I grant permission to the HSU Environmental Resources Engineering Department to use my work and images from Engineering 215, Fall 2020, for acts of education and promotion.

I license my work and images from Engineering 215, Fall 2020, as Creative Commons Attribution and Share Alike (CC-BY-SA).

Tricia Bender 12/10/2020

Claire Ingvoldsen 12/10/2020

Marty King 12/10/2020

Team Sailor Noobs

Fall 2020

Mobile Science Station

Tricia Bender, Claire Ingvoldsen, Marty King

Humboldt State Environmental Resource Engineering Department

Team Sailor Noobs

ENGR 215

Fall 2020

Contents

Figures

1 Problem Formulation

1.1 Introduction

The focus of section one is to introduce and define the problem that Team Sailor Noobs is tasked to solve. This section outlines the background of the problem, the formulated objective statement, and the black box model shown in figure _. The purpose of the black box model is to show the implications of the problems' solution upon completion.

1.2 Background

Team Sailor Noobs is an intrepid band of engineers at Humboldt State University. Team Sailor Noobs was established in ENGR 215 Intro to Design in September 2020 during the Fall Semester per Lonny Grafman's instruction.

Team Sailor Noobs goal is to ameliorate the unsafe conditions that Six Rivers Charter Highschool in Arcata, California is facing due to COVID 19 during their reopening for in person or hybrid instruction. While this is a multi-faceted problem, Team Sailor Noob is specifically tasked with creating an environment in which the students may complete their outdoor science labs safely and without disrupting Six Rivers Charter High Schools' curriculum in a way that holds true to Six Rivers' culture and ethos.

1.3 Objective Statement

The objective of Team Sailor Noob is to design a safe model for the conducting of outdoor science labs that can be reproduced and implemented at Six Rivers Charter School.

1.4 Black Box Model

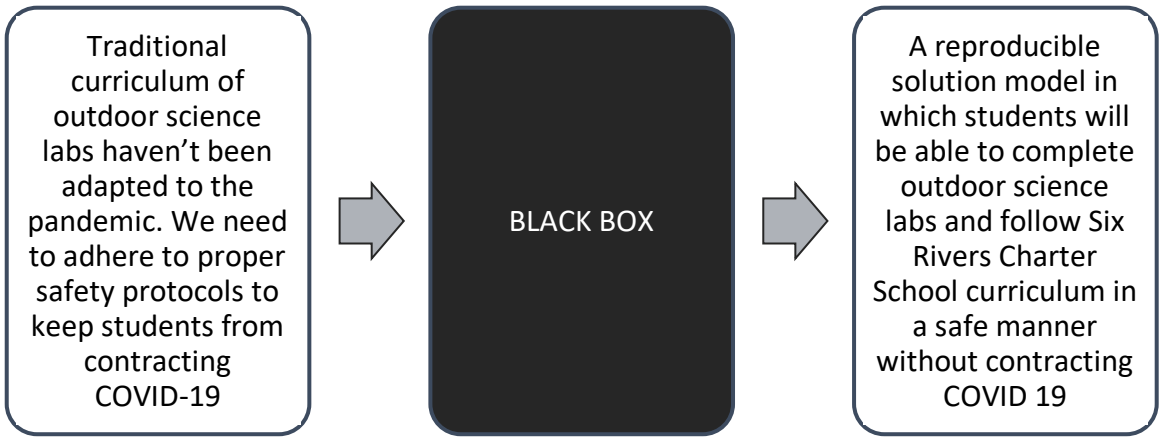


Figure 1.4-1 Black Box

2 Problem Analysis and Literature Review

2.1 Problem Analysis

2.1.1 Introduction to Problem Analysis and Literature Review

The purpose of Section 2 is to provide analysis of the problem of conducting outdoor science labs at Six Rivers Charter High School. This section defines the specifications, identifies the considerations, and formulates the constraints for crafting a solution for Bethany Schmidt, science instructor at Six Rivers Charter High School, and provides all appropriate research to aid in the formulation of a solution.

2.1.2 Specification

Specifications for building an outdoor science lab station that meets the needs for Bethany Schmidt's science class at Six Rivers Charter High School:

- Must be mobile, able to make repeated journeys from the classroom to the creek
- Needs to provide safe storage space for the lab materials being transported while keeping jostling at a minimum and guarding against breaks and spills.
- Has to be able to fit into the limited shared storage space within Bethany Schmidt's classroom

2.1.3 Considerations

While designing this project for Bethany Schmidt's outdoor science labs it is important to keep in mind these considerations:

- Has to be useful as and promote a COVID safe environment
- Should present little to no disruption of class time during set up
- Must be versatile as a science station for conducting different labs across multiple scientific disciplines
- Needs to maximize visibility for students of varying heights be able to see and fully participate in the demonstrations while responsibly socially distancing

2.1.4 Criteria and Constraints

Below in **Table 2.1** are listed the criteria for building the outdoor science lab mobile station solution for Bethany Schmidt's Six River's High science curriculum. Each criterion is expanded and detailed with the specified constraints provided by the client, Bethany Schmidt to best suit their needs in meeting curriculum standards of providing outdoor science labs during the fraught time of high school education during and after the COVID pandemic.

CRITERIA	CONSTRAINTS
Sustainability through materials	Our building materials criteria will be tailored to utilize repurposed and upcycled mats wherever possible
Mobility	The station needs to be able to be easily transported from the classroom to the creek. This is a .25-mile journey that spans pavement, gravel and trail and the cart must be able to roll smoothly so as not to disturb the scientific materials stored onboard.
Size/Space it takes up	Due to limited shared classroom storage, the station must fit into a 4' by 3' nook, hang on wall, or be able to pack up and be transported in Schmidt's vehicle
Cost	Must be as inexpensive as possible
Manufacturing time	Not take so long to build that the students do not get frustrated
Disinfection	Wipeable surface, easy to clean in as little time as possible
Set up time	To be able to be set up while impacting class instruction time as little as possible
Encouraging interactions	School colors and nautical theme! Make it fun and engaging for students.
Durability	The station should be built to last longer than a semester. Ideally providing a stable platform for outdoor science labs for years to come.

Table 1 Criteria and Constraints

2.1.5 Usage

The outdoor science lab mobile station will be used to take scientific measurements, give scientific information, conduct experiments, and to give scientific demonstrations by Bethany Schmidt, science instructor at Six Rivers Charter High School with her students, grades 9-12. The outdoor science lab mobile station is designed to be used throughout socially distanced learning during the pandemic through the return to in-person education with durability and usefulness to span many semesters into the future.

2.1.6 Production Volume

Team Sailor Noob's specific aim is to build one mobile outdoor science lab station specifically to solve the client, Bethany Schmidt's problem of outdoor science education at Six Rivers Charter High School. The team's ultimate ambition is, to create a solution so successful and easily explained that it can be reproduced simply, by any science class, at any grade level, around the world.

2.2 Literature Review

2.2.1 COVID 19

2.2.1.1 Introduction

COVID 19 is strain of coronavirus that caused the World Health Organization to declare a global health emergency on January 30th, 2020, and a global pandemic on Mach 11th, 2020 (Koley and Dole 2020). COVID 19 is most often transmitted between persons through respiratory droplets and can be transmitted from person to person contact or surface contamination. An infected person can have no symptoms of COVID 19 and be able to transmit the virus. (Viner et al 2020)

2.2.1.2 Recommendations and Guidelines

The Center for Disease Control recommends that to avoid transmission of COVID 19 people should frequently wash their hands, avoid being closer than 6 feet from other people, cover their mouth and nose with a face mask, cover all coughs and sneezes, and clean and disinfect frequently used surfaces daily (CDC 2020).

