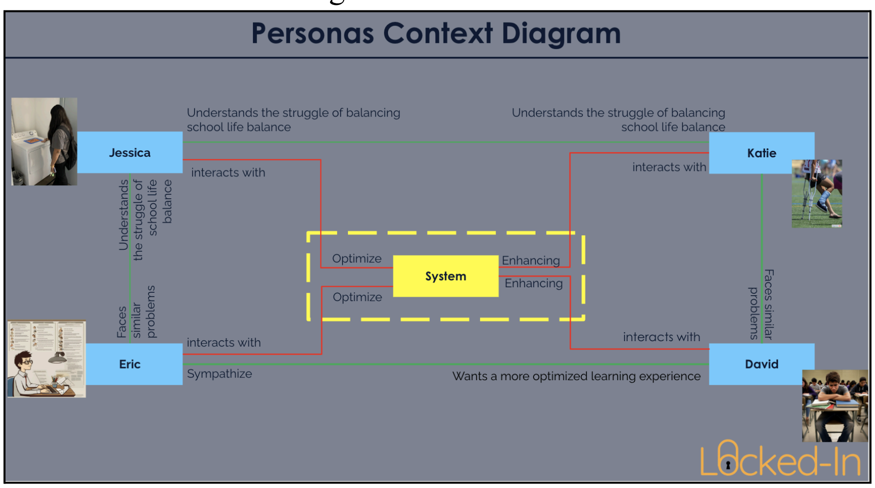


Figure 109: Personas Context Diagram

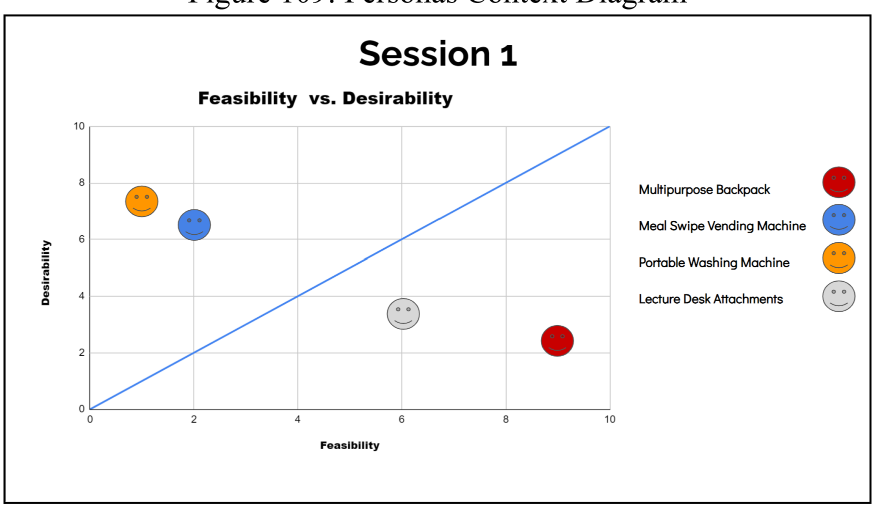


Figure 110: Desirability vs Feasibility Chart Session 1

Figure 111: Desirability vs Feasibility Chart Session 2

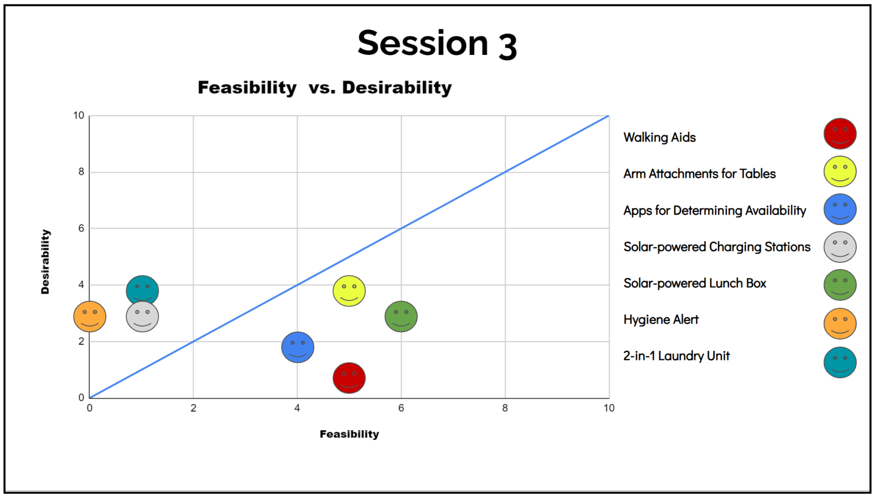


Figure 112: Desirability vs Feasibility Chart Session 3

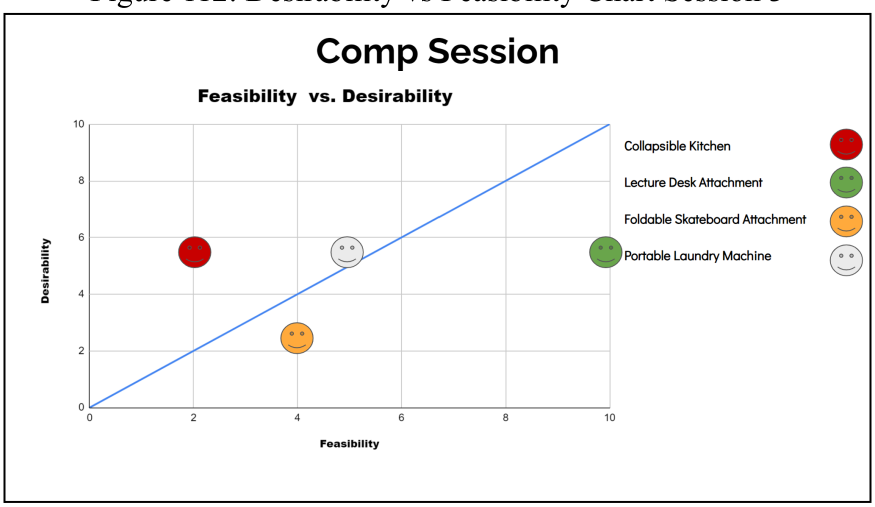


Figure 113: Desirability vs Feasibility Chart Comp Session

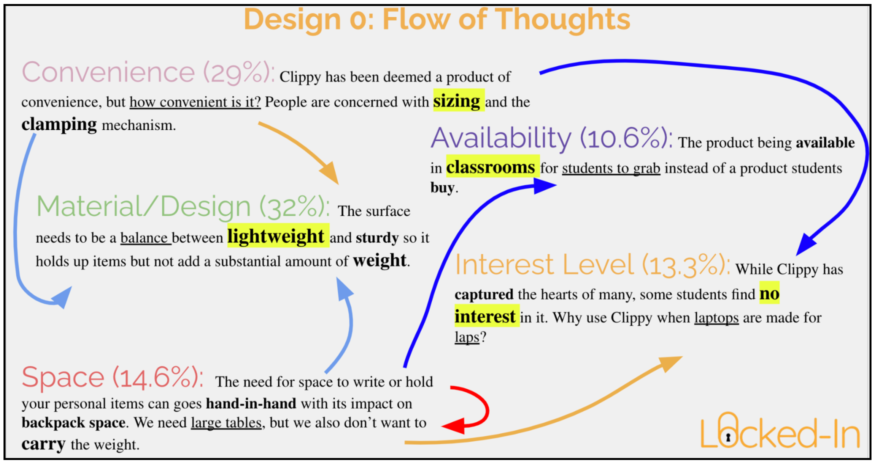


Figure 114: Flow of Thoughts for Design 0

	Convenience	School-Life Balance	Transportation	Healthy Living Habits	Access to Facilities		0.1915714286		
Convenience	1.00	0.32	0.74	0.35	4.76		0.2	Jin	
School-Life Balance	3.10	1.00	2.80	1.73	5.13		0.1	Ludia	
Transportation	1.15	0.37	1.00	0.57	2.64		0.2	Mehali	
Healthy Living Habits	2.86	0.58	1.52	1.00	5.14		0.1	Andrew	
