Redesigning the Step Stool Experience

BY SEDI-ANNE, JULES, ZOE, MARISOL, TAYLOR, AND DANA

Table of Contents

Introduction

Problem Statement

Users don’t have easy access to step stools and ladders when they need them, and can find existing products stressful and inconvenient. This can lead to misuse when performing maintenance or accessing storage, making everyday tasks unnecessarily risky and anxiety producing.

Some context...

2,000
ladder-related injuries every day
(ANSI)

+300
ladder-related deaths annually
(ANSI)

+130,000
emergency room visits related to ladders annually
(ANSI)

Design Research

01. Semi-structured interviews

02. Image Sorting

03. User Mapping

04. Takeaways

05. Secondary Research

01. Semi-structured interviews

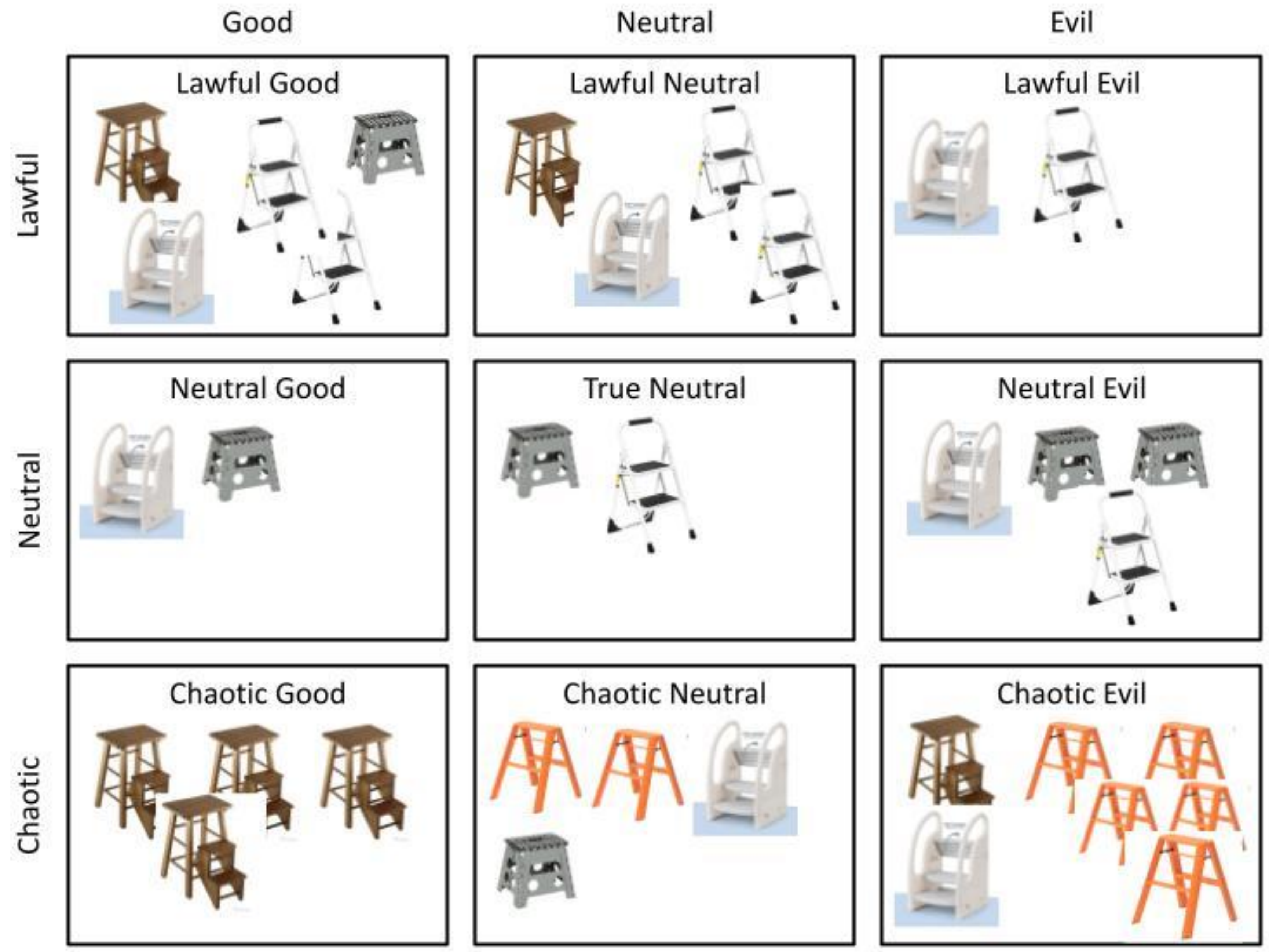
- Used 9 open ended questions to identify step ladder use cases and pain points
- Interviews conducted in pairs with one group member leading and one recording responses
- Interviewed 7 college students between 20 and 22

Example Response Matrix:

Associations	Target user	Use cases	Frequency	Storage	Frustrations	Notes
Household handiwork	Short adults	habitual housekeeping (such as changing batteries and lightbulbs)	once a month	empty room space	Stability	Unstable regardless of height
Kitchen	Children	incidental – reaching a high shelf	~ twice a year	garage, basement	Folding & Unfolding	Difficult to understand and use
	Extra tabletop space				Poor Quality	Could break while stepping on it

02. Image Sorting

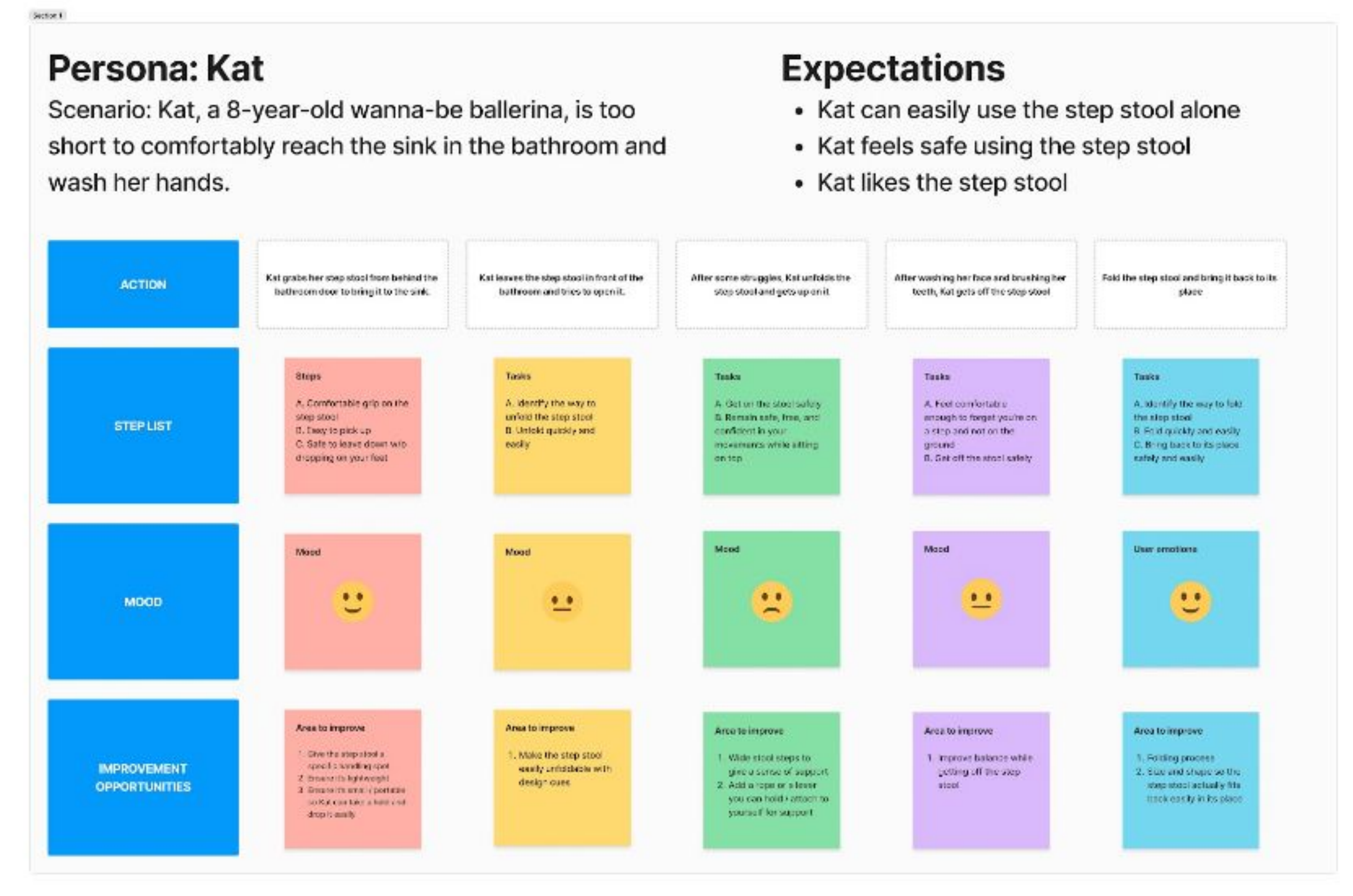
- Presented 7 participants with images of 5 step ladders
- Chose a variety of existing products based on price point and aesthetics
- Went through photos twice
    1. Asked for general impressions
    2. Asked to sort ladders based on D&D alignment system



03. User Mapping

- Created user maps based on interviews and hypothetical scenarios
- Defined action, tasks, mood and improvement opportunities

Example User Map:



Key Takeaway s

01.

Stability

Users feel discomfort and insecurity standing on top of step stools. They often support themselves by leaning on a wall or other furniture, increasing the risk of injury.

02.

Folding mechanism

Current folding and unfolding mechanisms are unintuitive and often pinch fingers, turning a simple process into a struggle.

03.

Quality

Users are often afraid that the step stool will break while they are standing on top of it, given that they are usually made of unsturdy plastic.

04.

Limited usability

Users are concerned about end of life for their step stools, as they take up space when no longer being used and have little use overall

General Associations

A total of seven students were asked to categorize five step stools according to the Moral Alignment Chart in order to evaluate the current associations they had to different designs.