To comply with these recommendations, schools across the country have experienced closures. Humboldt Counties schools closed on March 30th, 2020 (Schneider 2020). In order for Humboldt County Schools to reopen they must determine specific policies that will maintain physical distancing, including making assessments of classroom layout. (Hartley 2020). The Center for Disease control recommends that schools coordinate with their state and local health officials when considering reopening schools and recommends that all schools consider policies that enforce their transmission guidelines (CDC 2020).

2.2.1.3 Reopening in the Pandemic

Around the world countries have reopened schools. In Switzerland, schools have used tape outline six feet distances between desks (Barton and Parekh 2020). Japanese schools have adopted schedules that alternate student's attendance in order to decrease person to person contact (Barton and Parekh 2020). In Guangzhou, China, parents are required to take children's temperature before school and students must walk three feet apart, masks are required all day. Schools in part of the Netherlands have adopted policies that reduce class size to 8 students, and have no mask or distancing requirements among the students. (Burke and Xie 2020). The Independence School in Delaware has adopted policies that focus on teaching outside in tents as much as possible (Took 2020).

It is up to schools individually to outline their specific daily operations. Engineering students in Senegal have designed a robot that is able to measure a person's temperature from a distance that includes a mobile cart with mechanical arm. The Engineering students have also designed automatic hand sanitizer dispensers (Aljazeera 2020). A student in Jamaica has designed a device that uses ultraviolet light to kill pathogens on doorknobs that has been implemented in schools and hospitals. In Morocco, a student has designed an app-controlled drone that can administer COVID 19 tests. (Study International 2020). United States based manufacturing company UltraBoard is one of many companies that has designed plastic protective barriers that can be installed in classroom environments in order to separate persons, a common model for protection when space to physically distance is limited (UltraBoard 2020).

2.2.2 Maker Space

2.2.2.1 CoLab

CoLab is the name for the Six Rivers Charter High School maker space. It is currently closed off to students, along with the rest of campus, until such time as the district deems appropriate to reopen. It is accessible for Team Sailor Noob to use the Formlabs brand, Form 2 3D printer to create parts for a mobile cart solution for Prof. Bethany Schmidt (Sidell 2020). Team Sailor Noobs will be responsible for acquiring needed materials for any 3D printing.

2.2.2.2 FormLabs Form 2 3D Printer

The Form 2 (Figure 1.0) is an SLA (stereolithography) style 3D printer from FormLabs, a respected 3D printer manufacturer. It's an industry leading printer for its style and form factor according to the "editorially independent publication" ALL3DP industry magazine It won ALL3DP.com's "Best Resin 3D Printer" award for summer 2019 (all3dp.com 2019).

Figure 2.2-1 Form 2 3-D Printer

According to ALL3DP, the Form 2 offers some very intricate printing capabilities thanks to the 250mW violet laser and custom-built galvanometers. It can craft reasonably dense resins, especially with the Tough 2000 Resin available for $175/liter from FormLabs

(formlabs.com 2020). Unfortunately, the higher tensile resin requires an improved resin tank that costs $99 (formlabs.com) and those are not the only costs necessary for SLA format 3D printing production.

2.2.2.3 SLA Resin

The SLA printing resin is waterproof (Home and Hauseman 2017). The Tough 2000 resin available through FlowLabs is a more durable version of SLA resin with higher tensile strength and will be a perfect medium to use in fabricating outdoor lab materials.

2.2.2.4 Post-Production

Post-production is a necessary process with SLA printing (all3dp.com 2019). After hearing from Jason Sidell, it became clear the team would need to procure a FORMLABS finishing kit for the CoLab in order to run post -production on the Tough 2000 resin. The finishing kit, available at formlabs.com for $352 (formlabs.com 2020), was overbudget for the project and thus eliminated the possibility of using 3D printing to manufacture design components.

2.2.3 Client Interview

Three clients from Six Rivers Charter High School were interviewed to provided Team Sailor Noobs with the proper information to get started on the design process. The main client being worked with is Bethany Schmidt, a new teacher in charge of the science labs, and other useful information came from Ron Perry the principle for SRCHS and Jason Sidell who is in charge of the maker's space also known as the CoLab. Due to COVID-19 most of the clients that were interview had little to no information for when school would be returning.

2.2.3.1 History of Science labs at Six Rivers Charter High School

Six Rivers Charter High school shares classroom space with Arcata High school and does not have its own chemistry lab with a vented hood for certain experiments. Schmidt has a shared space with another teacher and only has a small nook provided to her to put her lab equipment. Arcata High Schools chemistry room is not a viable area to be a shared space due to AHS chemistry teacher using that space for their students. Due to COVID-19 and there not being a vented hood available for Schmidt to use, her lab classes will need to be held in an outside environment (Schmidt 2020). Students need to be able to see science experiments being done while still practicing social distancing. The lab material needs to be transported safely from classroom/chemistry shed to main AHS quad and nearby creek which is .25 miles from the school.

2.2.4 Health Matters

2.2.4.1 Personal Protective Equipment

Protective personal equipment or PPE is widely used in the medical field to protect workers and patients from harmful transmission or spreading of certain diseases, the biggest concern for 2020 is COVID-19. PPE differs from place to place but mostly consist of gloves, masks, and gowns used to protect from harmful pathogens. Due to the COVID-19 pandemic, PPE is being used for more than just medical workers which is causing a shortage around the world (WHO 2020).

2.2.5 Methods of Sanitation

There are many different tools used to protect one's self from getting sick, but the most overlooked one is hand hygiene. By simply washing your hands with soap and warm water for 20 secs (Osha 2020) every couple of hours throughout the day (BBC News 2020) with help protect individuals from COVID-19.

2.2.5.1 Hand sanitizer

Hand sanitizer is an alcohol-based method that helps clean people's hands without the use of soap and water. Still highly encouraged to wash hands when there is running water available due to the soap helping break down anything harmful on people's hands (BBC News 2020)

2.2.5.2 Ultraviolet

Ultraviolet light is most used in hospitals to kill off possible harmful microbes but can be potentially harmful to humans (ScienceMag 2018).

2.2.6 Arcata High School Campus Terrain

Arcata High School Campus terrain is important to the design process because we need the mobile science station to be able to transport glass material from classroom to final teaching locations.

2.2.6.1 The Quad

The quad is a very large outdoor space mostly made of large concrete slabs, figure 2.2.6.1. Due to the smooth surface of the concrete, glass materials that are in the mobile science station will have less of a chance of breaking on this terrain.

Figure 2.2-2 AHS quad

2.2.6.2 Green Area

The Green Area is located next to the quad and is an open field between classroom buildings. This space would be another idea location for Bethany to conduct outdoor science. With the terrain being made up of grass the team would need to take into consideration of possible holes or bumps in the grass. These might add more moved to the classroom material that is being transported, figure 2.2.6.2.

