ENGS 21: Group 11

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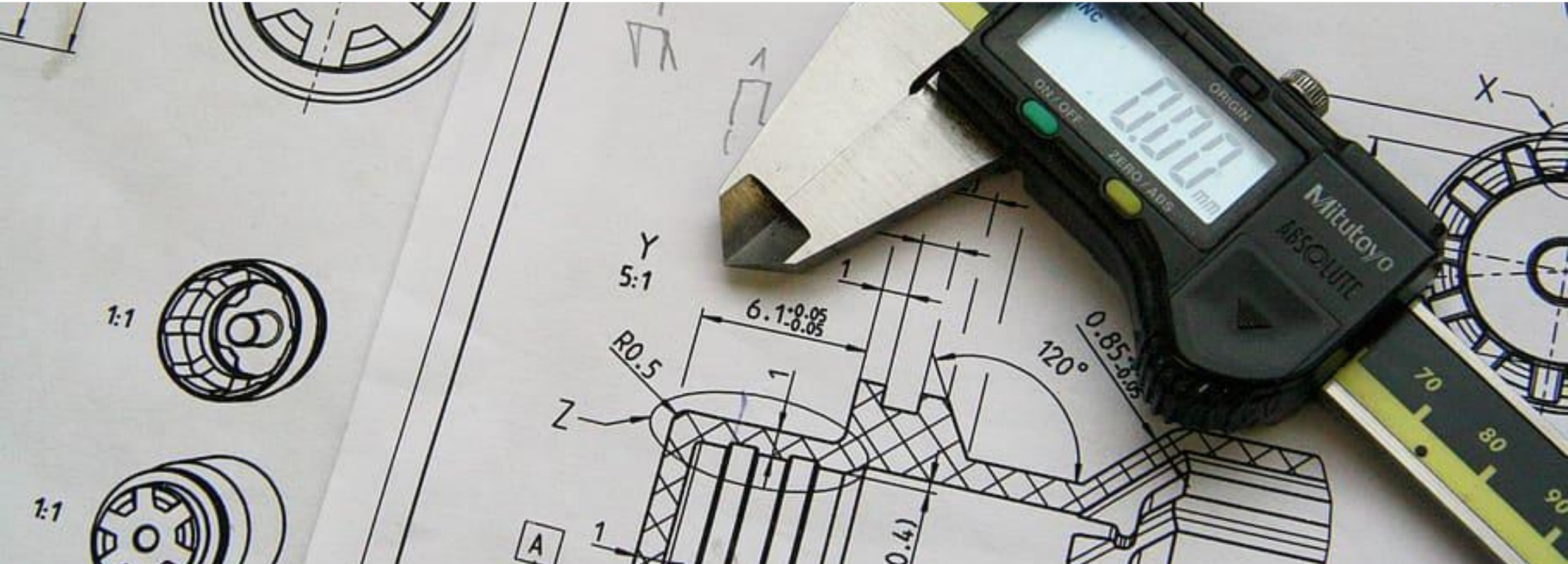
Final Presentation
“RECYCLEASY”

Problem, User & Specifications



Problem Statement

At Dartmouth College, dining patrons often fail to properly dispose of plastic bottles, leaving leftover liquids that can contaminate other recyclables. This places the burden of sorting and cleaning on recycling facilities as the college follows a Zero-Sort™ method for waste collection.

Users:

Dartmouth patrons, particularly those at Novack Cafe

Purchasers:

Dartmouth College Custodial Services

News

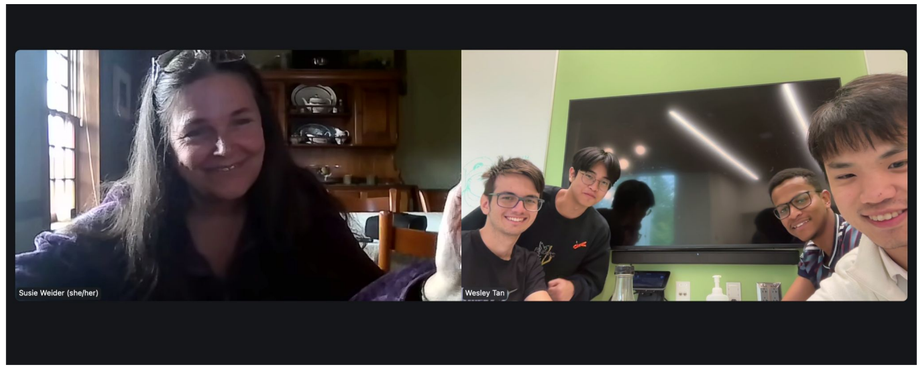
‘A tough nut to crack:’ Dartmouth faces ongoing recycling challenges

The College has decreased its proportion of waste sent to recycling programs in recent years due to strict regulations on contamination in recyclable materials, according to staff and students familiar with the issue.

Understanding our Users

Susan Weider *(CSV Contracts Manager)*

- **Manageable collection method**.
- **Infrastructure Requirements limiting where product can be placed**
  - If power is required, need to be next to a socket
- **User Convenience**: Including a visible sign of when the user can insert a bottle

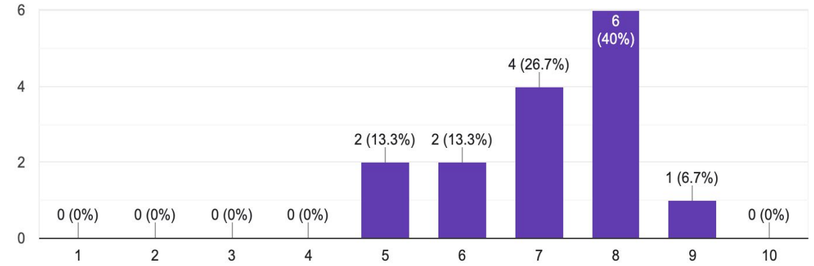


Students

On a scale of 1 (easy) to 10 (hassle), how much of a hassle do you think recycling plastic bottles is?

Copy chart

15 responses



Median: 7.13; Mean: 7; Mode: 8.0

This validates our problem statement.

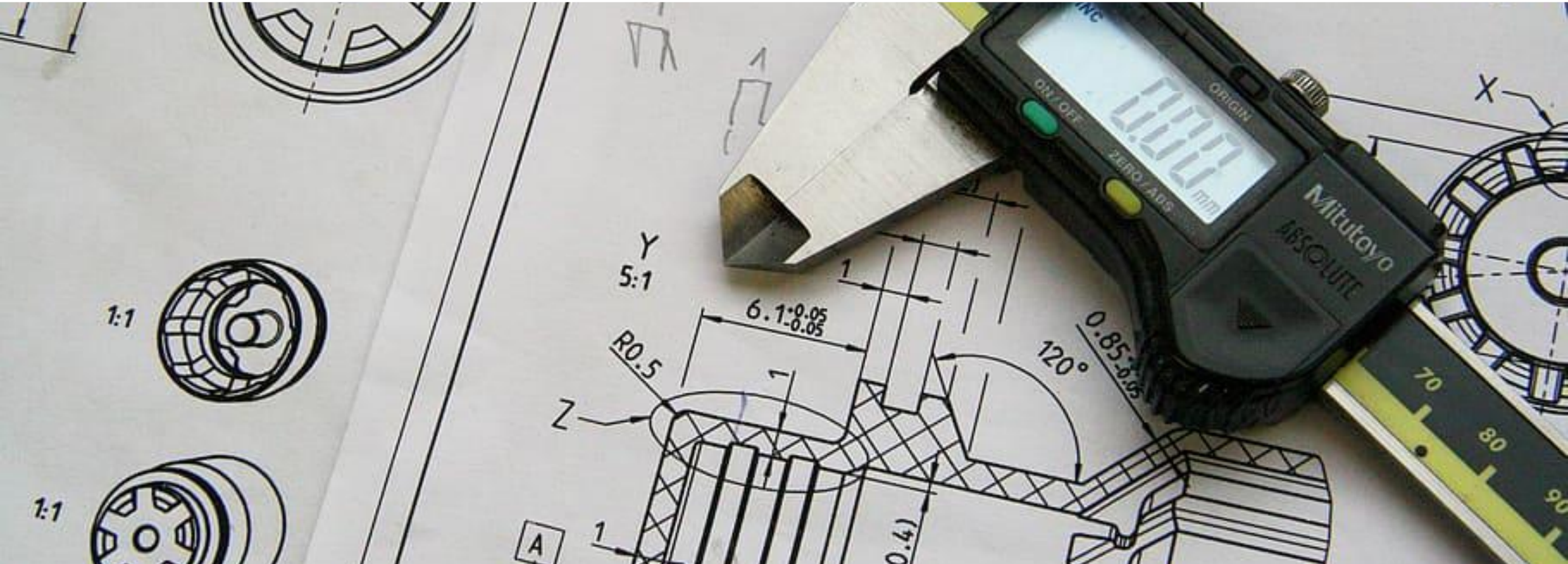
Original Specifications (1/2)