"Good"

Users generally classified safe, "sturdy-looking" step stool as "Good," suggesting that they equate a good, attractive product with safety.

"Neutral"

"Neutral" step stools had a standardized look with metal steps and stabilizers, suggesting that this design is acceptable but has disadvantages.

"Chaotic"

"Chaotic" designs stood out as multifunctional and adaptable to different interiors, indicating that users find it "out-of-the-ordinary" for a step stool to serve more than one purpose.

"Evil"

"Evil" designs stood out with a commercial and "potentially unreliable" look – typically plastic and unsupported.

User Demographics (Secondary Research)

- Infrequent use – but still a standard product
- Impact on health and work performance
- Niche user demographics have unique requirements
    - Need for inclusivity

Elderly People

People aged 65+ are 80% more likely to visit the emergency room because of a ladder fall

Limited knee extension strength, slower cognitive speed, and fear of falling increase discomfort and safety risks for elderly people (Pliner et al., 2021).

Additional factors that affect the step ladder experience include vision, vitality, and pain issues (Tiedemann, et al., 2007).

Manual Labor

The wellness of orchard and milling workers is put at risk every day at their workplace

According to Rosyidi et al. (2023), milling operators using step stools to do their job reported pain in their lower back, shoulders, wrists, and knees, and their working posture was reported as requiring “immediate intervention.”

Duraj and Fathallah (2020) discovered that orchard workers’ heart rate increased significantly together physical exertion when using a step ladder built according to current American National Standards.

Potential Safety Features for Improvement

01.

Wireless sensor for load & angle

STO Building Group, 2022

“Smart" sensors can be attached to particular steps. They can alert users and advise them to either take preventative action or stop using the ladder.

02.

Stabilizers to enhance safety

Shrivastava et al. 2018

Stabilizing elements at “extreme end positions with rubber paddings” and specific locking systems can improve stability and comfort for everyday tasks.

03.

Cross-shape spreaders

Mansori and Rink 2011

Cross-shape spreaders are equivalent to an increase the thickness of the front rails by 60% or their stiffness by 60%.

04.

Stool cap to lean on

Mansori and Dupont 2023

Users are most stable when a fixed reference is lightly touched. Designing a ladder with a surface to lean on will increase user stability.

Engineering Considerations

01. Human Factors

02. Final CAD Design Drawing

03. Testing Analysis

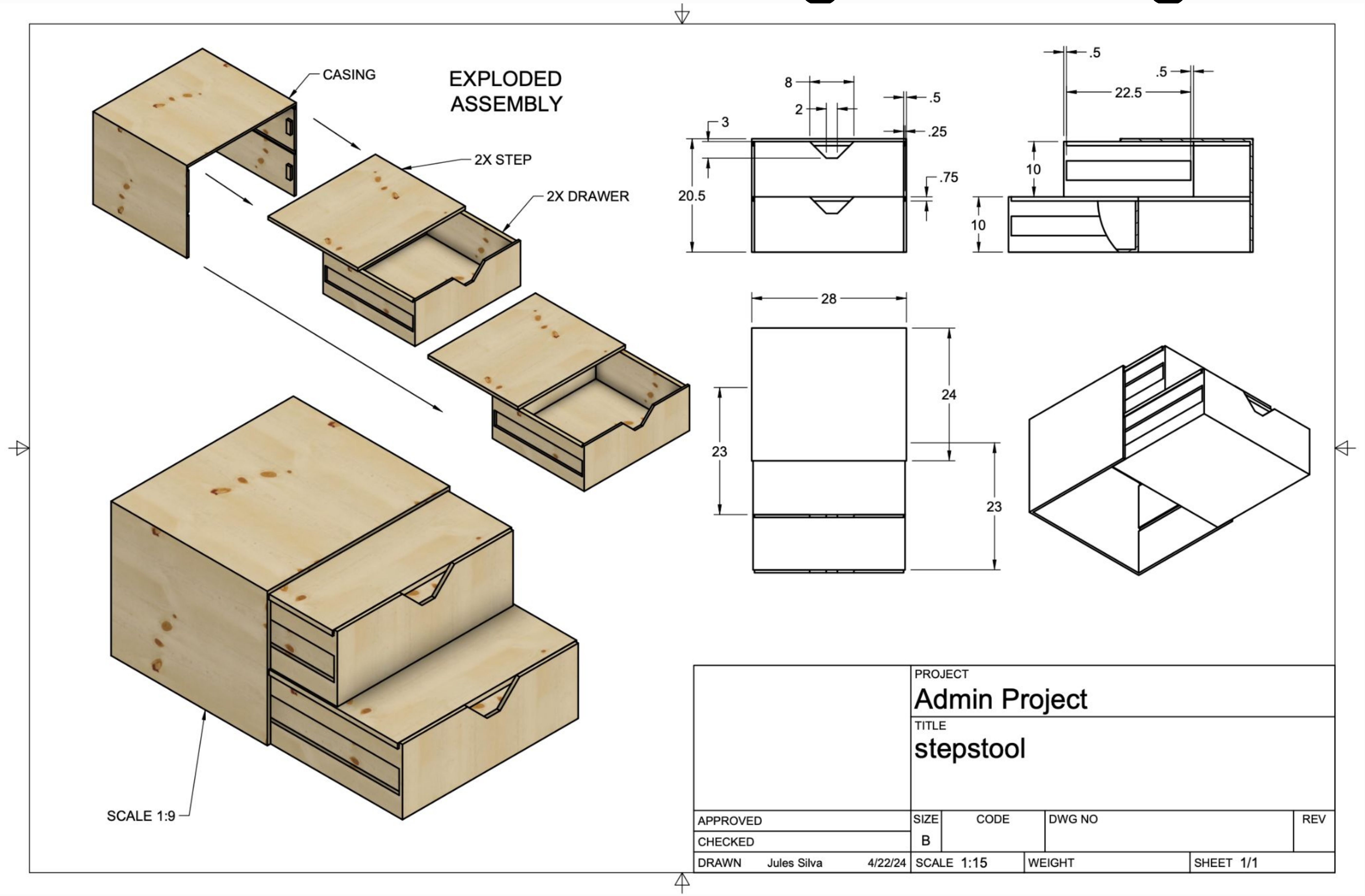
Human Factors Requirements

Design Requirements	Requirement Source
Step stools should have strong stability (e.g. use a splayed base).	Shepherd, G. W., et al. (2006)
Step ladder feet should be flexible rubber with serrations and incorporate an attitude pad such that contact area is maximized.	Shepherd, G. W., et al. (2006)
Step ladders and ladders should not be placed at too shallow an angle (less than 70°).	Shepherd, G. W., et al. (2006)
Step ladders' rung spacing of 26.7 cm leads to lowest perceived exertion.	Duraj, V., Fathallah, F. (2020)
Reducing step height and providing forward lean support for fall prevention.	Pliner, E.M., et al. (2020)
Step ladders should not cause discomfort in knees, wrists, shoulders, or the lower back.	Rosyidi et al. (2023)
Step ladders should not exasperate limited vision and everyday pain.	Tiedemann et al. (2007)

Key Points:

- Rung Spacing
- Step Height
- Stability

Final CAD Design Drawing



- Exploded Drawing
- Isometric Views
- Rendering in plywood
- Component part views exposed through window
- Used to determine OSHA compliance

Engineering Analysis

OSHA Standards	Requirement Source
Rungs, cleats, and steps of step stools of the base section of extension trestle ladders shall be not less than 8 inches apart, nor more than 12 inches apart, as measured between centerlines of the rungs, cleats, and steps.	OSHA 1926.1053(a)(3)(ii)
Rungs, cleats, and steps of most portable ladders and fixed ladders (including individual-rung/step ladders) shall be spaced not less than 10 inches (25 cm) apart, nor more than 14 inches (36 cm) apart, as measured between centerlines of the rungs, cleats, and steps.	OSHA 1926.1053(a)(3)(i)
The top or top step of a stepladder shall not be used as a step.	OSHA 1926.1053(b)(13)
Each step or rung of a fixed ladder must be able to support a load of at least 250 pounds (114 kg) applied in the middle of the step or rung.	OSHA

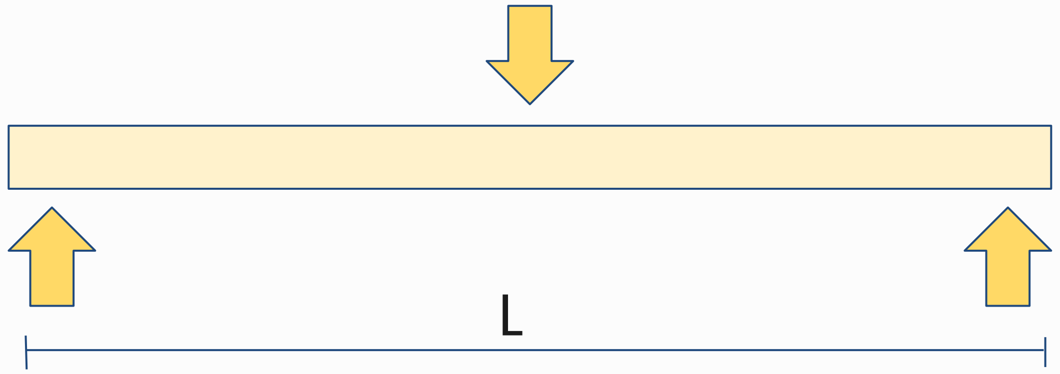
Test Specification:

- 250 lb load applied at center

Analysis:

- Beam bending with support at both ends and center force

Engineering Analysis



Specifications for Analysis:

- 672 sq-in Plywood panel
- OSHA standard of 250 lb load at center
- Young’s Modulus of Plywood 7 GPa (conservative estimate)
- Max tensile strength of plywood in 17.6-34.5 Mpa range