Figure 2.2-3 Green area

2.2.6.3 Creek Path

The creek path will be the roughest terrain that the mobile science cart will have to endure. The path starts off with concrete as we head from classroom to quad, then to parking lot made up of asphalt, to a gated drive that turns into a small pebble path. The path to the creek is blocked by a lock gate that may or may not be open from day to day and that trail leading to the creek becomes very narrow, figure 2.2.6.3.

Figure 2.2-4 Locked gate at start of creek trail

2.2.6.4 Classroom space

The amount of space in the classroom is very limited, so the mobile cart will need to be able to collapse down and fit into the spaces provided. The mobile cart will either need to fit into **Error! Reference s ource not found.** or **Error! Reference source not found.**, or be able to hang on the wall,**Error! Reference source not found.**.

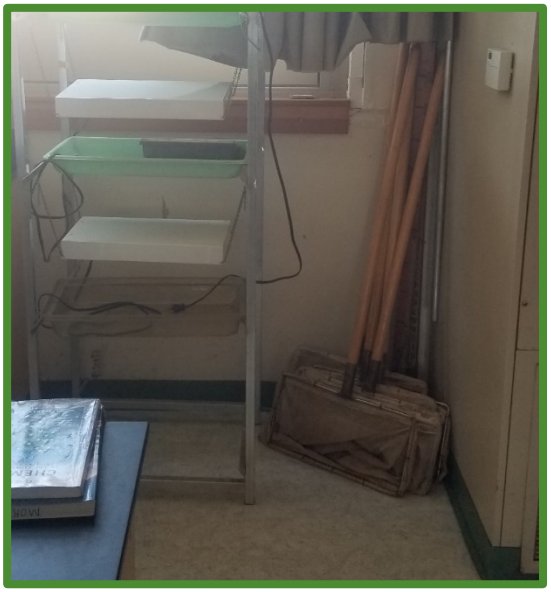


Figure 2.2-7 Nook In Classroom

Figure 2.2-5 Nook In Classroom 2

Figure 2.2-6 Nook In Classroom 3

2.2.7 Collapsible carts

The collapsible cart will need to have a cleanable material, durable wheels, collapsibility, and be able to safely transport classroom material to different lab locations. Four different carts were looked at to help make a final decision.

2.2.7.1 Ozark Trail Multipurpose All-Terrain Cart

Figure 2.2-9 All-terrain cart with 8-inch oversized wheels for easy mobility on different terrains. Removable insert, mesh bottom, and polyester material for easy cleaning. Made with a sturdy metal frame to easily carry up to 225 pounds. Dimensions are 35.5 in L x 18.9 in W x 23.1 in H with a starting price of $68.00 Walmart.

Figure 2.2-9 All-terrain cart

Figure 2.2-8 Mulitpurpose cart with tailgate

2.2.7.2 Ozark Trail Multipurpose Cart with Tailgate

Figure 2.2-8 Mulitpurpose cart with tailgate with 7-inch wheels for easily mobility on different terrains. Removable insert, mesh bottom, and polyester material for easy cleaning. Made with a sturdy metal frame to easily carry up to 225 pounds. Dimensions 37/49.5 in W x 19 in D x 21.6 in H with a starting price of $58.00 Walmart.

2.2.7.3 Ozark Trail Multipurpose Cart

Figure 2.2-11 Mulitpurpose cart with 7-inch wheels for easily mobility on different terrains. Removable insert, mesh bottom, and polyester material for easy cleaning. Made with a sturdy metal frame to easily carry up to 225 pounds. Dimensions 35.50 in L x 18.90 in W x 21.60 in H with a starting price of $44.88 at Walmart.

Figure 2.2-11 Mulitpurpose cart

Figure 2.2-10 Seina Utility Wagon

2.2.7.4 Seina Utility Wagon

Figure 2.2-10 Seina Utility Wagon with 7-inch wheels for easily mobility on different terrains. Polyester material for easy cleaning and made with a sturdy metal frame to easily carry up to 150 pounds. Dimensions 29.5 in H x 17.9 in W x 18.5 in D with a starting price of $55.99 Target.

2.2.8 Material Consideration

This section will describe materials that will be used for the mobile station that will need to be durable and last well beyond COVID-19.

2.2.8.1 Wood

There are many good qualities when it comes to using wood it is aesthetically pleasing to the eye, relatively inexpensive or possibly free, light weight and durable. However, it is a porous material, so it will need to be sealed or painted over in order for it to be COVID-19 friendly.

2.2.8.2 Wood Working

Woodworking is the art of making something from different woods and tools, if you enjoy working with your hands. Woodworking is a satisfying job once you are done with whatever it is that you are making. All of the tools can be bought at any hardware store, as well as the wood need for the project (try to upcycle)

2.2.8.3 Hinges

Hinges are mechanical devices that help attach two different pieces together and allow them to rotate around.

Figure 2.2-12 Hinges (thomasnet2020)

2.2.8.4 Wood screws

Wood screws help connect two different parts together without the hassle of having to use cut joinery. Handy for quick builds and reenforcing certain parts to help it stay together. Many different kinds just look for the ones you need.

Figure 2.2-14 Woodscrews (woodworkersjournal)

Figure 2.2-13 Woodglue (cottagelife2020)

2.2.8.5 Wood glue

Different types of wood glue have a different uses and strengths, so make sure you are getting the right kind when buying it for your wood working project. Wood glue is used as an added support for keeping different pieces of wood together.

3 Alternative Solutions

3.1 Introduction

Alternative Solutions illustrates the brainstorming that was conducted by Team Sailor Noob in the process of developing alternative solutions to better meet Six Rivers Charter High School's need for a portable platform for conducting outdoor science lab classes.

3.2 Brainstorming Process

Our brainstorming sessions occurred over several informal zoom meetings and especially took off after we were able to meet with and interview the client, Bethany Schmidt, science instructor at Six Rivers. Through a series of interviews and emails Bethany was able to give the Team enough information to better frame the problem and begin brainstorming solutions. After several sessions utilizing brainstorming techniques such as Association, Break Physics, and Exaggeration, Team Sailor Noob created a design matrix that was sorted by combining varying features of a portable mechanism devised through brainstorming.

3.3 Alternative Solutions

Below are the potential designs for Team Sailor Noobs solution synthesized through client feedback from interviews, literature review research of designs, and structured brainstorming. Section 3.3.1-3.3.9 detail and differentiate the possible designs that meet Team Sailor Noobs specifications and were curated to take into account the design project's criteria, developed by Team Sailor Noobs along with input from the client, Bethany Shmidt.

3.3.1 Everything In the Basket

Everything In the Basket, as can be seen in Figure 3.3-1 is a rectangular cart built from plastic that collapses sideways with hinges. The storage mechanism is directly underneath the top surface and slides out when the cart needs to be folded for storage. The top of the cart has several ring style stands and glassware clamps that can be unmounted and fit into the pull out basket when the cart needs to be collapsed.