Access to Facilities	0.24	0.22	0.35	0.19	1.00		0.33	Iyana	
Sum	8.35	2.50	6.42	3.84	18.67		0.111	Xavi	
							0.3	Brandon	
	Convenience	School-Life Balance	Transportation	Healthy Living Habits	Access to Facilities	Weights			
Convenience	0.119760479	0.1292814794	0.1153258735	0.0911790757	0.2549954465	0.1421084708			
School-Life Balance	0.371257485	0.4007725861	0.4363681701	0.4506851456	0.2746558097	0.3867478393			
Transportation	0.1377245509	0.1501294108	0.155845775	0.1477101026	0.141426046	0.1465671771			
Healthy Living Habits	0.3425149701	0.230444237	0.2373531154	0.2605116449	0.2753522259	0.2692352386			
Access to Facilities	0.02874251497	0.0893722867	0.05510706605	0.04991403116	0.05357047196	0.05534127417			
Sum	1	1	1	1	1				
							Weight sum vector	Criteria weights	Consistency Vector
							0.7329823479	0.13238	5.536956851
							1.98718387	0.487087	4.07973087
			0.8695652174				0.7536250032	0.138622	5.436546892
Convinence: day to day wants that would enhance experience		2.12					1.405721433	0.182053	7.721495568
School-life balance: balance academia and life			0.35	4.166666667			0.2791037009	0.059858	4.662763555
Transportation: getting around campus			1.739130435	4.484304933				average consistency (lambda)	5.487498747
Healthy Living Habits: Food and living conditions				2.828054299				consistency index (l-n)/(n-1)	0.1218746868
Access to Facilities: accessibility, study areas				5.219206681				consistency ratio, CR/RI	0.08405150812
								CONSISTENT!!	
Convenience: 7									
School-Life Balance: 9									
Transportation: 5									
Healthy Living Habits: 7									
Access to Facilities: 4									