Force at Center

$$F = 114\,kg\,x\,9.81\,\frac{m}{s^2} = 1117.2\,N$$

Beam Displacement at Load

$$\delta = \frac{FL^3}{48\,EI} = 3.41\ mm$$

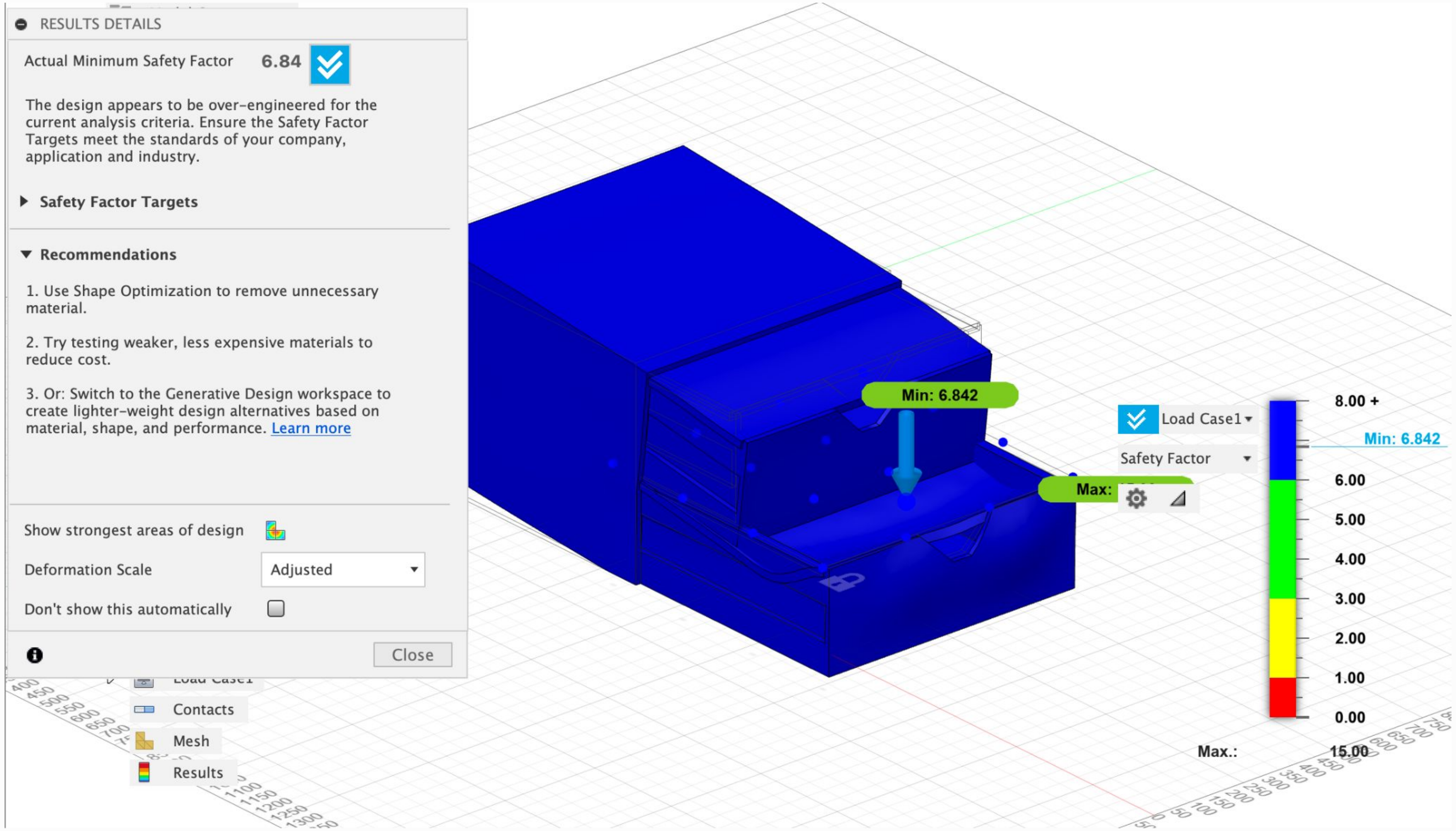
Area Moment of Inertia

$$I = \frac{bh^3}{12} = \frac{(609.6\,mm)(19.05mm)^3}{12} = 351195\,mm^4$$

Stress at Load

$$\sigma = \frac{y_{max}FL}{4I} = 5.39\,Mpa$$

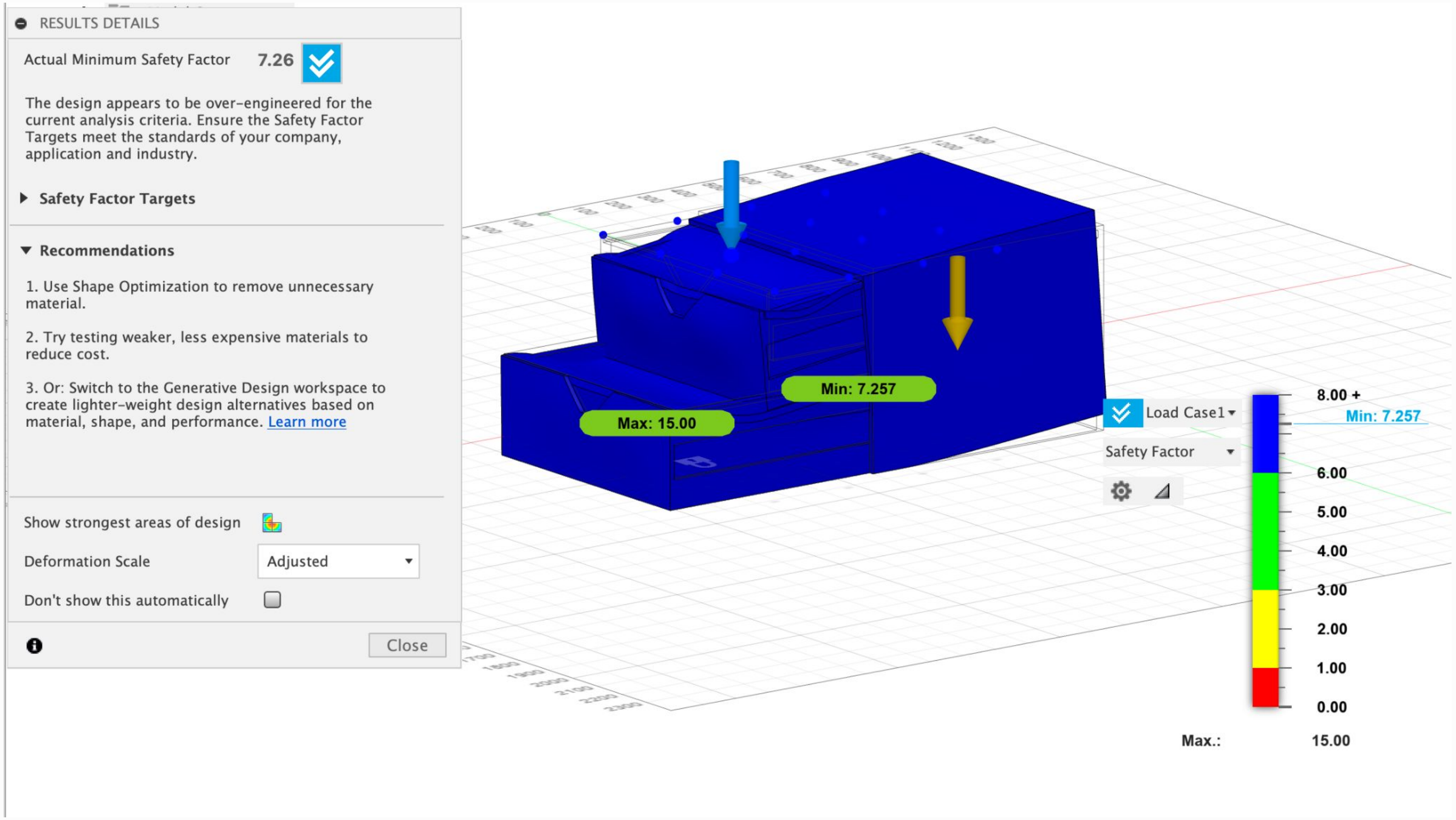
Load Assessment (Engn Considerations)



Bottom step load assessment using OSHA standards in terms of certifiable applied force on a stepstool.

Load Case also includes gravity and constrains the bottom drawer to the floor (which would naturally occur with applied weight).

Load Assessment (Engn Considerations)



Top step load assessment using OSHA standards in terms of certifiable applied force on a stepstool.

Load Case also includes gravity and constrains the bottom drawer to the floor (which would naturally occur with applied weight).