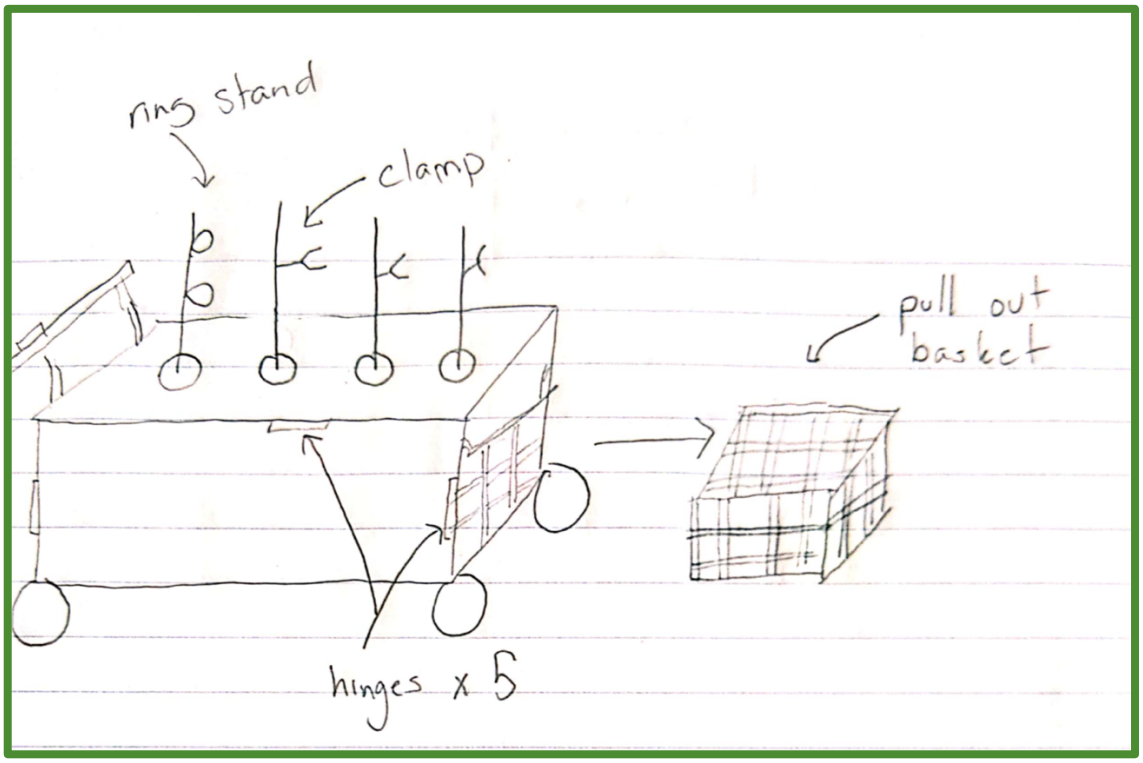


Figure 3.3-1 Everything in the Basket (Claire Ingvoldsen)

3.3.2 Magnets do the Work

Magnets do the Work is a square cart made of a hard material. The top surface is electro-magnetic, and the cart comes with magnets that can detach from universal glassware. It has hinges so that it may collapse sideways and the top surface may be opened and fold flat when collapsed. Inside of the storage under the top surface there is housing for a battery and a switch. The battery may be removed to be recharged, and/or when the cart is collapsed for storage. Perpendicular to the side of the cart that has the pushing handles there are hooks mounted for any additional PPE.

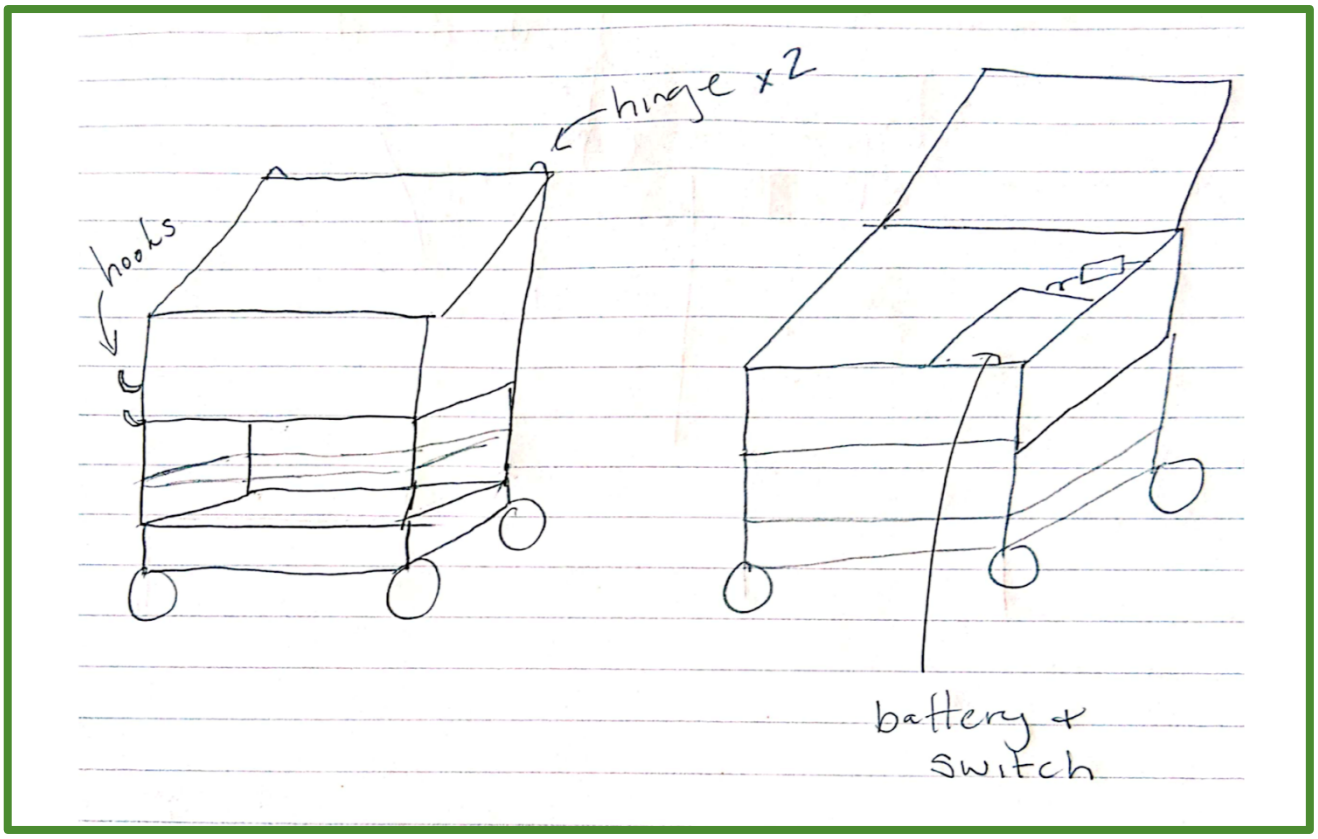


Figure 3.3-2 Magnets do the Work (Claire Ingvoldsen)

3.3.3 BallPark Titr*ations*

BallPark Titrations, as seen in Figure 3.3-3 is a wooden box that is carried on the shoulders modeled after ballpark hotdog trays and cigar trays. It is carried with canvas straps by the shoulders. The box is hollow so that it remains light and there are specific holes cut out of the top surface to house specific universal glassware with appropriate circumferences to hold them in place. There is a removable second top to cover all glassware while being transported.