Figure 115: AHP

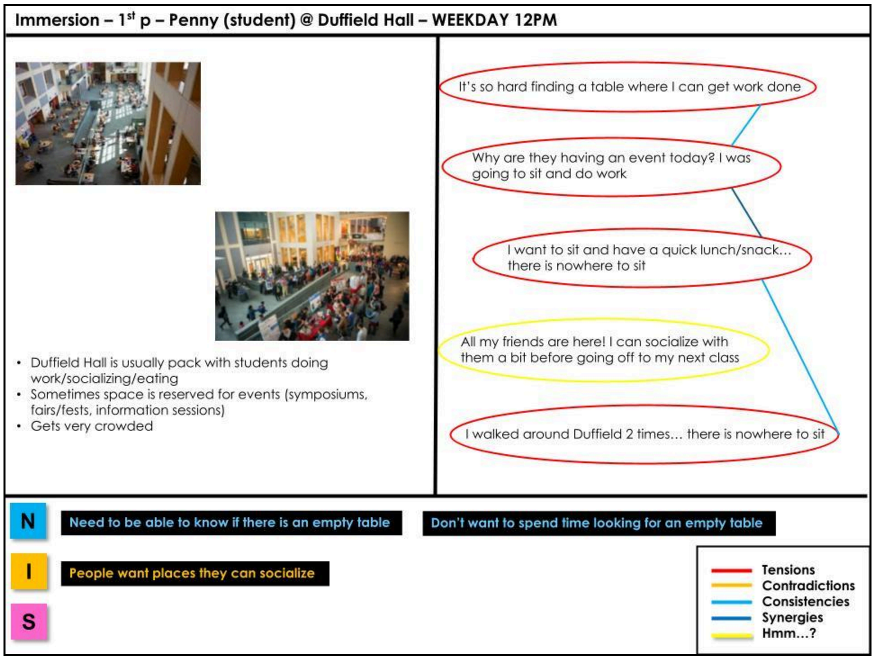


Figure 116: Unpacking

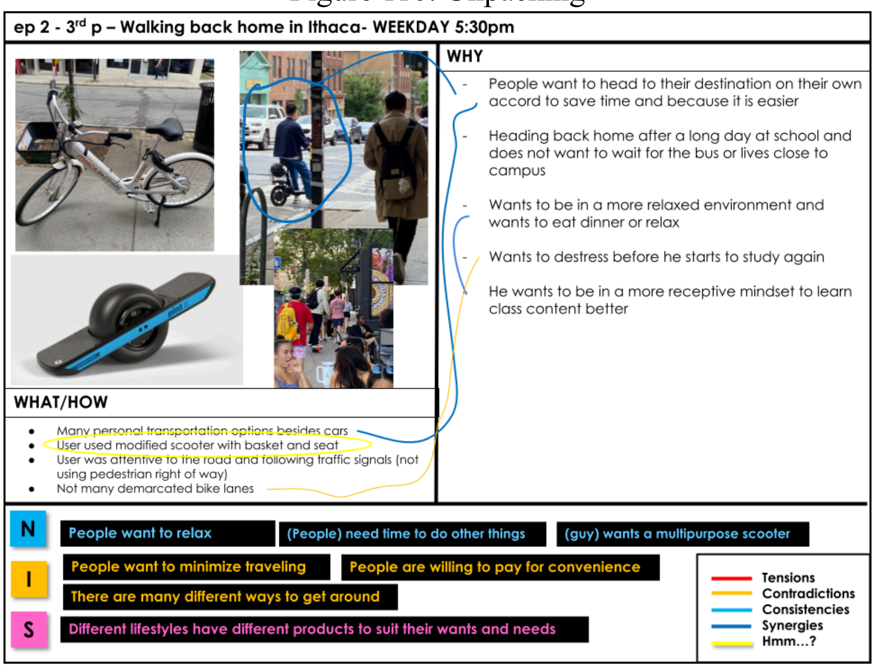


Figure 117: Unpacking

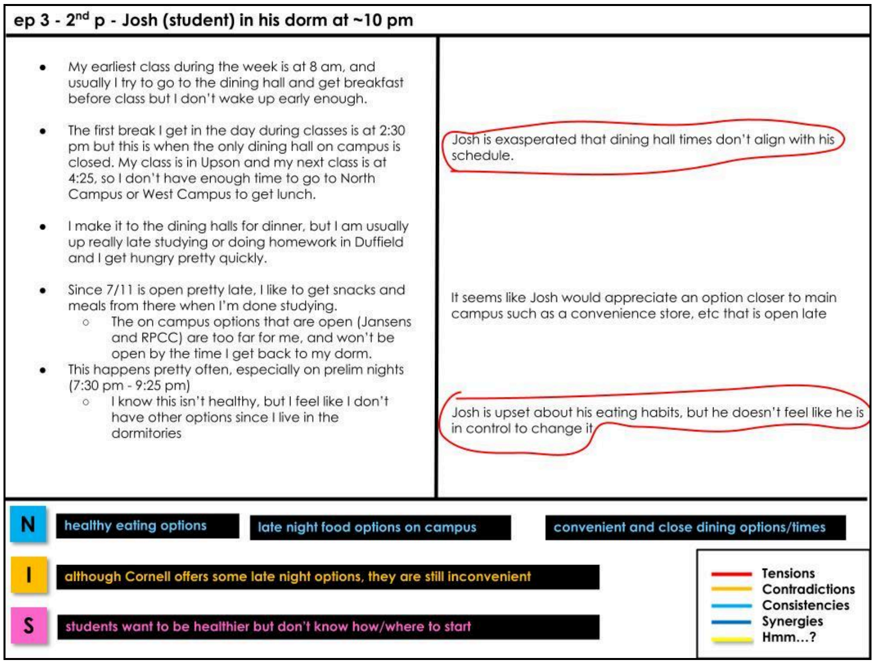


Figure 118: Unpacking

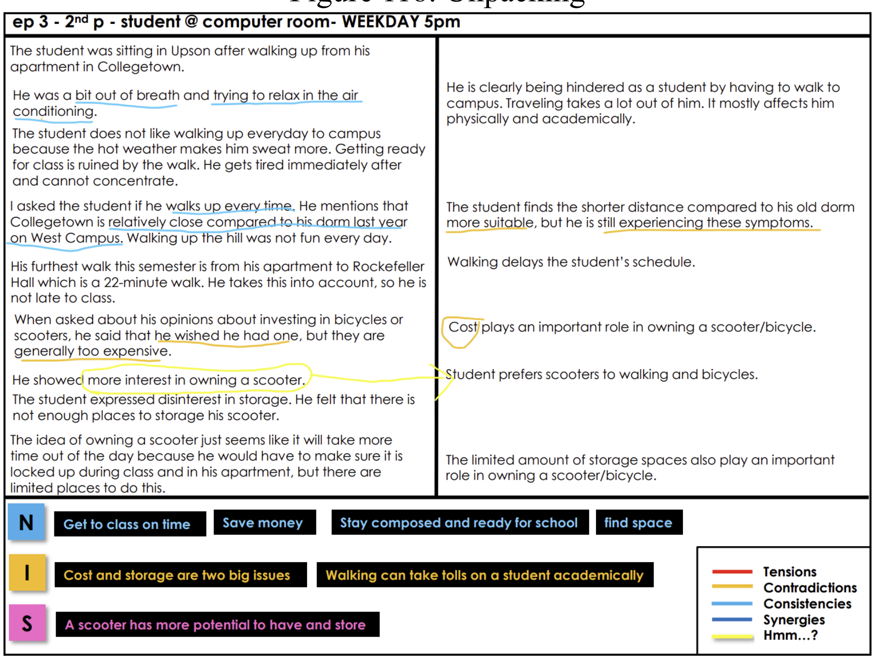


Figure 119: Unpacking

ep 1 - 1st - Immersion with window@ Home - WEEKDAY 3pm

- I realized that the windows in the rooms around our house were not good insulators
- windows are old, missing modern technology
- cold drafts enter the house

- I feel as though the window itself is not enough to protect against Ithaca's harsh weather
- I feel like this can be detrimental to health, especially during the cold winter days.
- In the cold, having a well insulated apartment will be important to many students
- There should be a product that can bridge the gap between current and newer windows

N Reliable insulation | protection from harsh weather conditions | warmth

I windows are outdated | older window pane and frame

S most students put up with the cold in their room

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Figure 120: Unpacking

ep 4 - 3rd p – Biker @ Rainy Day at School - WEEKDAY 3pm

WHAT/HOW

A student (presumed) is on a bicycle on a rainy day

Waiting for the light to turn Green for him. Resting his bike on one foot

WHY

- Because it is the end of the day for the student and he has to get back to his dorm on North Campus
- Because the student prefers the time saved by using a bicycle
- Because he presumably does not have a car, or did not drive his car that day
- Because the student perhaps did not know that it would rain that day,
- Because he has to bring his bike back with him to his dorm
- Because walking all the way from Engineering quad to North Campus can take 20+ minutes on a rainy day like this

N Save time going home | Get home | Somehow bring the bike back with him

I It is very difficult to bike safely in rain.

S People are willing to risk a lot of things for time

Tensions
Contradictions
Consistencies
Synergies
Hmm…?