Manufacturing, Materials, Components

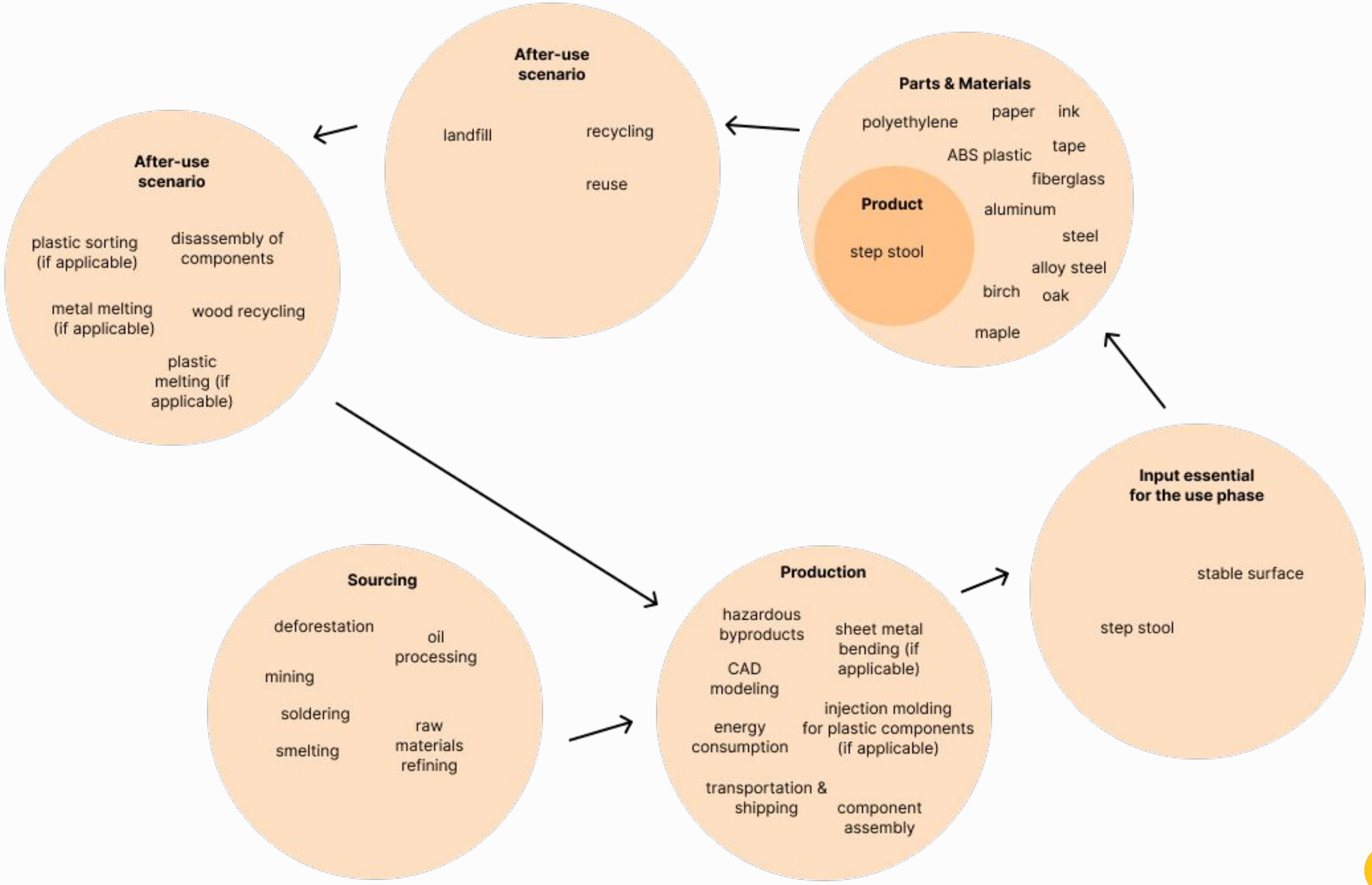
01. Environmental Considerations

02. Life-Cycle Assessment

03. Material Considerations

Environmental Considerations

Even though step stools are not necessary on a daily basis, this doesn't reduce their potential negative impact on the environment and their users.



Environmental Considerations

Materials

Polyethylene and ABS plastic – common materials used for the base of the step stool – can be extremely harmful due to their oxidation in landfills and greenhouse gases. Aluminum - another materials whose recycling requires a lot of energy

Chemical exposure

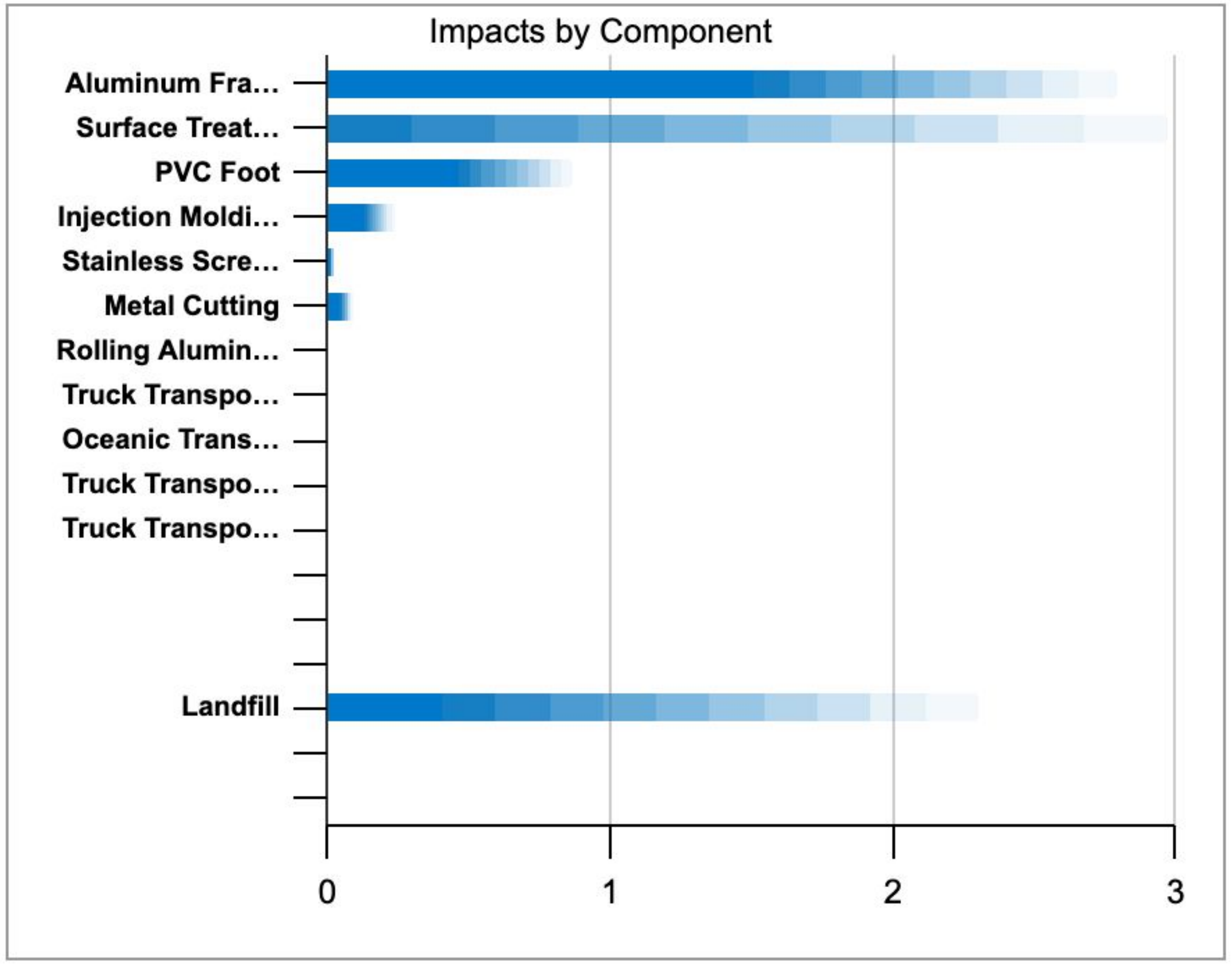
Polyethylene has been shown to "leach" toxins that cause harm to many aquatic ecosystems and cause anti androgenicity, which is a sign of endocrine disruption.

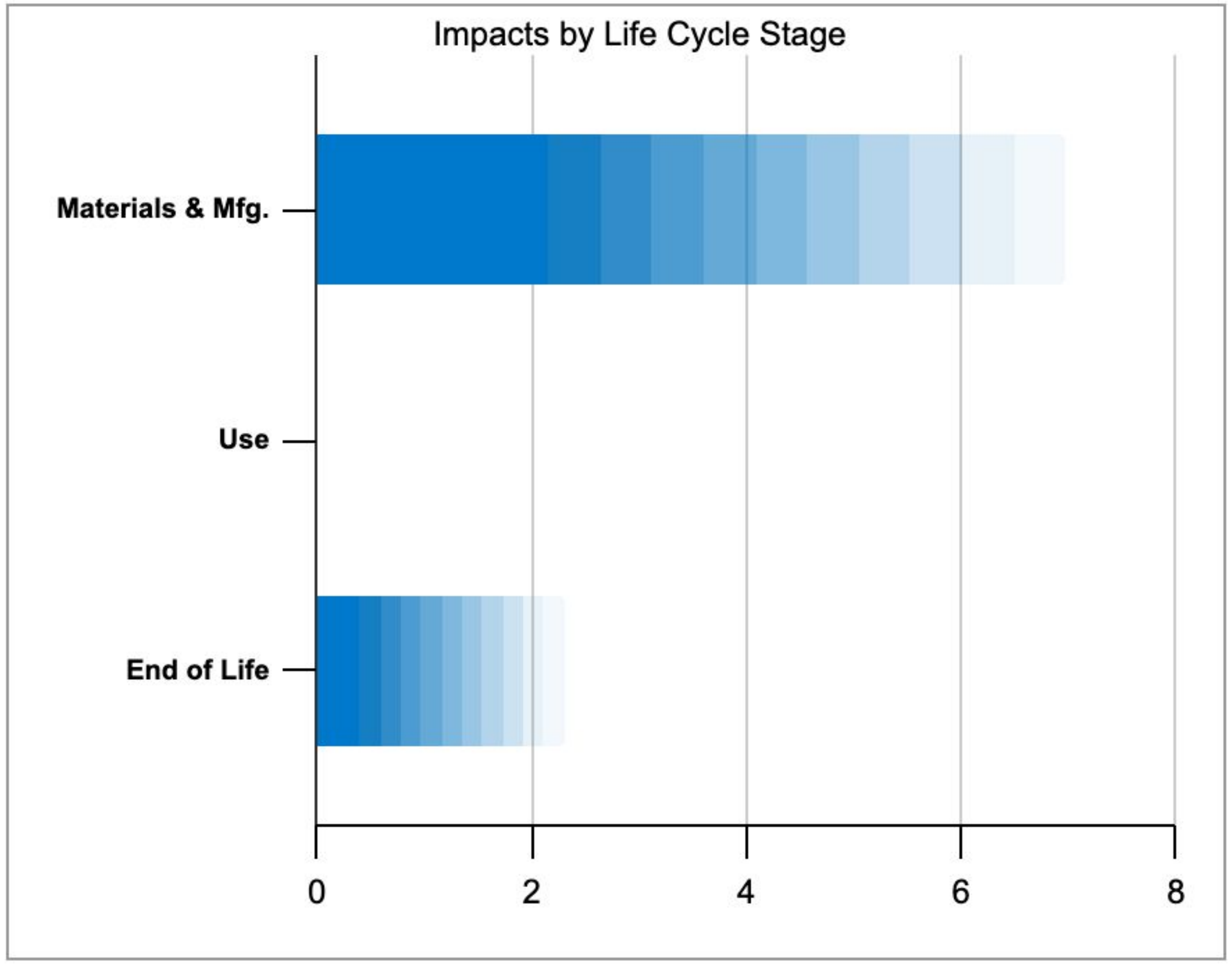
Limited functionality & lifespan

Step ladders are rarely used more than once a month (if even that often), suggesting that the materials and environmental footprint that go into its production is much bigger than the payoff.