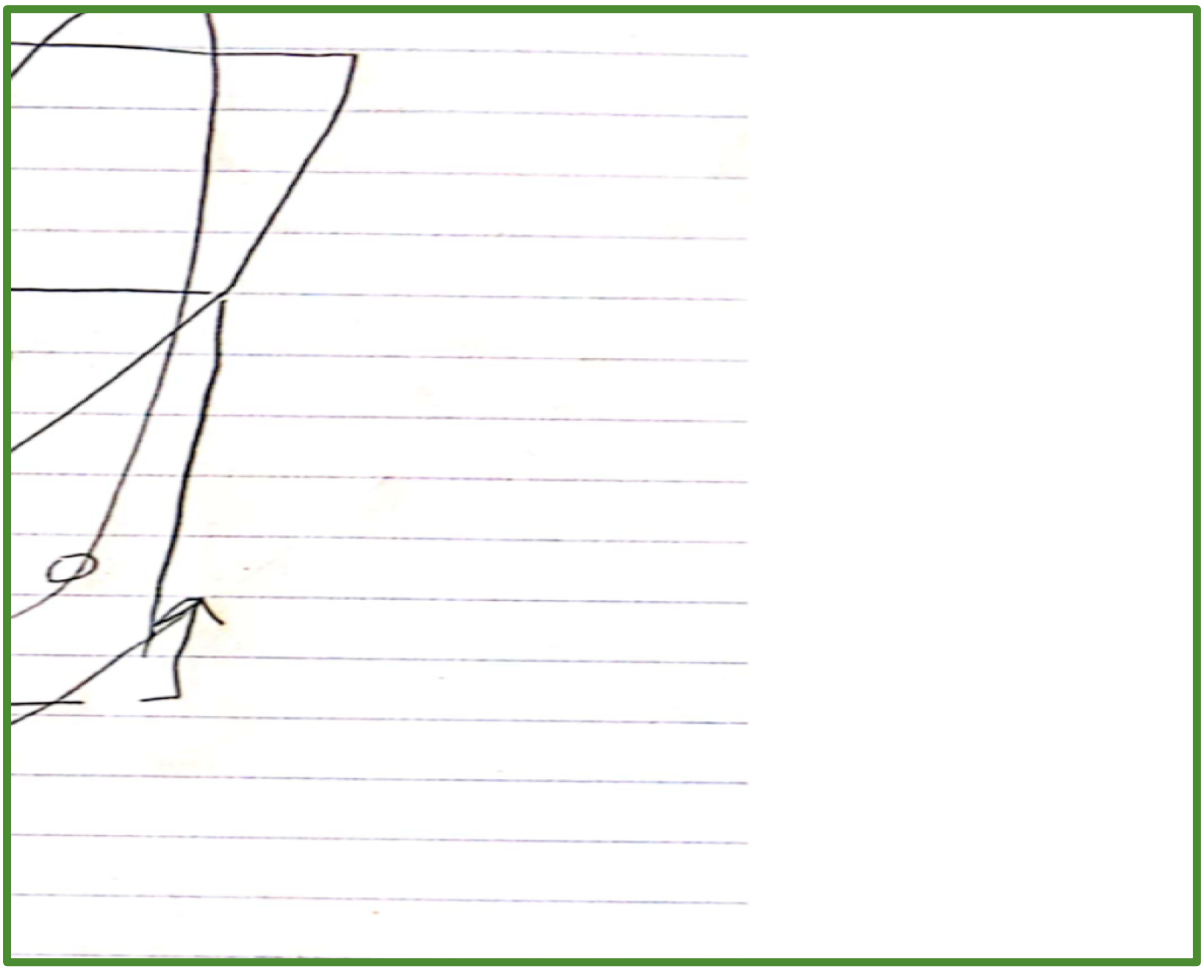


Figure 3.3-3 BallPark Titrations (Claire Ingvoldesn)

3.3.4 According to Science

According to Science is a square mobile lab station that is made of wood that folds like an accordion with a lid that folds over, so the station can either be mounted on a wall or placed in a corner of the classroom. As depicted in Figure 3.3-4 the station has a liftable lid that allows for extra storage space for lab equipment and classroom supplies. Hardtop lid that can be used as a workspace equipped with chemistry clamps to hold specimens for students to be able to see more clearly.

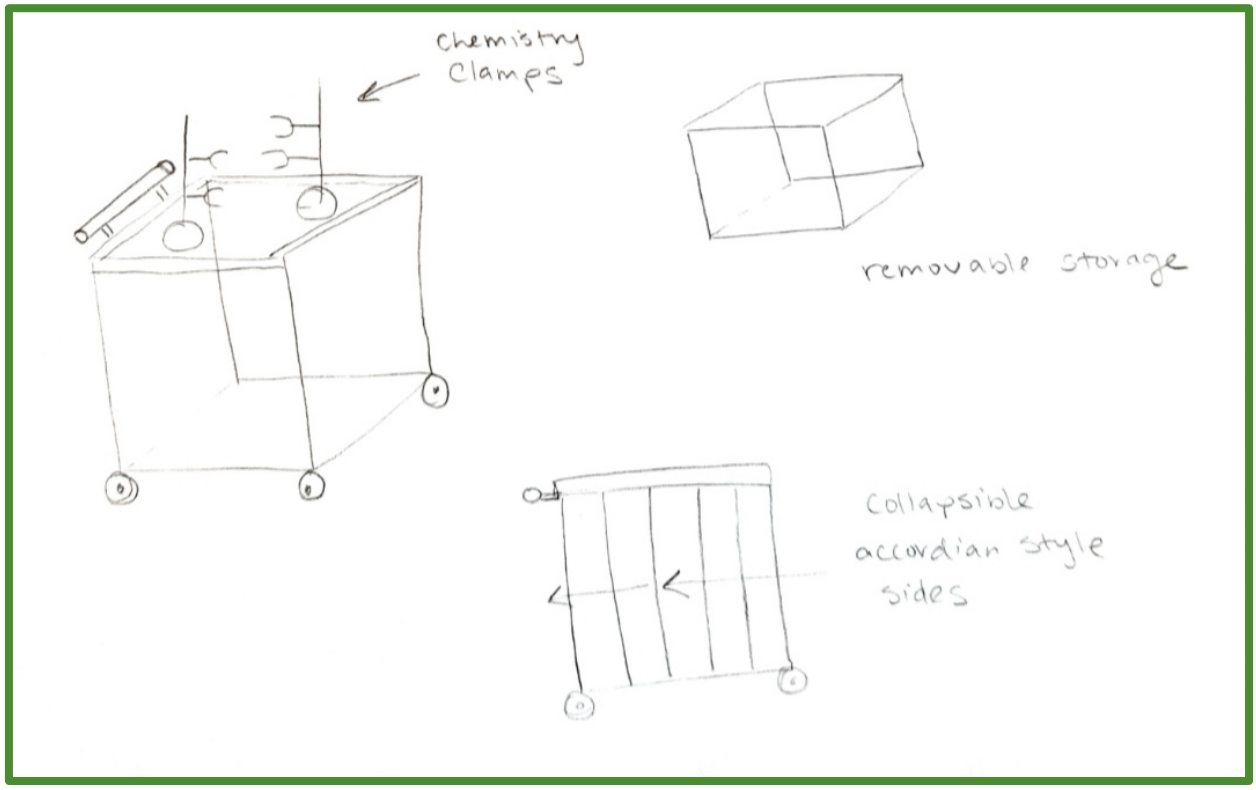


Figure 3.3-4 According to science (Tricia Bender)

3.3.5 High quality H_2O

High quality H_2O is a rectangle mobile station that is made of wood and can be easily pushed by the user. The mobile station has a liftable lid with storage underneath that allows for a crate to be placed inside in order to carry water and class supplies to creek or quad when needed to conduct outdoor science labs, as seen in Figure 3.3-5. Hardtop lid that can be used as a workstation is equipped with chemistry clamps that allow for better viewing of specimens by the student. Lots of surface space could attach PPE dispenses such as masks and gloves on the side.