Figure 121: Unpacking

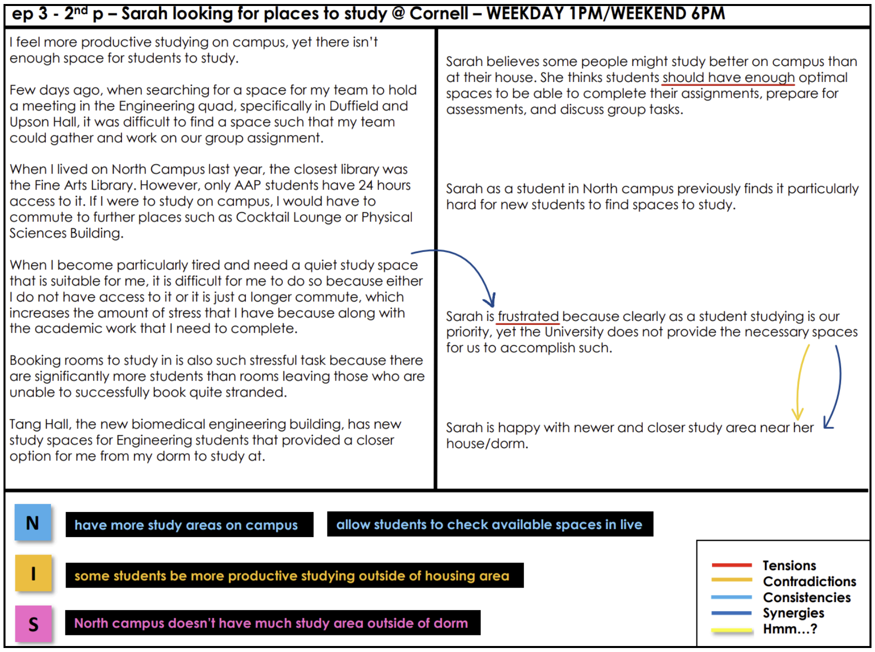


Figure 122: Unpacking

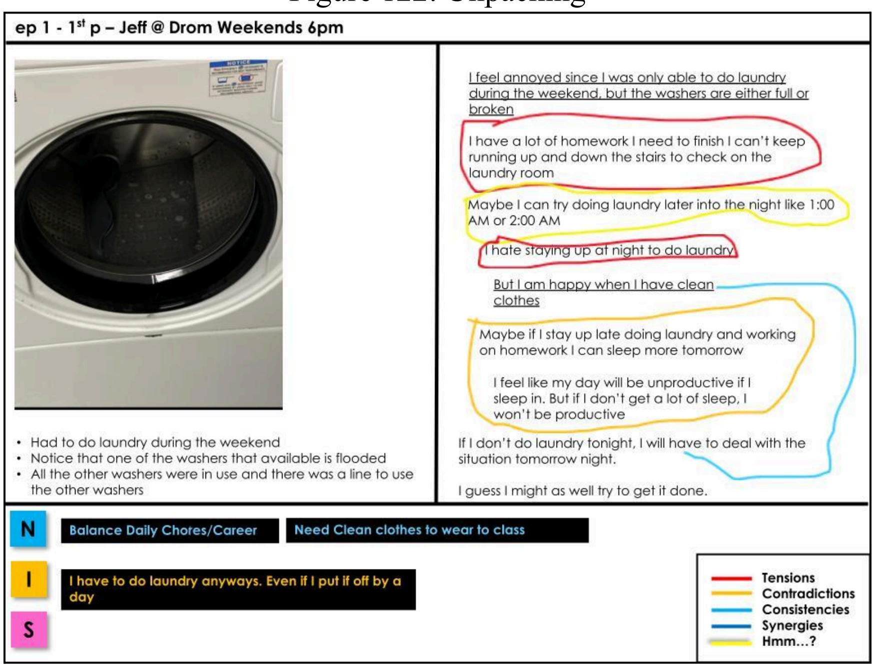


Figure 123: Unpacking