Life Cycle Assessment (LCA)

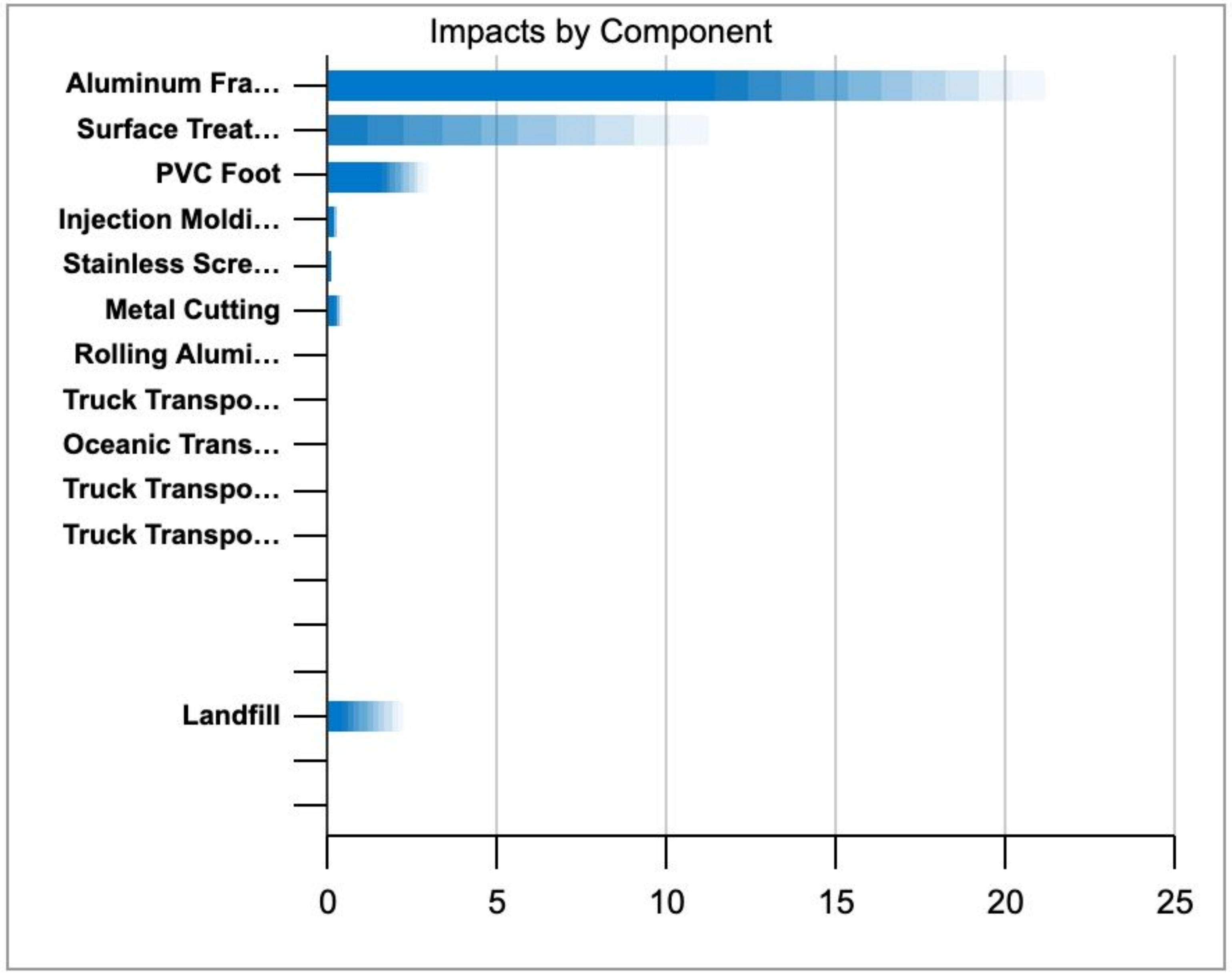
Total Eco-Costs

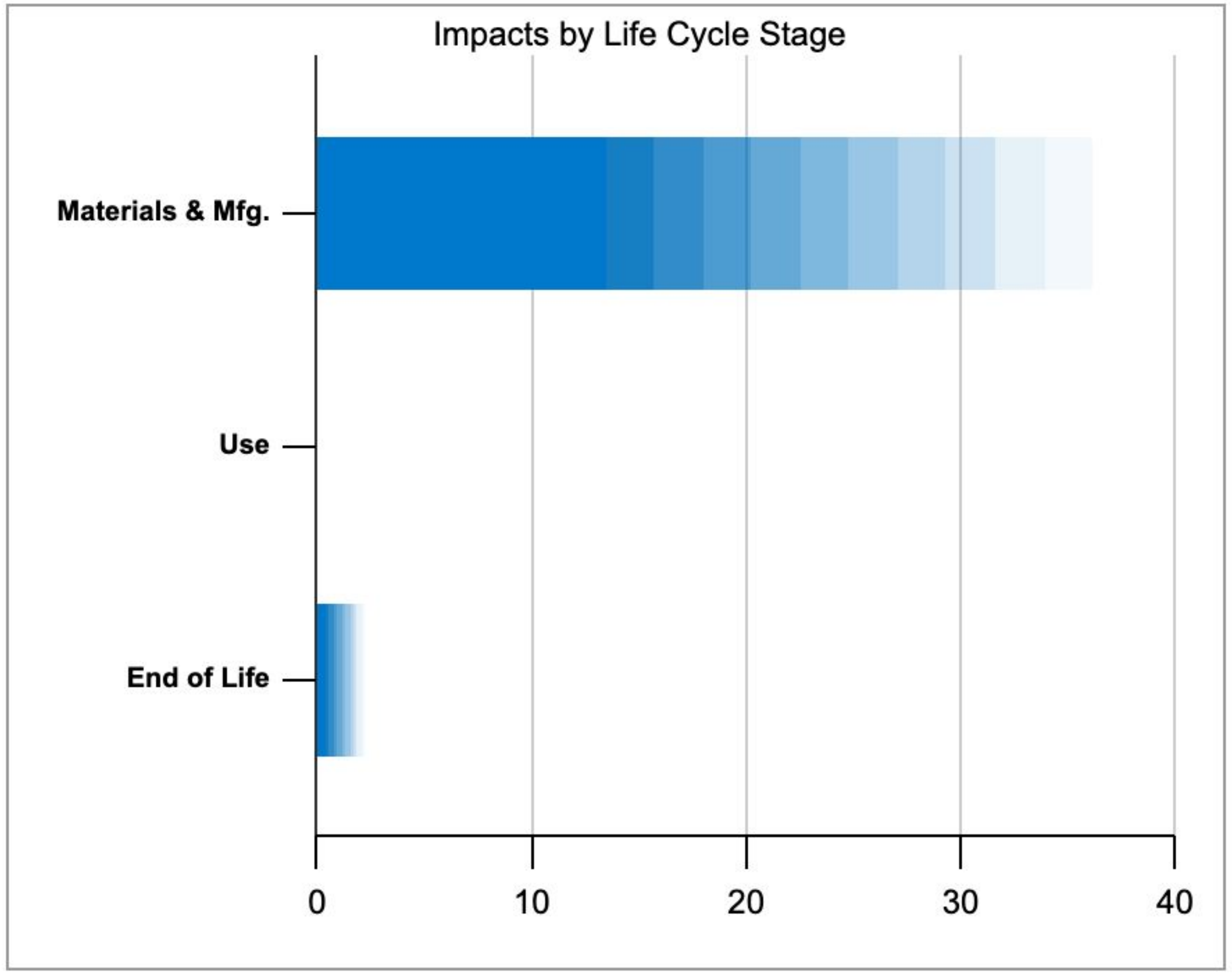




Life Cycle Assessment (LCA)

Carbon Footprint





Material Considerations (MDF & Plywood)

01. **Can Hold Weight**

02. **Not Fossil Fuel Based**

03. **Easy to shape**

04. **High Fidelity**

Ideal Material: Solid Wood

Sustainably sourced hardwood (pine, cherry, hickory, etc.) treated with bio-based wood protectant