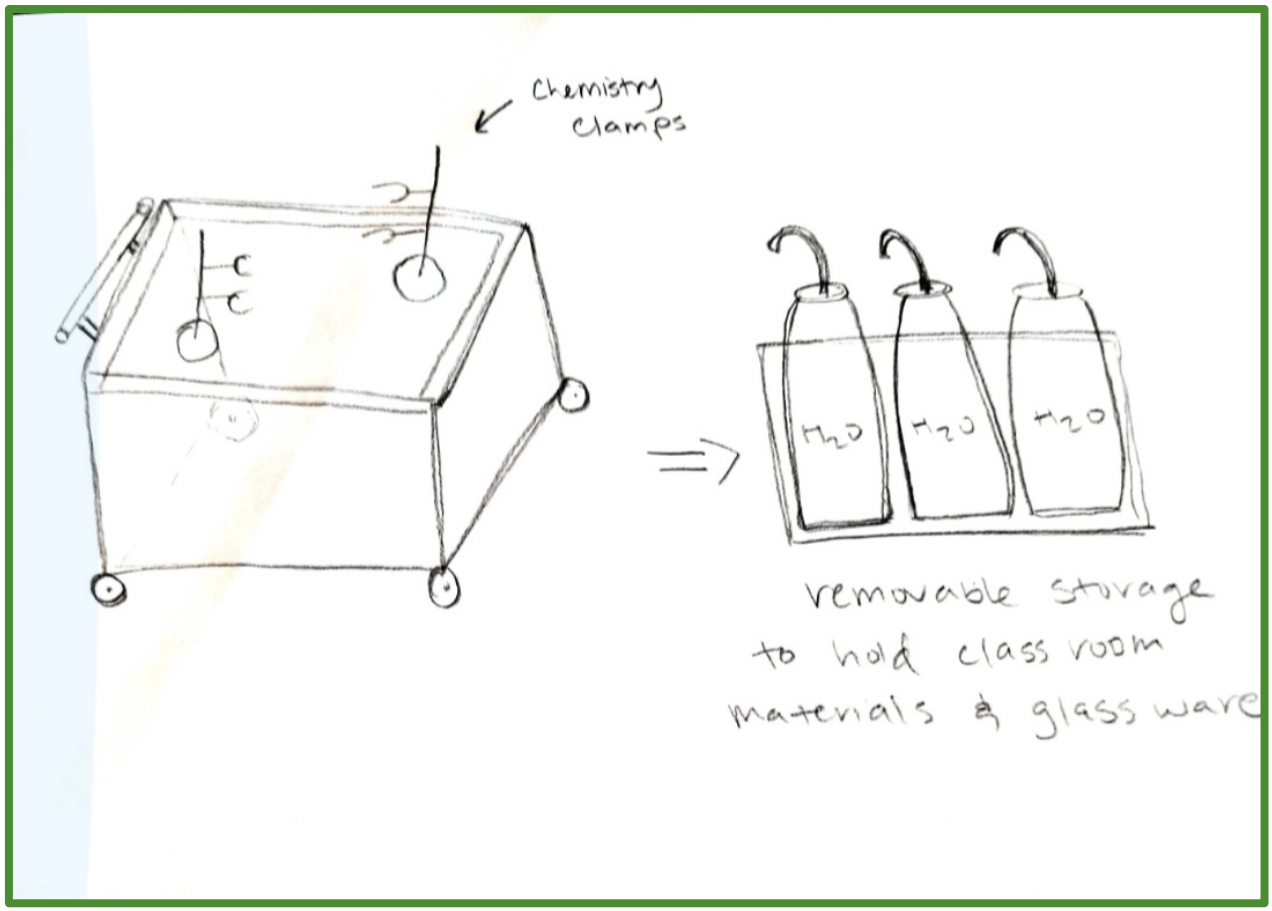


Figure 3.3-5 High Quality H2O (Tricia Bender)

3.3.6 I'm a Pusher, Not a Puller

Figure 3.3-6 I'm a Pusher, Not a Puller (Tricia Bender) is a rectangle mobile station made from wood and canvas that can be folded up and stored on a wall with a hook. With an electro-magnetic top that has different sized magnets for the universal glassware to be attached to. Liftable lid for storage of removable crate for classroom materials and a slot for a removable rechargeable battery/switch for electro-magnetic surface, as seen in

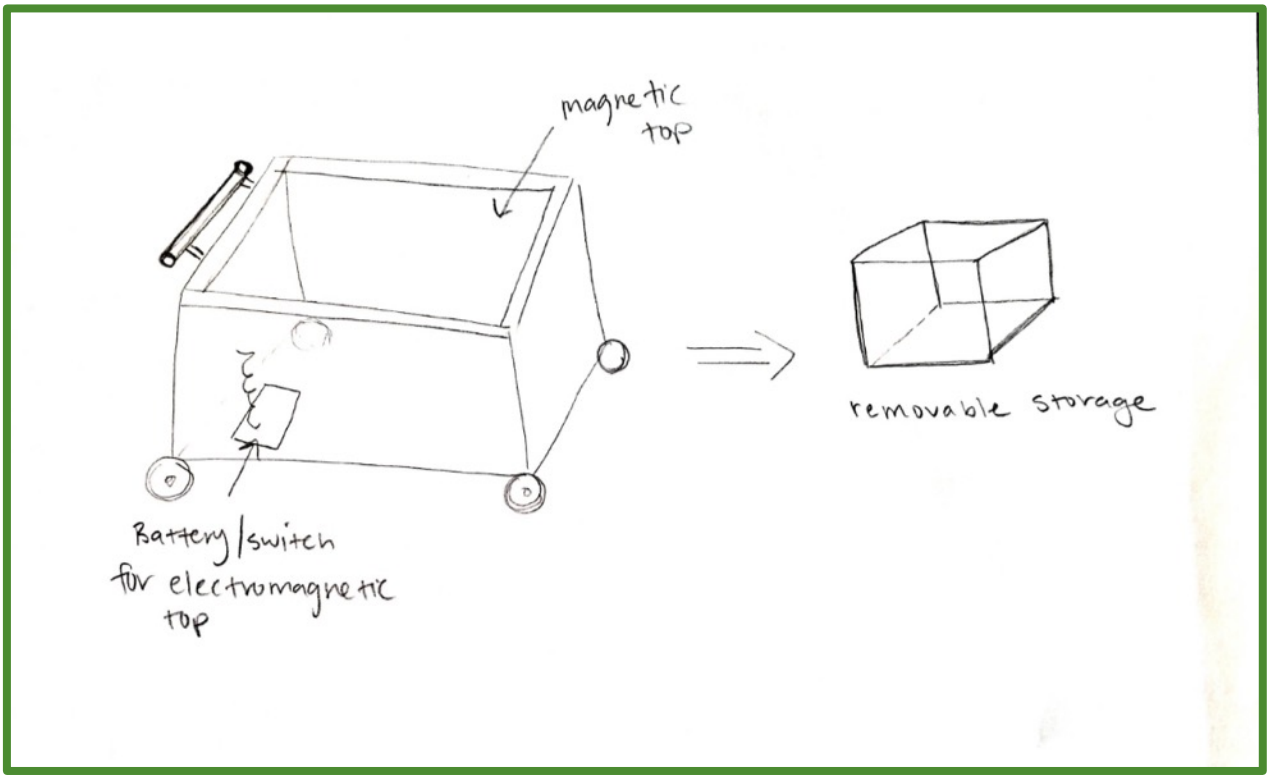


Figure 3.3-6 I'm a Pusher, Not a Puller (Tricia Bender)