Specification	Justification	Quantification
Legality and Ethics	Needs to abide by the laws	Yes/No
Cost	Should be made at minimum cost to make it affordable for implementation	< $100
Safety	Should be well insulated to prevent the users from disturbing the cables	< 1 accident per 1000 bottles
Size	Size should be comparable to a typical recycling bin to conveniently replace traditional bins	< 50cm x 50cm x 100cm
Ease of use	The users should be able to use conveniently	> 7 on 1-10 survey results

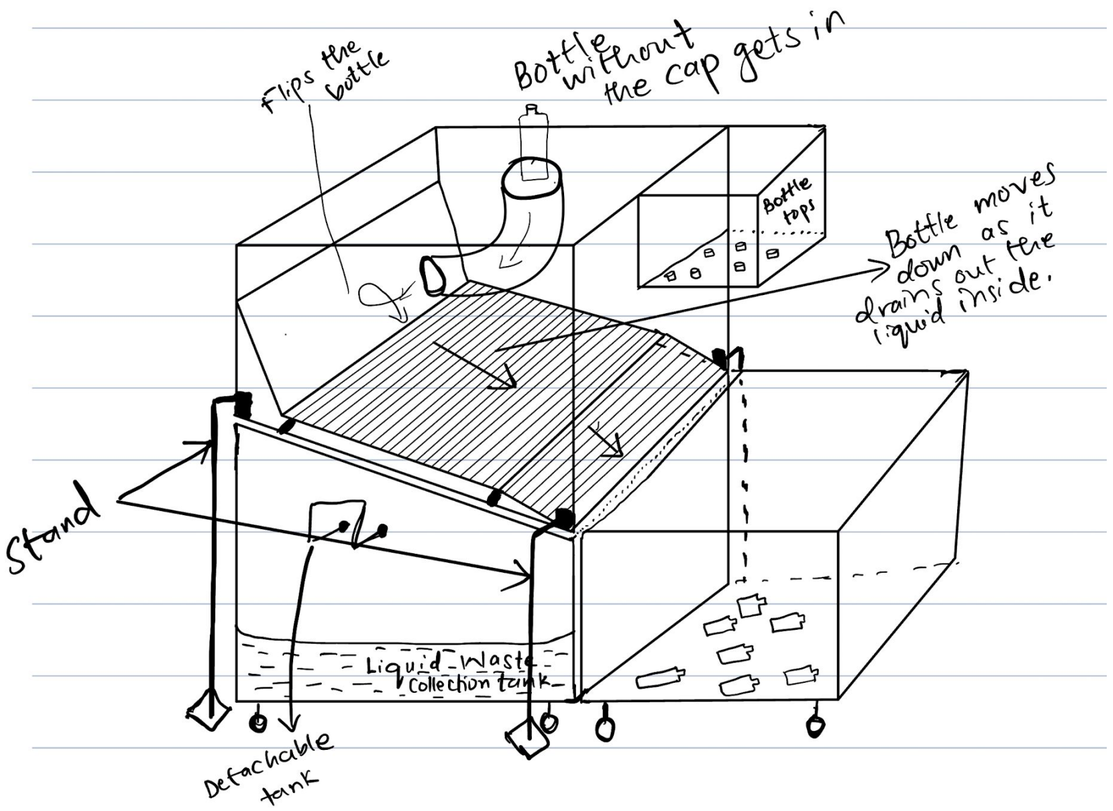
Original Specifications (2/2)

Specification	Justification	Quantification
Durability	The machinery should work faultlessly for months with minimal maintenance	Life expectancy > 30000 bottles
Toughness	The design must resist improper usage (e.g. putting the bottles in with too much force)	Testing
Capacity	The design should have sufficient bottle and liquid storing space relative to its size	> 80% of the size is used for storage
Effectiveness	Is the effectiveness of draining worth the extra costs of installing and maintaining the mechanism	Drains ~90% of the liquid, or reduced the liquid waste per bottle to less than 10mL.
Aesthetics	Given that this will be a trash can for public spaces, it needs to fit in with the environment aesthetically	> 6 on 1-10 survey results