Design Iteration and Prototyping

01. Design Requirements
02. Initial Sketching
03. Prototyping Process

Design Requirements

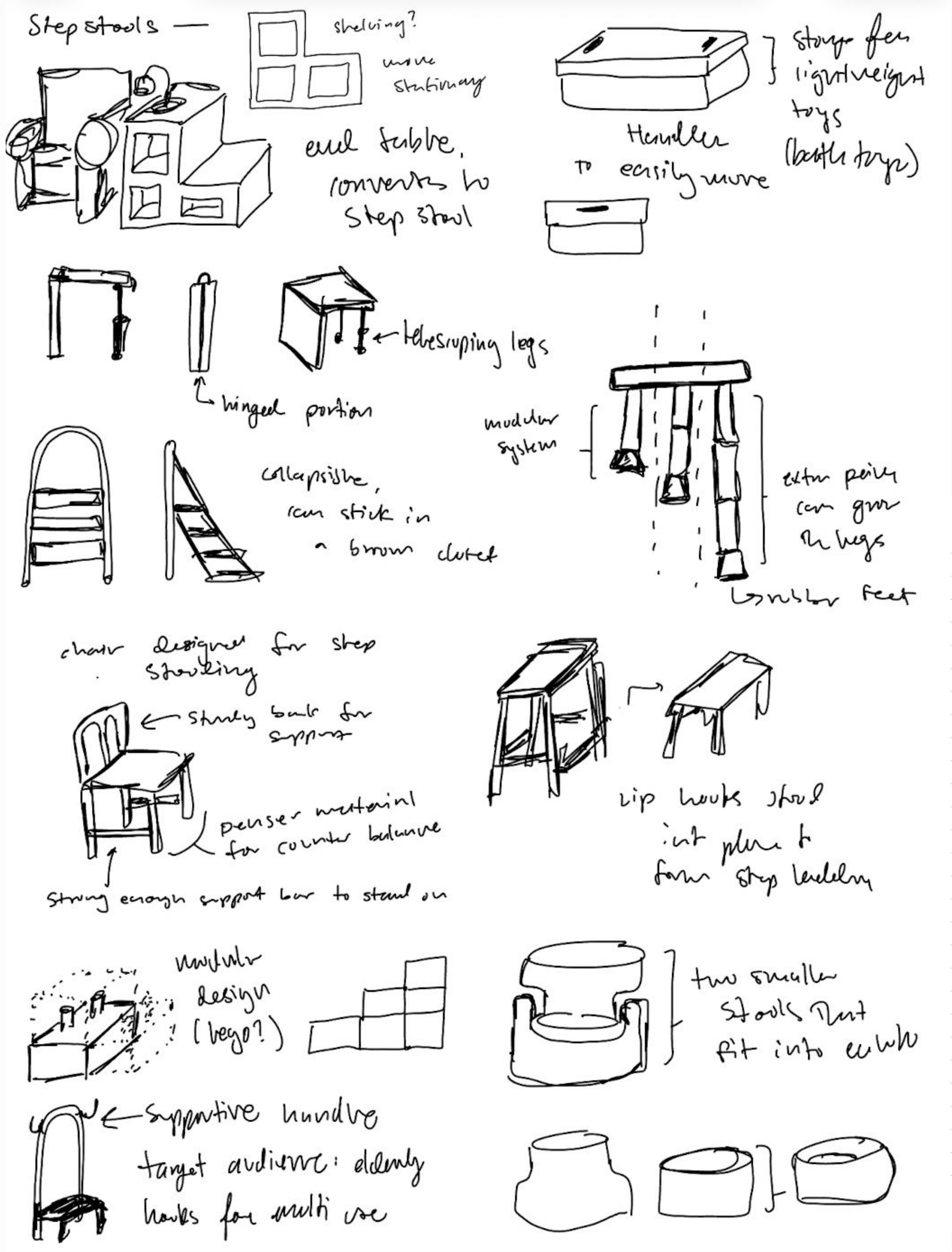
01. Safe and stable

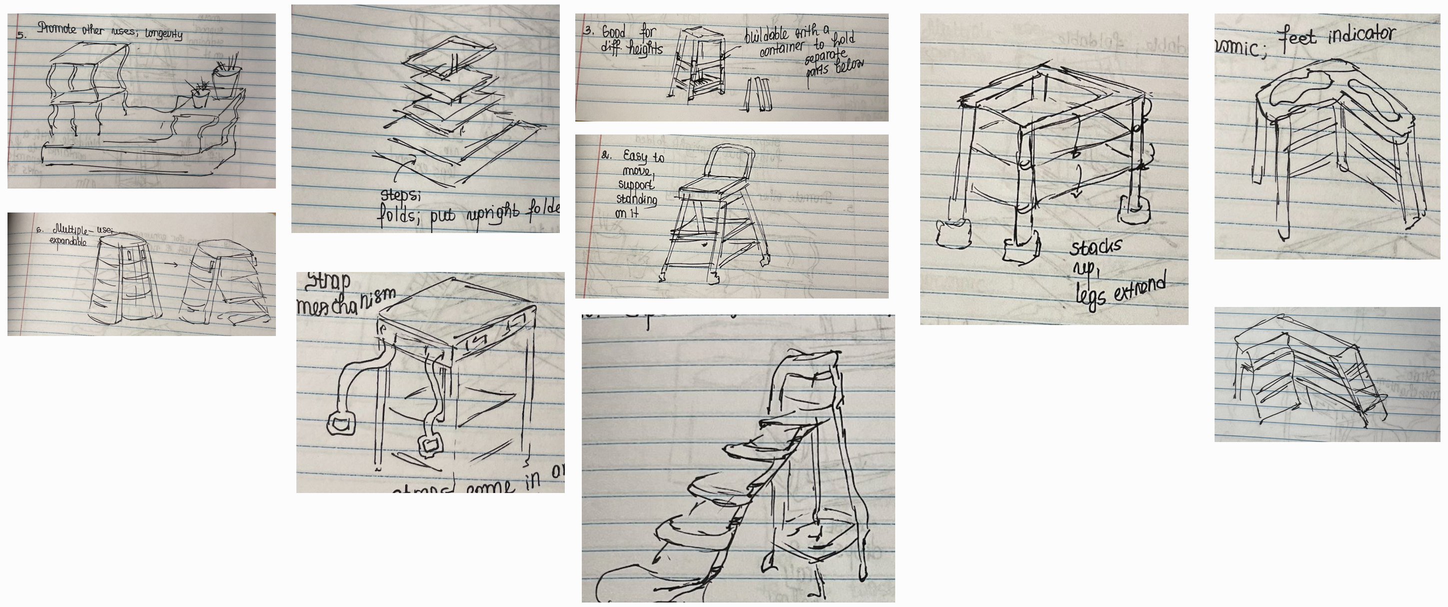
02. Sustainable and materially safe

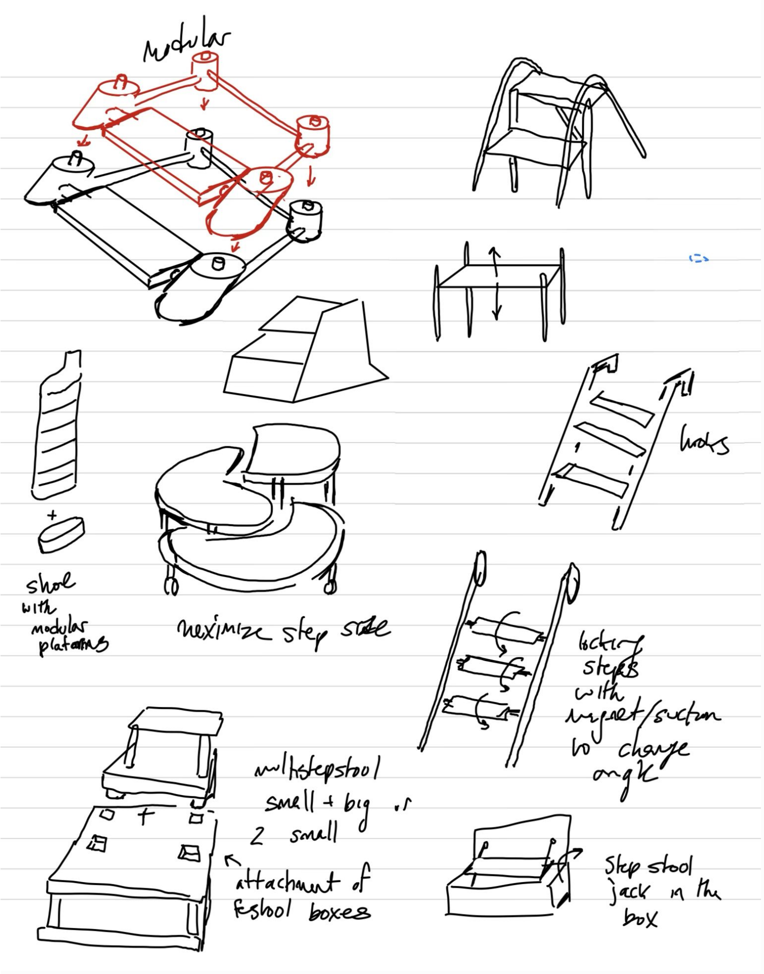
03. Accommodating

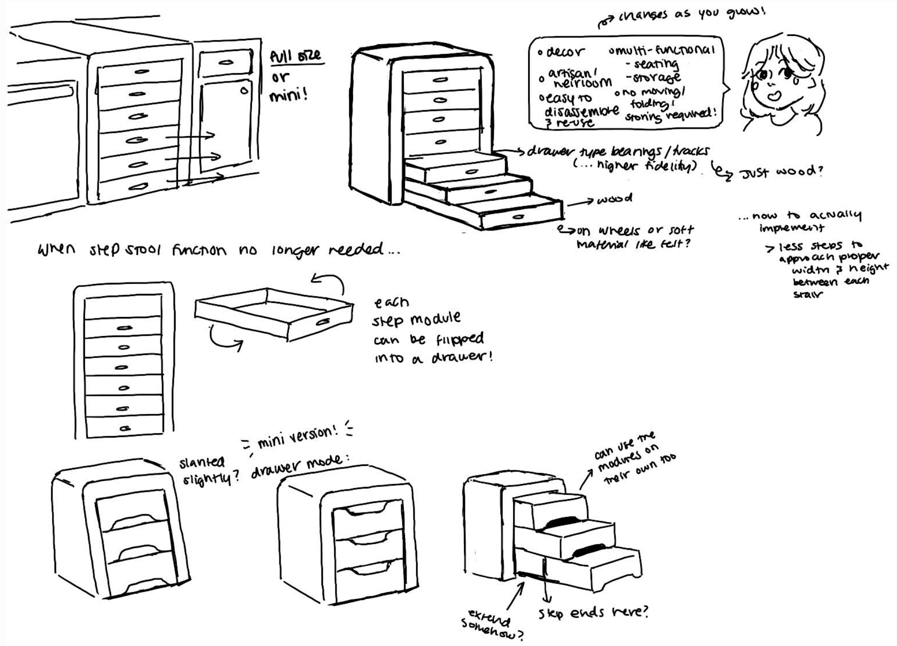
04. Accessible and easy-to-use

Initial Sketches