3.3.7 Everything's Gone Gooey

Figure 3.3-7 Everything's Gone Gooey (Marty King) is a square mobile cart design with four wheels and a handle for pushing but what really separates it from the herd is a work/storage space comprised of Goo technology. Gooey filaments such as the Kapoosh™ brand from Bath and Body Works allow for firm yet forgiving support of scientific instrumentation and samples. It will keep test tubes from rattling off and is completely free from the restrictions of the cookie cutter or "cup holder" style of support outlined in other prototypes.

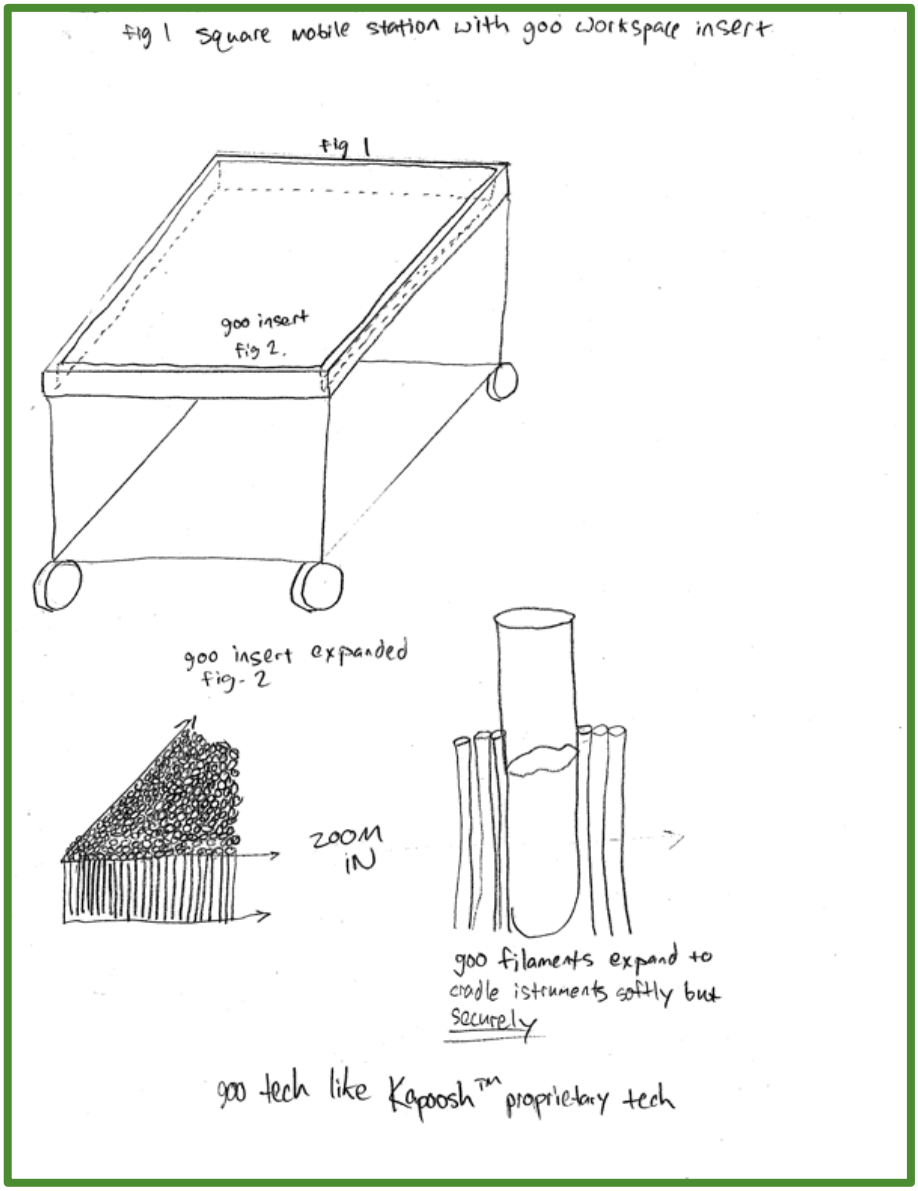


Figure 3.3-7 Everything's Gone Gooey (Marty King)

3.3.8 Foam If You Want To

Figure 3.3-8 Foam If You Want To (Marty King) is a versatile rectangular mobile cart design with articulating lid, removable storage, and interchangeable memory foam inserts for the lid workspace. The precision cut memory foam blocks, with specific slots for each instrument, can be swapped out and rearranged by the teacher to best meet the demand of various lab styles across multiple scientific disciplines.