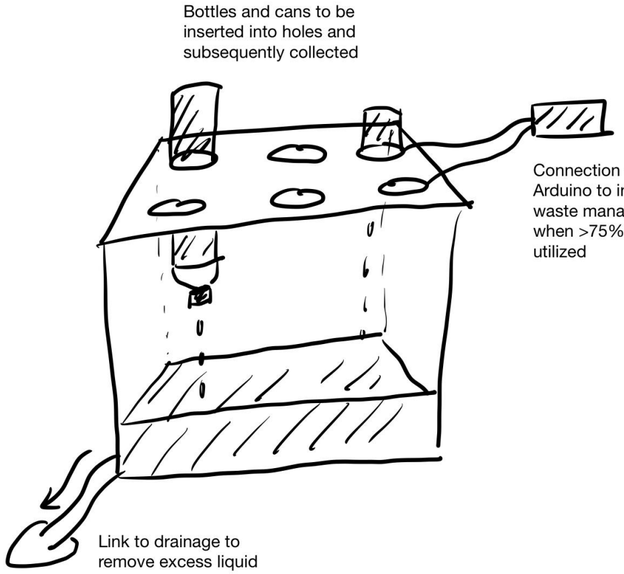
Prototypes & Drawings

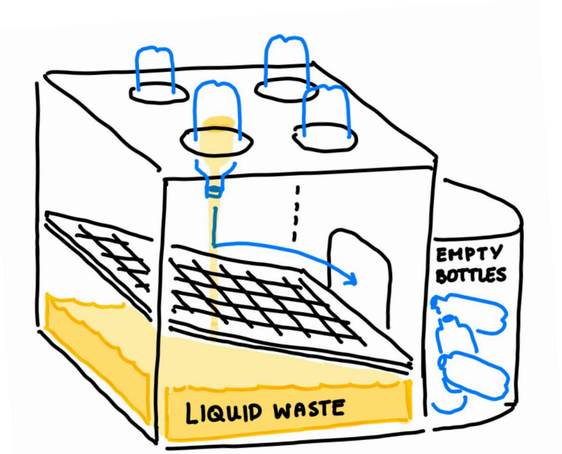


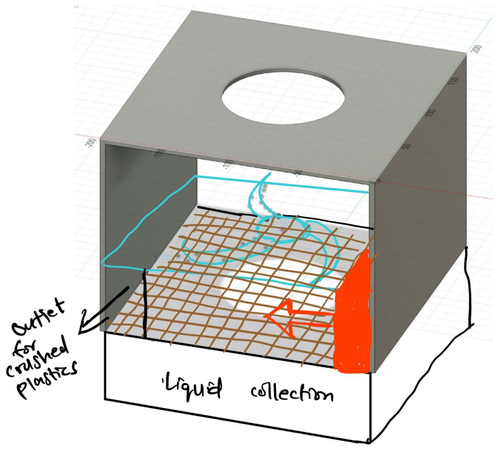
Prototypes: Initial Drawings

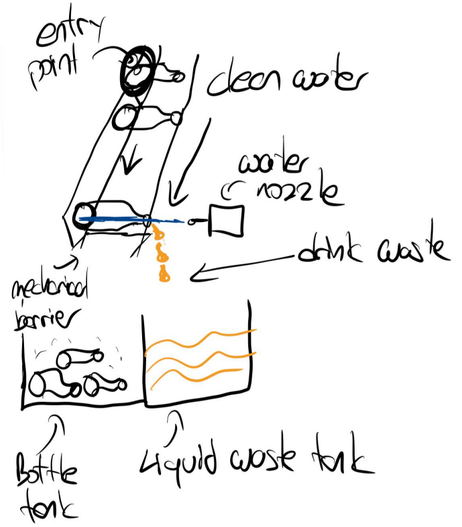


Fundamental mechanism

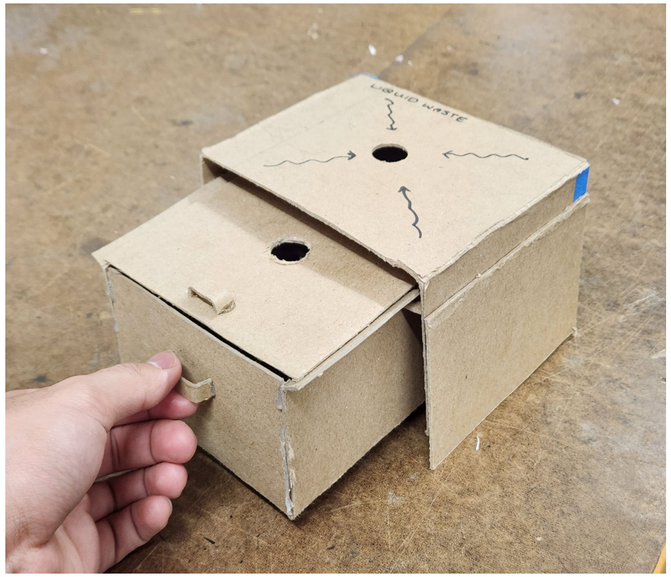








Prototypes: Individual Prototypes

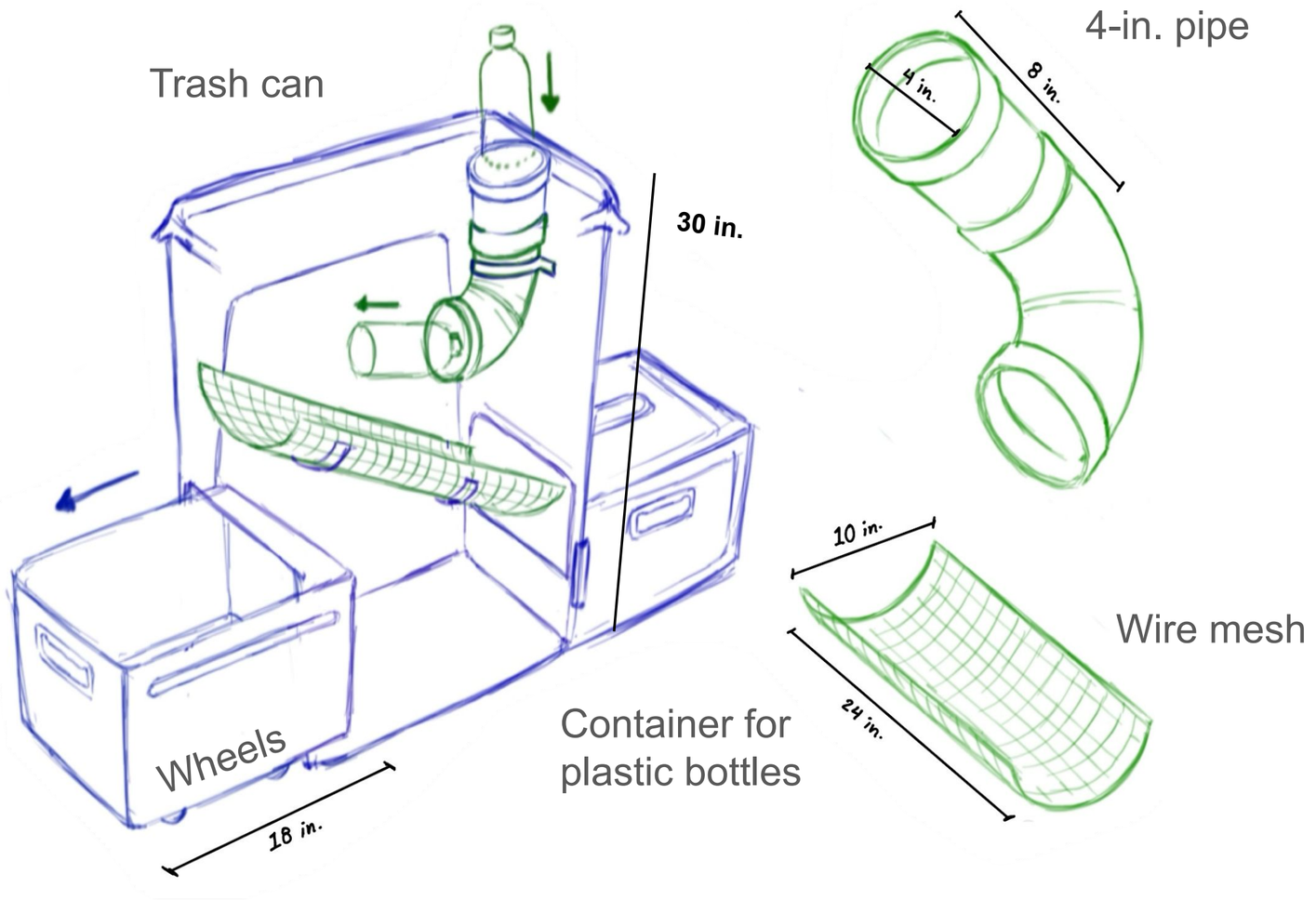


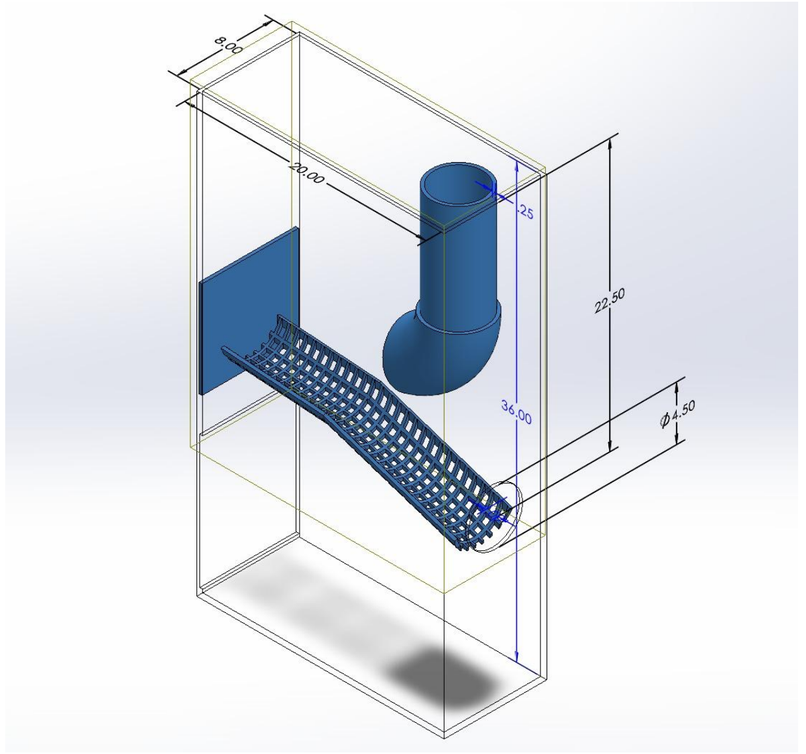
Easy removal mechanism for liquid waste

Tube mechanism to ensure bottle ‘flips’