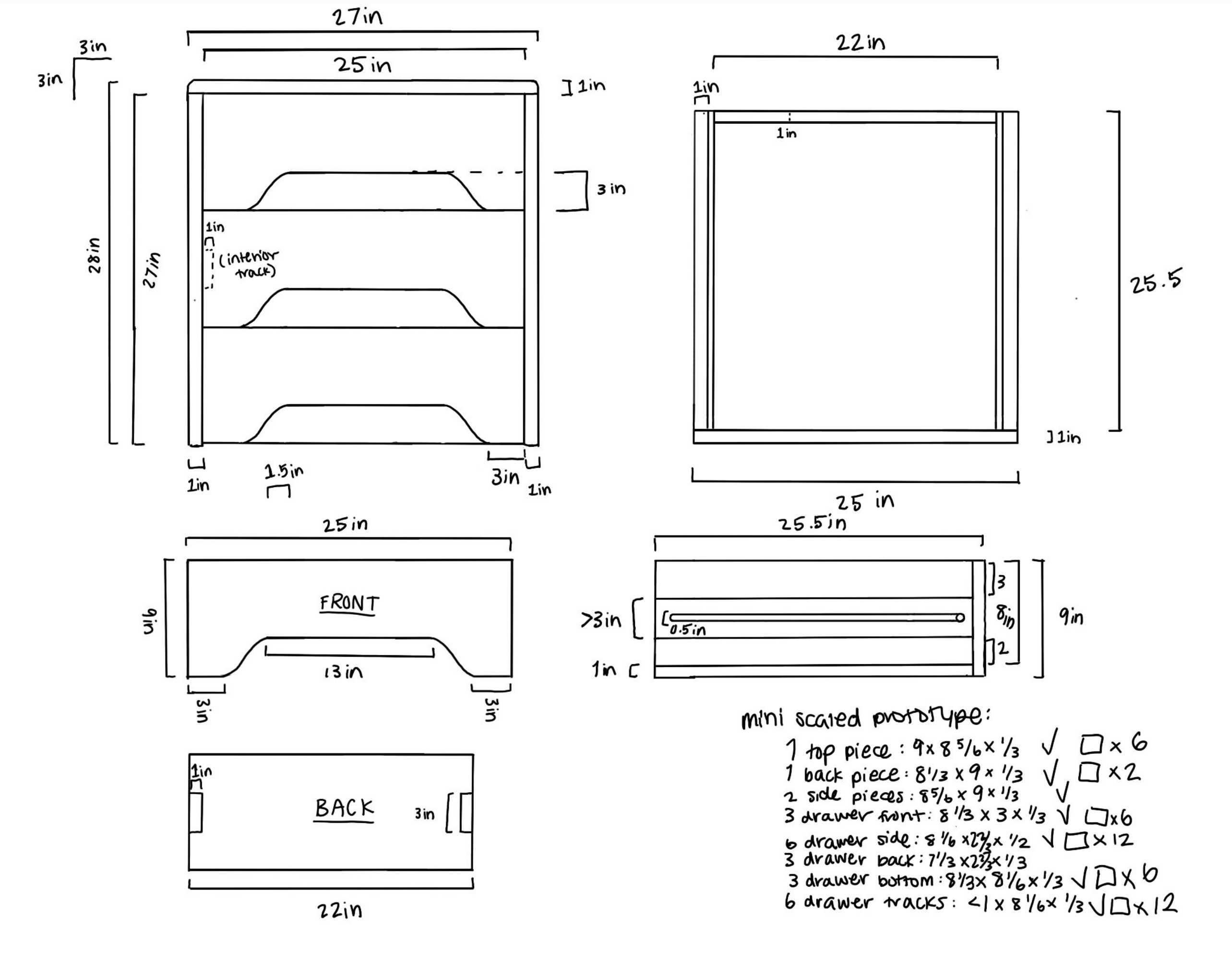




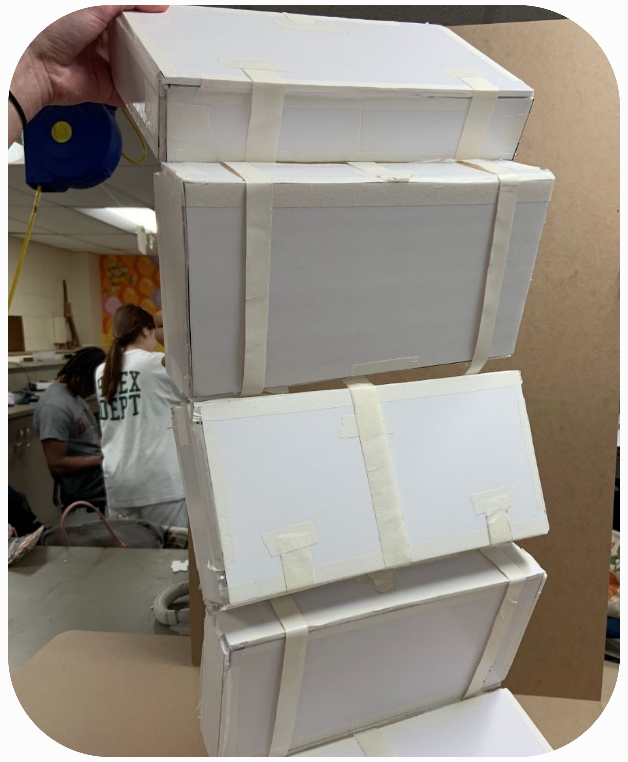
Takeaways:

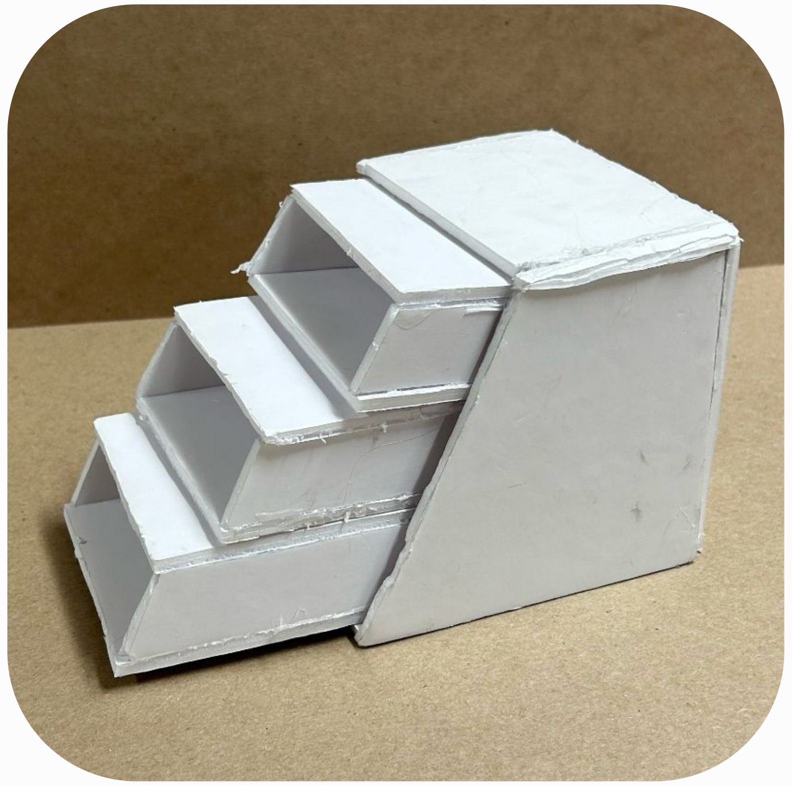
- Modularity
- Multiuse
- Transformation
- Longevity

Prototyping #1



- 6 low-fidelity prototypes
- evaluate designs based on requirements and compliance with all engineering considerations
- Final choice on prototype to ideate on done through primary research with students.