Wire mesh to filter the water

Prototypes: Drawings for RECYCLEASY 1.0



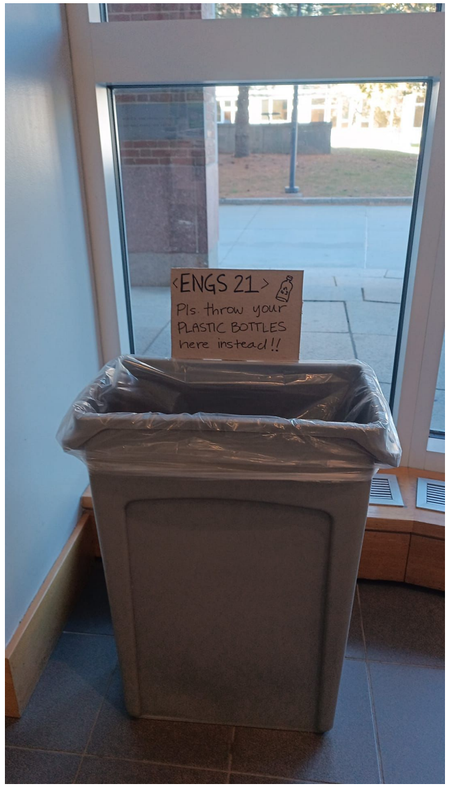


Prototypes: RECYCLEASY 1.0

Lacking:

- Bottle capacity
- Missing a liquid waste tank
- Missing container for emptied bottles
- Draining mechanism was not yet working

Benchmark Testing

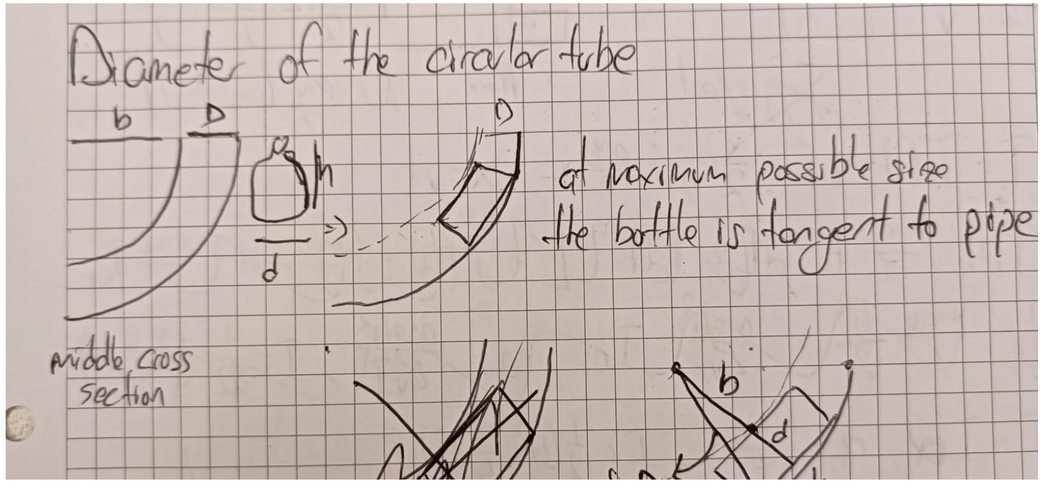


*From Oct 18-22, we placed a trash can at Novack and collected **10 bottles** which contained **290mL liquid waste (29ml avg)***

Benchmark Testing

Specification	Target Value	Evaluation and Testing
Effectiveness After speaking to Susan, this is defined by *how well the bottles are drained*	90% of the bottles are drained: final liquid per bottle <10mL	Run tests with a sample size of 30 bottles and check if the machine effectively drains them. **Based on our benchmark testing on a regular trash can, an average PET bottle is discarded with about 30 mL of liquid*
Capacity	Target value is 60% of maximum capacity, so 24 bottles.	The capacity of a regular trash can of the same size is approximately 40 PET bottles
Ease of use	Users should be able to open and insert the bottle under 3 seconds	A regular trash can takes under a second to use

Analysis Testing



The cross-section of the circular tube is illustrated below:
The relevant geometry leads to the following conditions:

$$(b+d)^2 + \left(\frac{h}{2}\right)^2 = (b+D)^2$$

Expanding this expression:

$$b^2 + 2bd + d^2 + \frac{h^2}{4} = (b+D)^2$$

Thus, the minimum diameter $D_{\min}$ required for the tube is given by:

$$D_{\min} = \sqrt{b^2 + 2bd + d^2 + \frac{h^2}{4}} - b$$

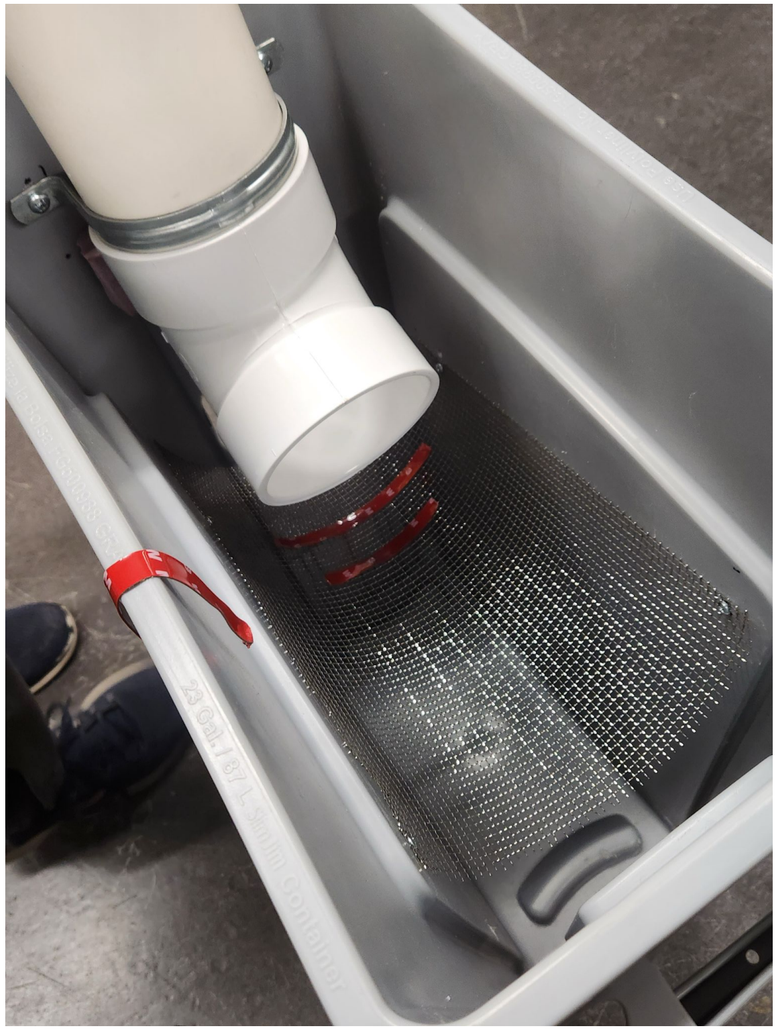
Calculations to determine the **minimum tube diameter** for a given bottle height, diameter, and radius of curvature.

For our maximum values of b = 5in, h = 10in, d = 3in, the minimum diameter **D ≈ 4in.**

Thus, we got pipes with diameter 4in.

Prototypes: Improving the Drainage Process

How do we ensure that there is sufficient time for the liquid to drain?



Iterations:

- Angle of the mesh
- Higher friction surface (e.g., rubber)
- Slowing down bottles
  w/ obstructions (e.g., pipe cleaners)

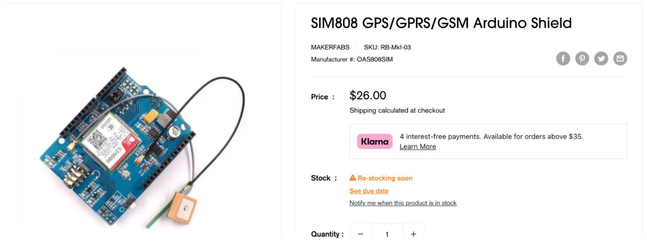
- Pivoted to → Sensor Operated Door

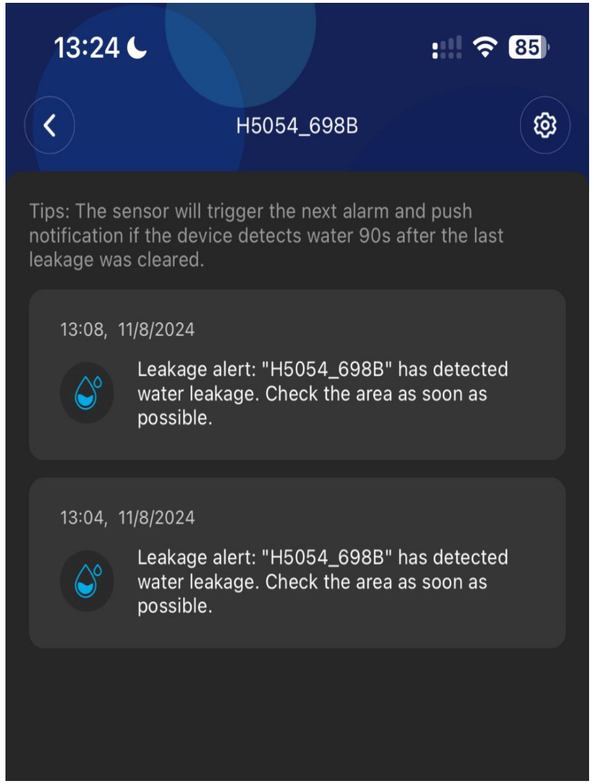
Prototypes: Sensor Operated Door

We pivoted to using Arduino:

Prototypes: Water Sensor

How do we notify the custodial team when maximum capacity is about to be reached?
This prevents overflowing of water & bottles.





Prototypes: Safety

Wire mesh: Mesh can be a safety risk, so we put a cover on top

Wires & electronics: We are handling liquids, so covering the wires and electrical components is imperative

Prototypes: RECYCLEASY 2.0

All put together...

** with lid*

** without lid*

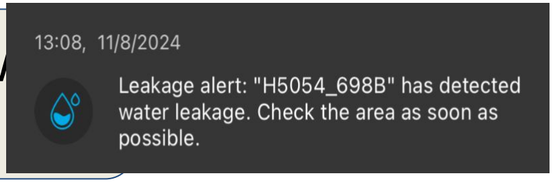
User Journey + Demo

Users

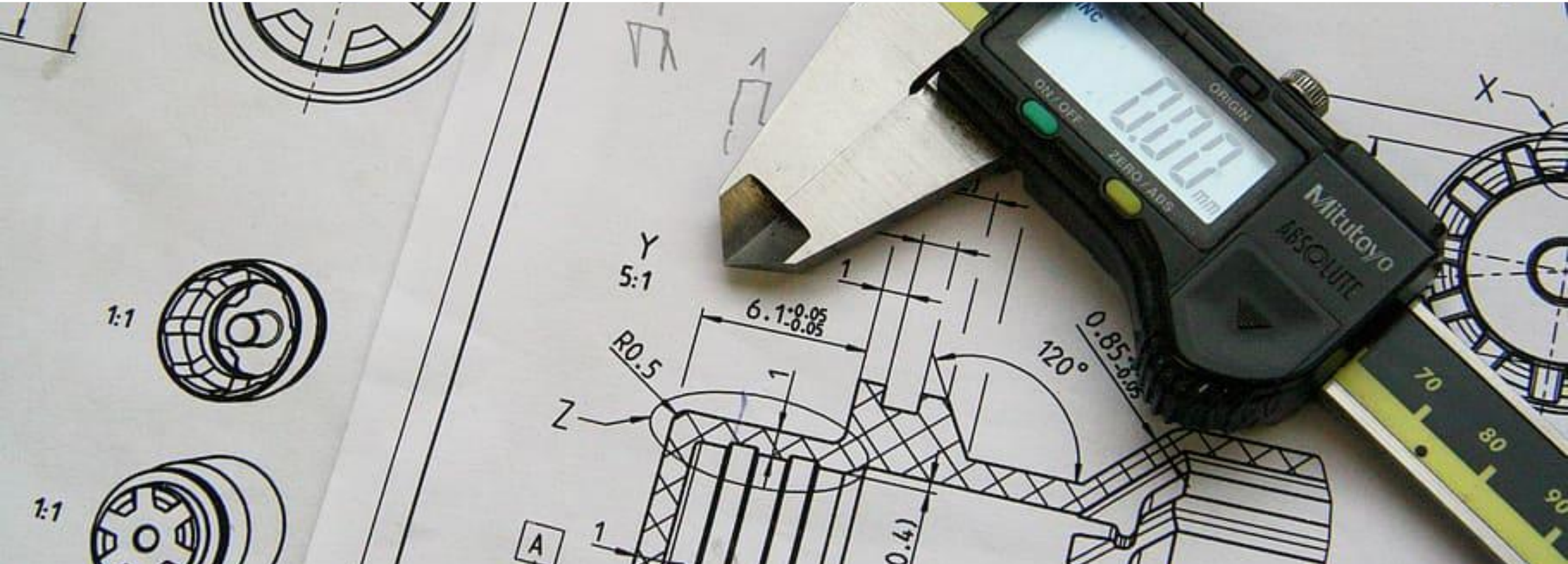
1. Acquire bottle
2. Uncap bottle
3. Place cap in black compartment
4. Place bottle in dedicated opening

Custodian

1. Get notified when sufficient w
   is collected
2. Collect liquid waste tank
3. Drain liquid tank and place back
4. Replace battery if needed
5. Collect bottles