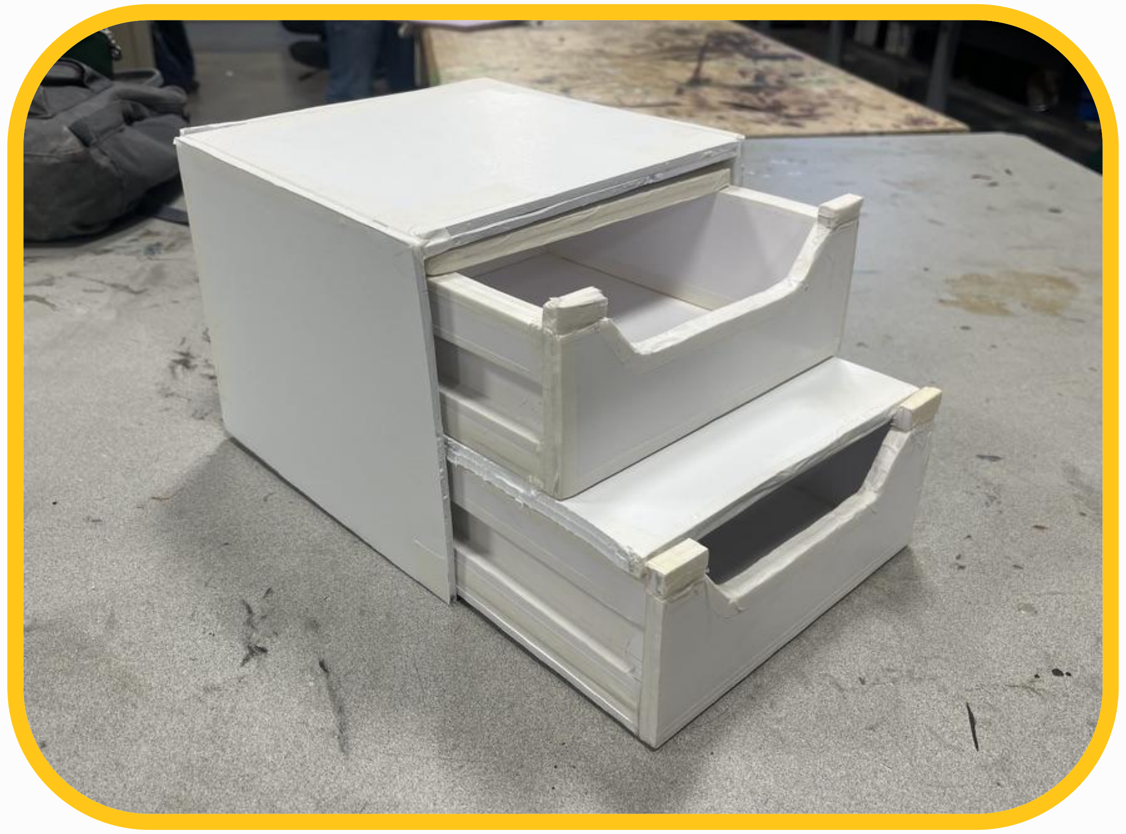
Prototyping #2

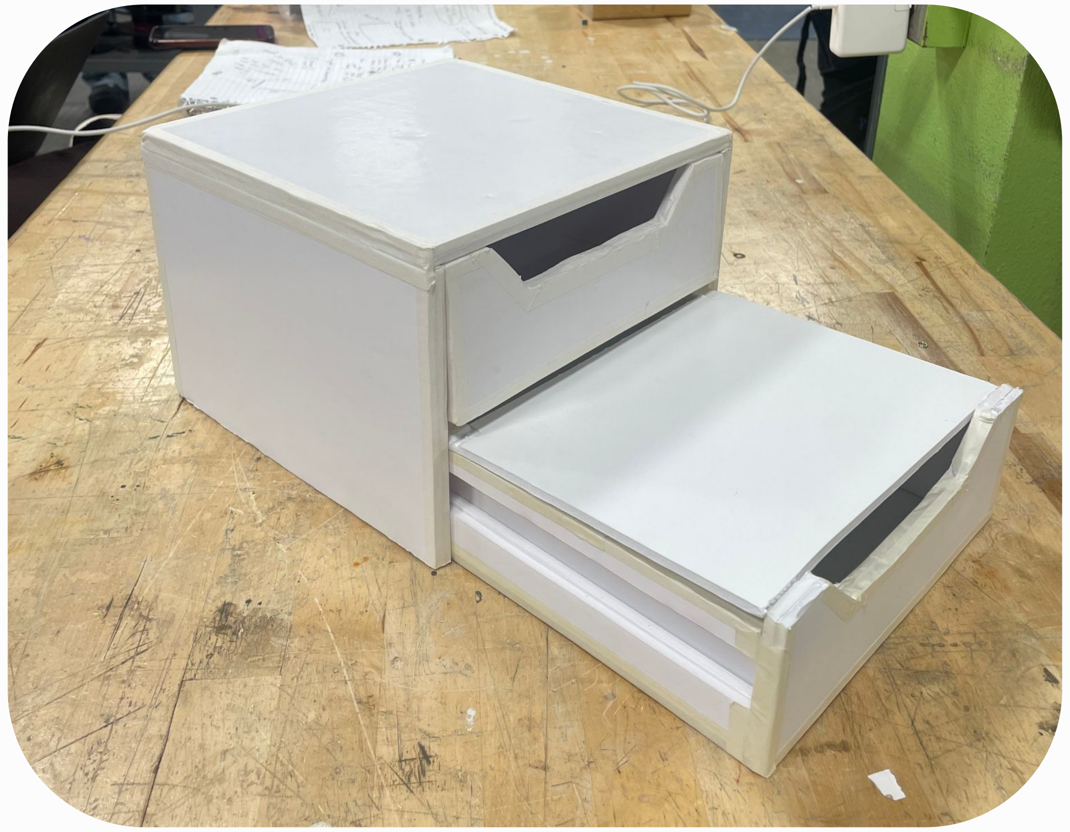
Key considerations included:

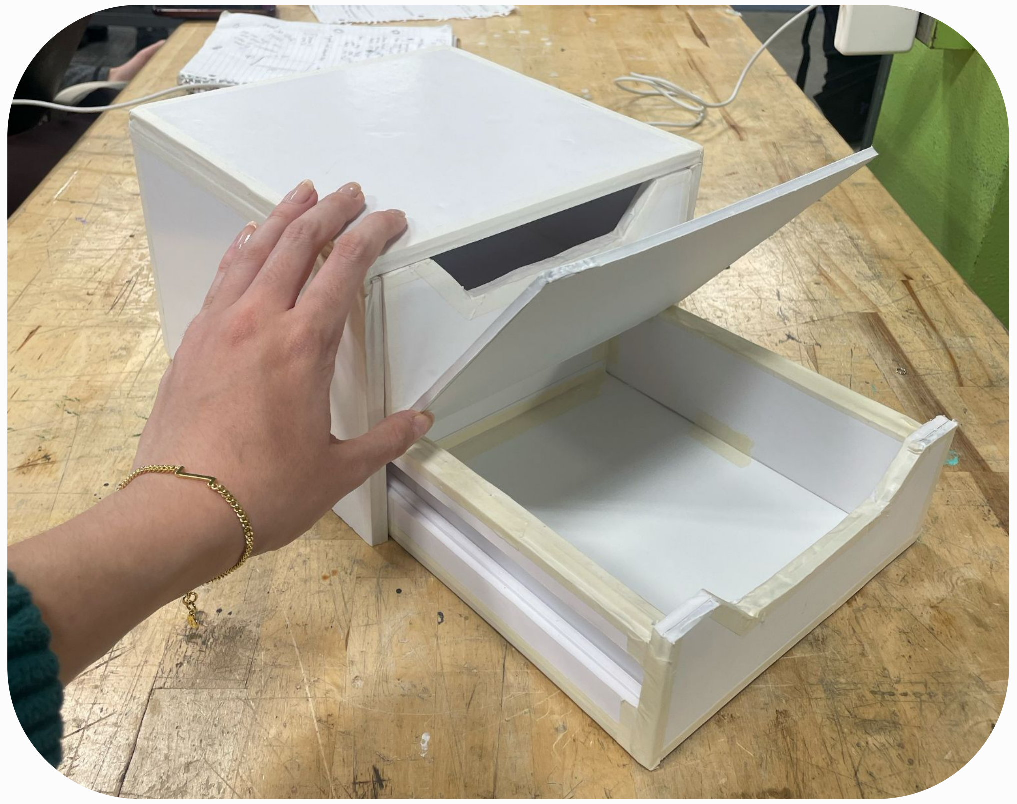
1. Integration vs Individual Piece of Furniture
2. Enhanced multi-functionality
3. User Experience
4. Choice of a sliding mechanism

sliding

hinge







Prototyping #3

Completed after the CAD model, load assessment, and final engineering drawing

Key design and manufacturing choices:

1. Usage of brackets for connection to top panel
2. Router for tracks and filleted edges
3. Finger holes for easier step adjustment
4. Higher fidelity using wood that can support OSHA compliant weight

Final Design

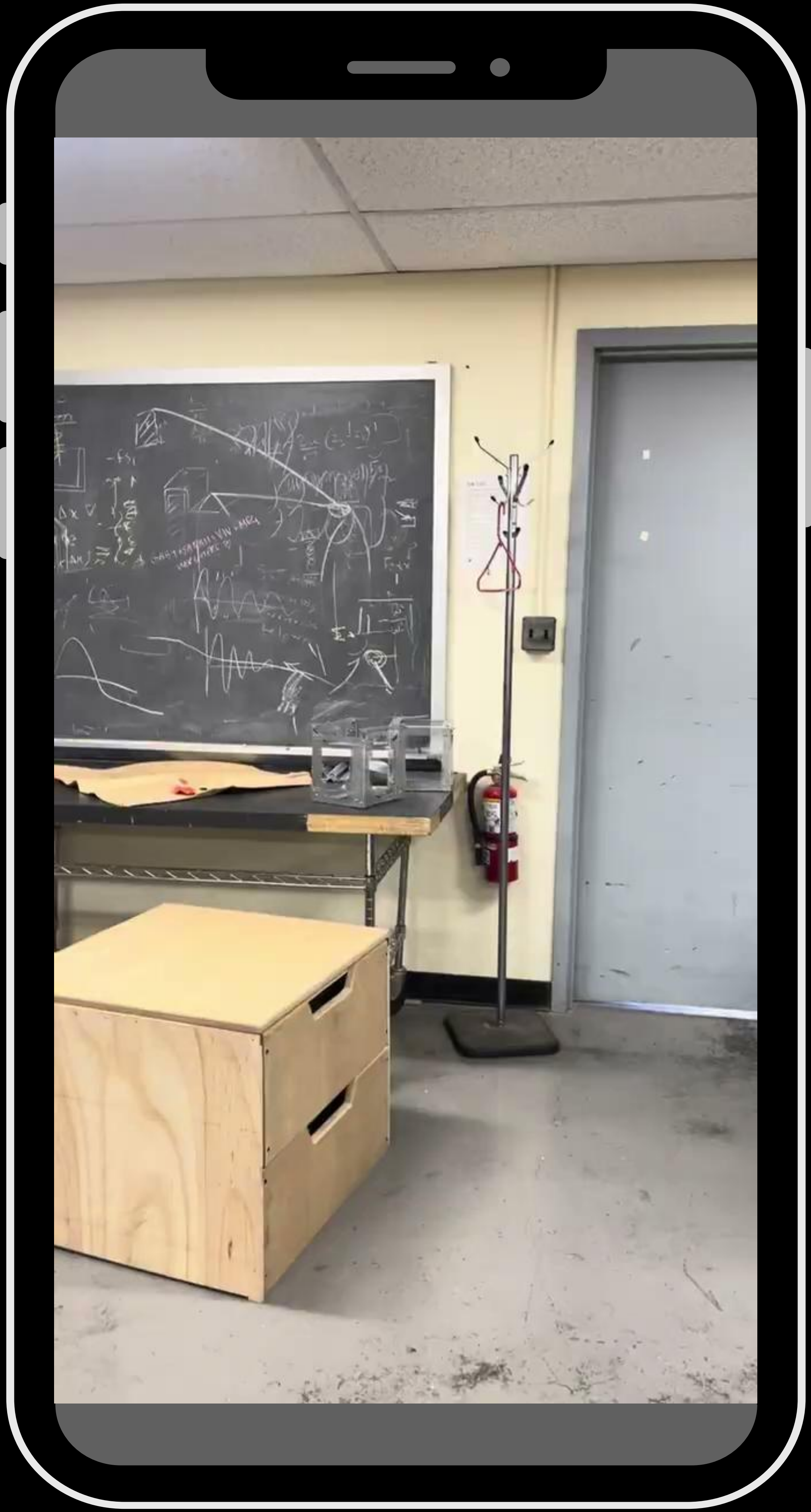
Front
Closed

Front as Step
Ladder

Back Side

Open as Drawer

Final Design



Future Direction

- Built in Furniture opportunities; extending past the dorm
- Current Customer: Colleges purchasing in bulk
- Mass manufacturing using CNC machining rather than hand routering and chiseling
- Joinery rather than brackets for the lid

"It looks like something that would be in a dorm! We must have it in our apartment. So good! You could paint the h*ll out of it" - some rando

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Thank You