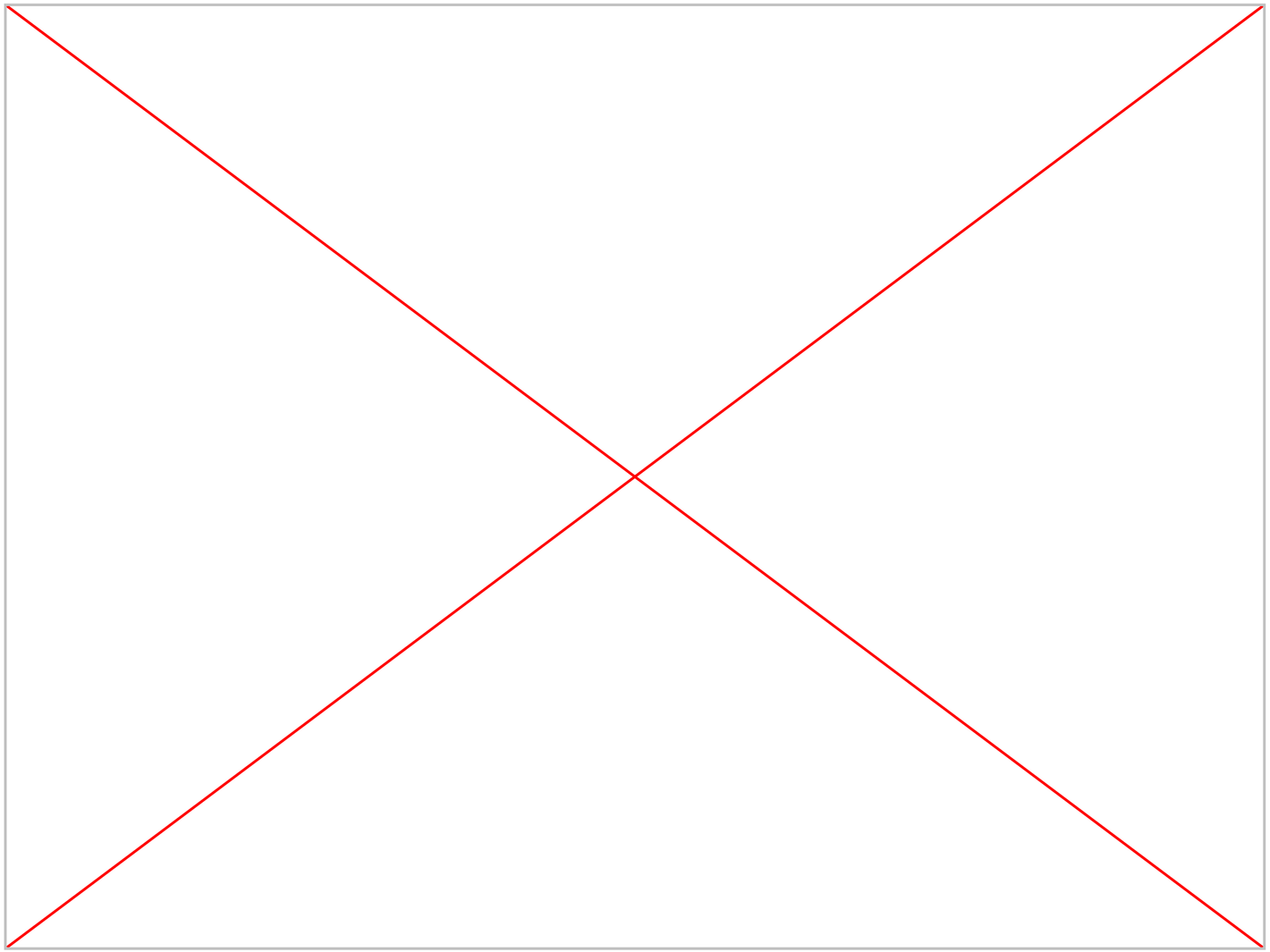
Testing & Feedback



Testing 1: Water Drainage Tests

For each volume (50, 100, 150, 200, 250, 300 mL), we drained the bottle (Pure Leaf, Gatorade) through our prototype and then recorded the remaining water in the bin, averaged over three trials.

(Video taken from water test for FINAL prototype)



Testing 1: Water Drainage Tests (RECYCLEASY 1.0)

Bottle Type	Volume Tested (mL / bottle)	Results (mL / bottle)	Remaining Liquid (%)
Gatorade 	50	40	80
	100	82	82
	150	124	83
	200	170	85
	250	217.3	87
	300	266.67	89
Pure Leaf 	50	40.5	81
	100	83	83
	150	126	84
	200	168	84
	250	212.3	85
	300	256.7	86
			Avg: 84%

Testing 1: Water Drainage Tests (RECYCLEASY 2.0)

Bottle Type	Volume Tested (mL / bottle)	Results (mL / bottle)	Remaining Liquid (%)
Gatorade 	50	20	40
	100	20	20
	150	23.3	15.6
	200	28.3	14.2
	250	33.3	13.3
	300	43.3	14.4
Pure Leaf 	50	2	4.0
	100	2.3	2.3
	150	2.3	1.5
	200	2.4	1.2
	250	2.3	0.92
	300	2.5	0.77
			Avg: 10.6%

Testing 1: Water Drainage Tests

Takeaways (RECYCLEASY 1.0 → 2.0): Limited water drainage in early designs.

- **Angle of Mesh**: Adjusting the mesh angle was critical to improve bottle drainage and ensure bottles move correctly.
- **Location of Pipe (Orientation)**: Strategic placement and orientation of the pipe for efficient drainage and bottle positioning.

- **Solution**: Developed a sensor and motor system to improve drainage efficiency and automate bottle processing.

Benchmark tests (RECYCLEASY 2.0):

- 29 mL left on average, our prototype leaves less water than that :)

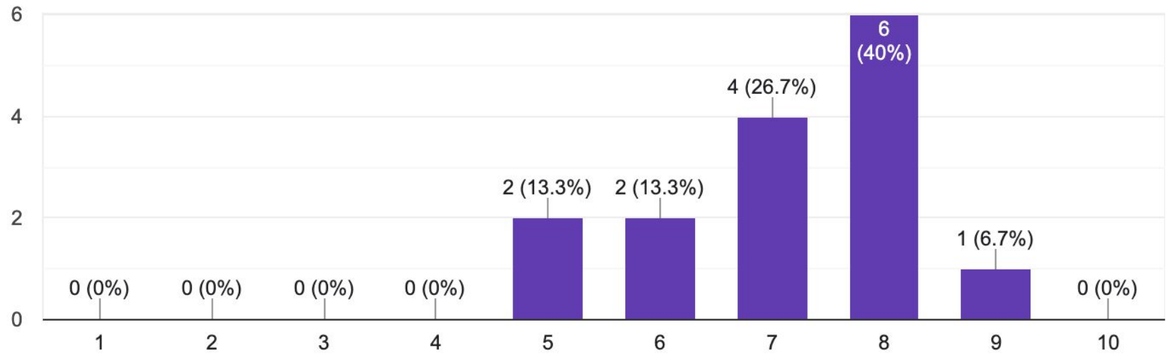
Testing 2: Surveys

This validates our problem statement.

On a scale of 1 (easy) to 10 (hassle), how much of a hassle do you think recycling plastic bottles is?

Copy chart

15 responses

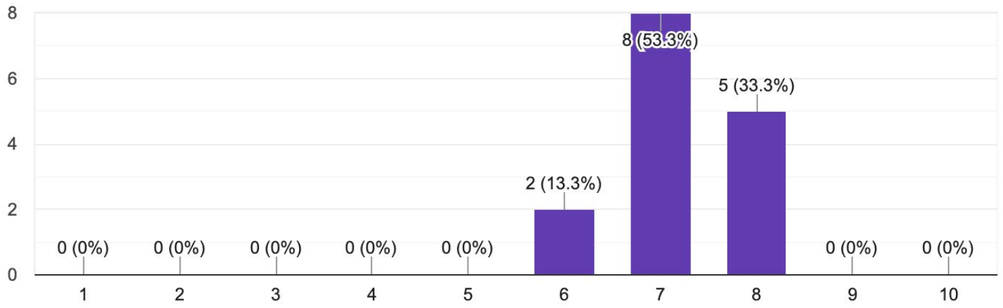


Median: 7.13; Mean: 7; Mode: 8.0

On a scale of 1 (hard to use) to 10 (easy to use), what did you think of our current prototype

Copy chart

15 responses

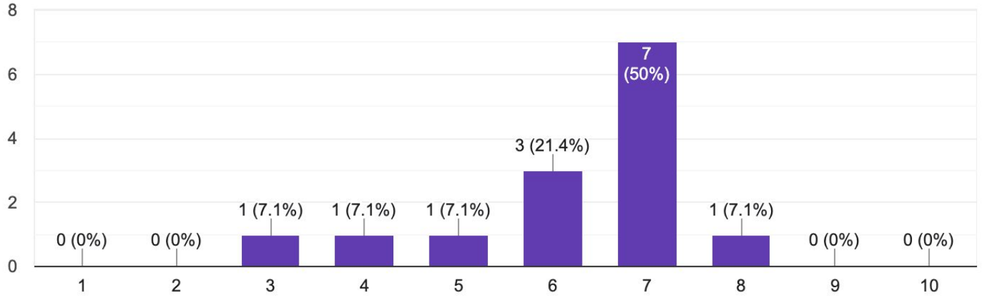


Median: 7.0; Mean: 7.2; Mode: 7.0

On the scale of 1 (unpleasant to the eyes) to 10 (pleasant to the eyes) how aesthetically pleasing is our prototype?

Copy chart

14 responses



Median: 7.0; Mean: 6.21; Mode: 7.0

Testing 2: Surveys

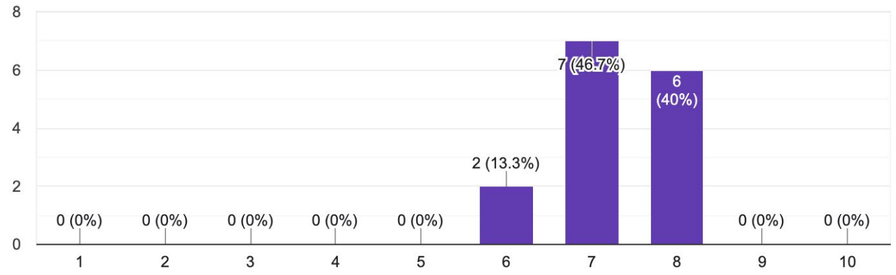
Learning points:

- ***Increased sensor sensitivity***
- ***In future iterations, increased durability***
- ***Room for improvement for ease of use, aesthetics***

On a scale of 1 (not at all) to 10 (yes), will this prototype increase the likelihood of you deciding to recycle?

Copy chart

15 responses

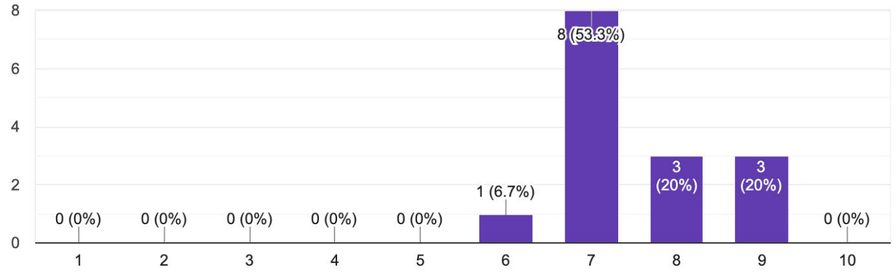


Median: 7.0; Mean: 7.27; Mode: 7.0

Would you use our prototype for recycling?

Copy chart

15 responses



Median: 7.0; Mean: 7.53; Mode: 7.0

What issues do you see with the current prototype?

15 responses

The bottles might get stuck

The volume is a pretty big issue. I don't know if it can hold that many bottles. If you compare it to the normal trashcans it probably can't hold that many bottles.

not sure if the liquid leaking might be an issue. the tank might not catch everything that drips from the bottle.

The volume seems to be the biggest problem with the current prototype. It might be a hassle for employees to collect the liquid or the plastic bottles because the containers are so small.

Looks small, not many bottles can fit into the trash can

The mesh

sometimes the sensor does not work

People may misuse it and place multiple bottles

I think the pipe is too narrow, a bigger hole would have been nice

no issues

it looks flimsy

People may take off the lid and throw things

nothing

Bottle doesn't drain completely

Sensor may not work

Testing 3: Custodian

"Very interesting setup"
- Steven

Main concerns:

- Capacity of prototype

- Placement of LEDs which notified users if they can drop another bottle
  - Initially, next to motor, made it more visible

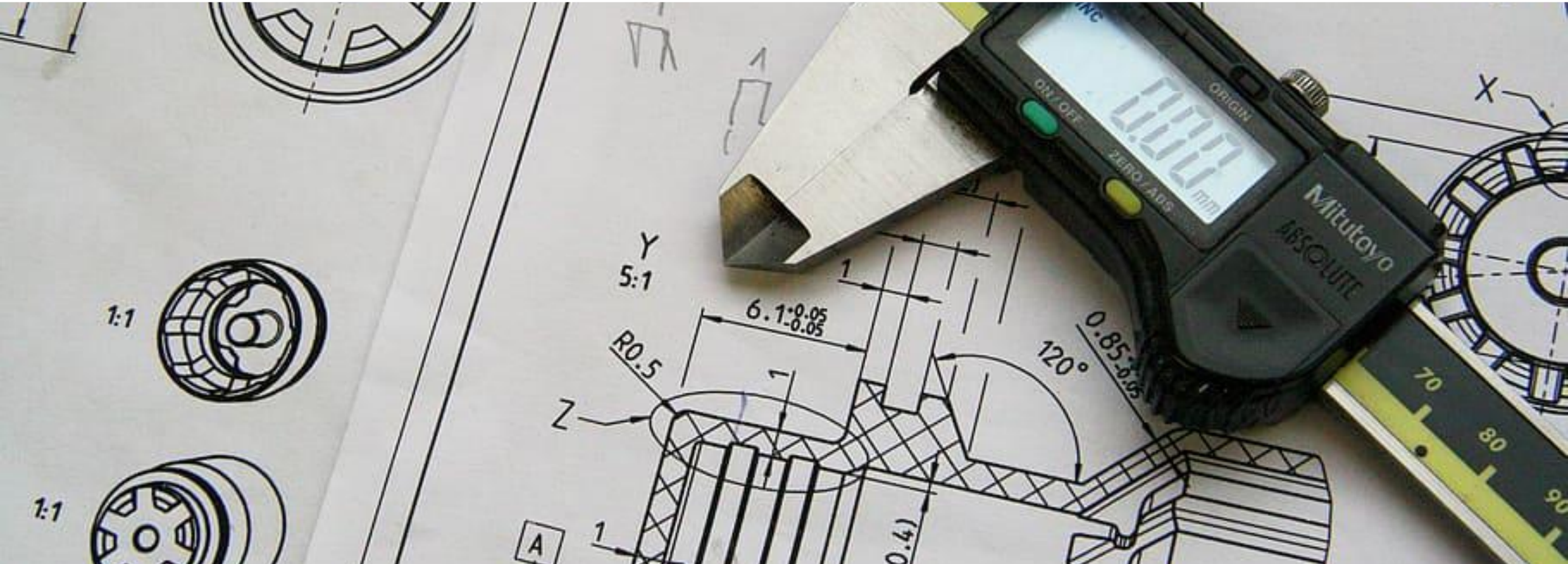
Specifications (1/2)

Specification	Justification	Quantification	Final Results
Legality and Ethics	All projects need to be legal and ethical	Yes/No	
Cost	The project must cost appropriately to allow for large scale implementation around the campus	< $100	$25 (Arduino) + $40 (Trashcan) + $15 (Sensor) + $15 (Misc. Parts) = $95
Safety	The liquid tank must be properly isolated and kept away from the circuitry to not cause electrical accidents	< 1 accident per 1000 bottles	A lid covers the inner workings of the machine and all of the liquid containers are properly sealed to eliminate leakage
Size	The size should be comparable to a typical recycling bin to properly replace traditional bins	< 50cm x 50cm x 100cm	The extra trash can used for bottle collection makes the design larger in width than was desired.
Ease of use	Given that the project seeks to make recycling easier, the product should be easy to use	≥ 7 on 1-10 survey results	7.2/10 Mean 7/10 Median

Specifications (2/2)

Specification	Justification	Quantification	Final Results
Durability	The machinery should work faultlessly for months with minimal maintenance	Life expectancy > 30000 bottles	There remains a significant possibility of bottles jamming the machine
Toughness	The design must resist improper usage (e.g. putting the bottles in with too much force)	Testing	For the most part, but still prone to misuse if people put too many bottles at once
Capacity	The design should have sufficient bottle and liquid storing space relative to its size	> 80% of the size is used for storage	The current capacity is 24 bottles, or 60% of maximum capacity
Effectiveness	Is the effectiveness of draining worth the extra costs of installing and maintaining the mechanism	Drains ~90% of the liquid, or reduced the liquid waste per bottle to less than 10mL.	The prototype provides results above the specs in one type of bottle and below the specs in another.
Aesthetics	Given that this will be a trash can for public spaces, it needs to fit in with the environment aesthetically	≥ 6 on 1-10 survey results	6.2/10 Mean 7/10 Median

Sustainability, Ethics, Business Plan & Reflections



Ethical Considerations

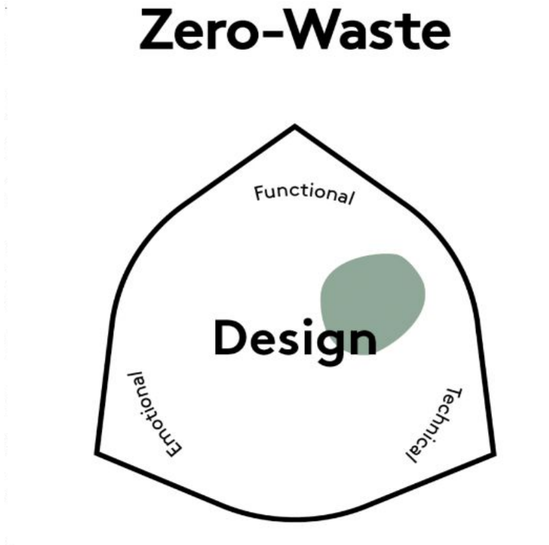
Potential Problems and Safety Concerns:

- Since the design involves draining liquids from bottles, there might be issues with leakage
  - Funnel, tank
- Components like the wire mesh or any sharp edges could pose safety risks if not properly shielded. **Our group has ensured that users are not exposed to the mesh.**

Unintended Uses and Operation:

- Users may try to dispose of non-plastic items or place filled bottles without removing the cap, which could clog the system.
  - Misuse could be addressed by **clear signage and instructions.** Simple user journey.

Sustainability



Functional:

Our prototype separates liquids from plastic bottles, enabling

- individuals to recycle more easily
- sorting facilities to more efficiently recycle plastics

Technical:

Our solution is largely passive (i.e. low energy use) and relies on minimal plastic and material use when building the prototype

Negatives:

Our current design uses a **PVC-pipe**, which has a high Okala impact score compared to other possible alternatives and is generally bad for the environment. This could be further refined by looking at **eco-friendly alternatives (clay, cast iron).**

Our team holds sustainability to the highest priority; waste reduction and environmental sustainability comprise the core ethos of our product

Business Plan Canvas

Key Partners

Dartmouth Custodial Services Team to help **pinpoint the most important design elements**

Casella to help determine the acceptable amount of liquid contamination

Key merchants:
- **Home Depot**
- **Amazon**
- **Walmart**

Key Activities

Prototype iteration and testing
Quality control procedures
Assembly process optimization

Key Resources

Physical: 4-inch diameter pipes, Wire mesh filtration system, Liquid collection tanks, Arduino sensors

Human: Engineering team, Maintenance staff

Value Proposition

Improves campus **recycling efficiency** by separating liquids from bottles

Reduces contamination of recyclable materials

Decreases workload on recycling facilities

Simple 3-second bottle disposal process
Capacity for 25 bottles (60% of normal trash can)

Customer Relationships

Direct user feedback collection
Collaboration with sustainability groups
Performance reporting to stakeholders (e.g. Dartmouth)

Channels

Dining halls
Campus custodial services
Managers of public spaces
Social media and campus communications

Customer Segments

Purchasers:
Facilities management team
Recycling facility workers

Users:
Dartmouth College students
Faculty and staff
Dining hall patrons

Cost Structure

Fixed Costs: (per annum):
Workshop Rent – $10000
Machinery – $1000
Electricity – $1000

Total FC – $12000

Variable Costs (per unit):
$25 (Arduino) + $40 (Trashcan) +$ 15 (Sensor) +$ 15 (Misc. Parts) = $95
Assembly – 1 hr x 20$/hr = $20

Total VC – $115

Revenue Streams

Business-to-Business (B2B) sales with campus and other institutions' custodial services (bulk purchases)
Selling utility and design patents
12000/(200-115) =141.1

As such, say we sell at $200, breakeven would require 142 units (likely lower if mass produced due to EoS)

Our Team

Member	Contributions
Nigel Testing Lead	• Designed the media content, which includes visuals, presentations, and any multimedia aspects needed to present the project. • Assisted in the testing phase and in building the prototype • Testing the project's functionality to ensure smooth user interaction.
Wesley Resources Lead	• Contacted stakeholders to gain a deeper understanding of the project requirements, website creation and documentation • Oversaw resource allocation and financial management, business plan • Conducted research on latest advancements and potential challenges
Swabir Design Lead	• Created detailed diagrams for the wire mesh design and constructed prototype • Monitored and organized required session attendance. • Helped in building the prototype, including the Sensor Operated Door
Batu Mechanics Lead	• Ensured the smooth integration of mechanical components, did calculations to derive dimensions of objects (pipes, etc.) • Designed the bottle flipping mechanism • Oversaw the building of the first prototype

Reflections

What can we improve on?

- **Scope:** Our machine is also effective for cans
  - Next steps: Extensively test cans

- **Mesh angle**: Steeper mesh could make draining more effective
  - Next steps: Could iterate more on the angle of the mesh.

- **Resource Allocation**: “Make things, break things” approach. Should have used more resources from the start for more iterations.

- **Container Size**: Larger trash can & collection bin = more bottles collected and less frequent maintenance
  - Next steps: Test different container sizes

Reflections

- **Testing:** More tests to answer the question: how often do the liquid waste and bottles have to be collected?
  - Next Steps: Test at different locations (e.g., Novack)

- **Early & constant feedback:** More and earlier feedback from all stakeholders (students, custodians, Casella, sorting facilities, etc.) for better design choices

❤ Special thank you to:

- Prof. Vicki
- Susan Weider
- Kevin Baron
- Review Board
- Tad Truex
- Danny DeNauw
- Joe Poissant
- Marina (our TA)
- MShop & ENGS 21 TAs

Thank you!