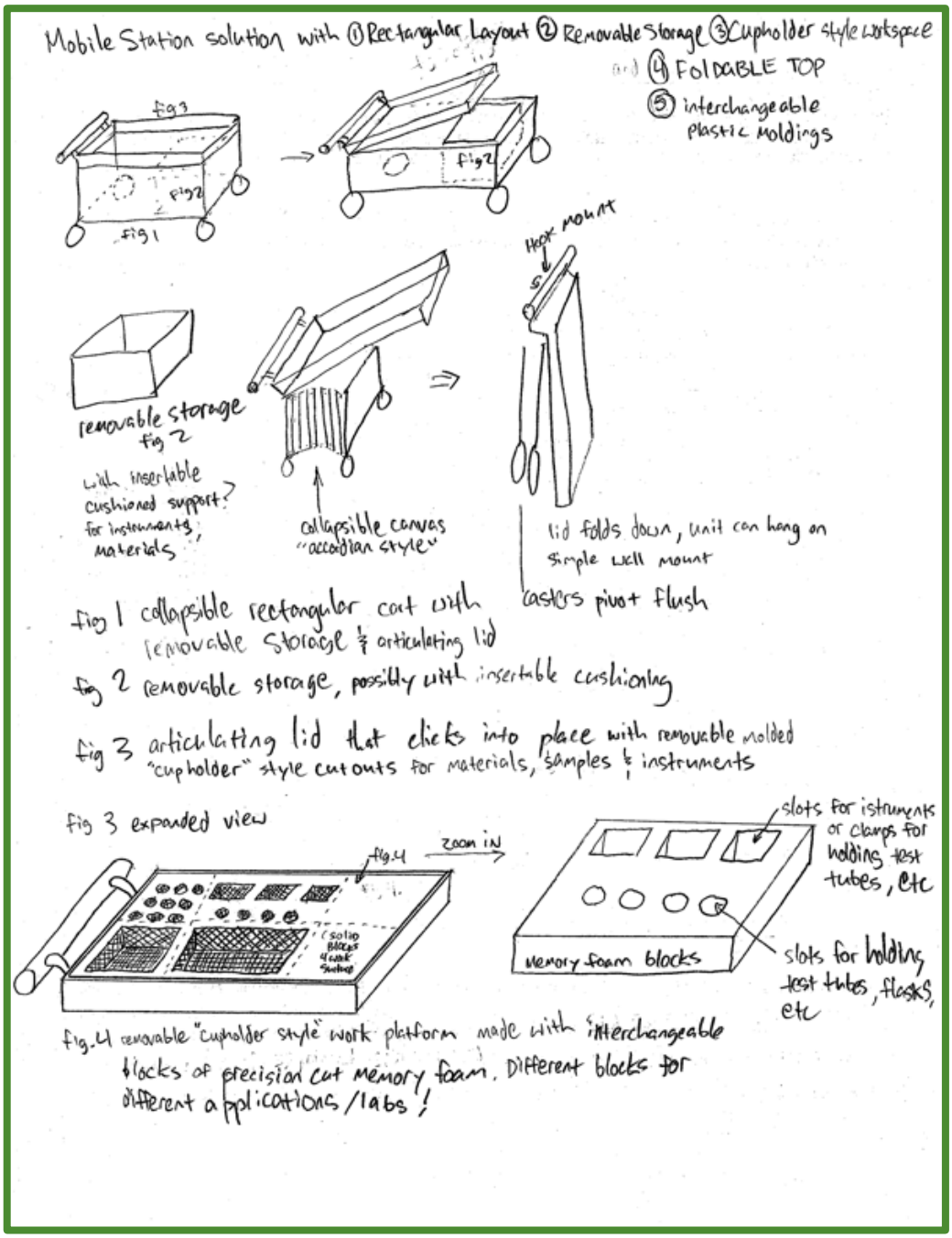


Figure 3.3-8 Foam If You Want To (Marty King)

3.3.9 One word: Plastics

Figure 3.3-9 One Word: Plastics (Marty King) is a design almost exactly like Foam If You Want To with one important difference: Rather than precision cut memory foam blocks, the workspace is comprised of custom 3D printed SLA plastic molds. The upside of this would be ridiculously specific molds for various instruments but, realistically, at $175/L the resin might be outside of Team Sailor Noob's budget.

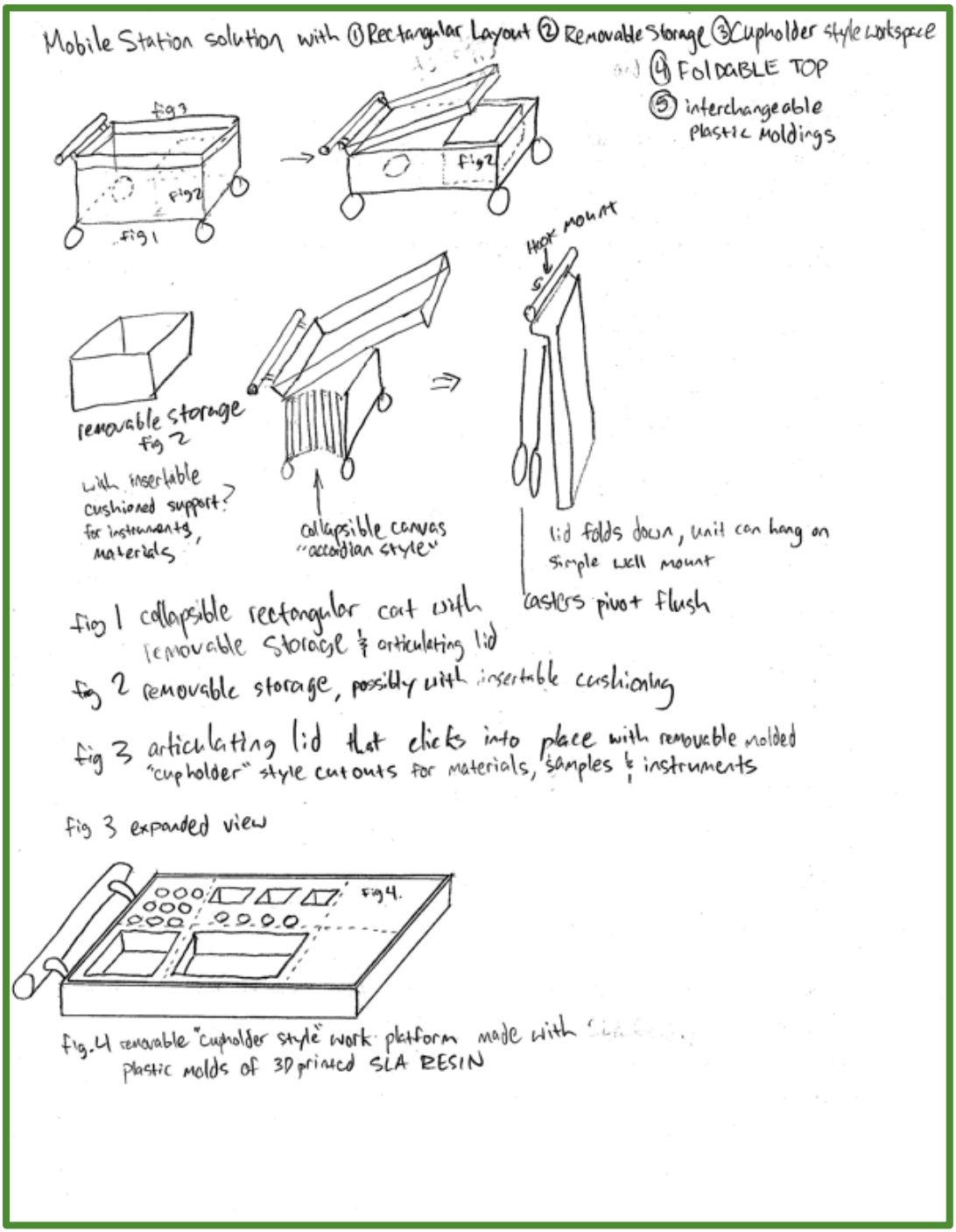


Figure 3.3-9 One Word: Plastics (Marty King)

4 Final Decision

4.1 Introduction

Section 4 includes a combination of both section 3 Alternative solutions and section 2 literature review. The final decision was based upon criteria found in section 2 that was put into a Delphi Matrix, *Figure 4.1* that helped the team decide on final specifications of the design.

4.2 Criteria

The following criteria from Section 2 was used in the final decision process.

CRITERIA	CONSTRAINTS
Sustainability through materials	Our building materials criteria will be tailored to utilize repurposed and upcycled mats wherever possible
Mobility	The station needs to be able to be easily transported from the classroom to the creek. This is a .25-mile journey that spans pavement, gravel and trail and the cart must be able to roll smoothly so as not to disturb the scientific materials stored onboard.
Size/Space it takes up	Due to limited shared classroom storage, the station must fit into a 4' by 3' nook, hang on wall, or be able to pack up and be transported in Schmidt's vehicle
Cost	Must be as inexpensive as possible. $325 spending limit
Manufacturing time	Not take so long to build that the students do not get frustrated
Disinfection	Wipeable surface, easy to clean in as little time as possible
Set up time	To be able to be set up while impacting class instruction time as little as possible
Encouraging interactions	School colors and nautical theme! Make it fun and engaging for students.
Durability	The station should be built to last longer than a semester. Ideally providing a stable platform for outdoor science labs for years to come.

Table 2 Criteria and Constraints

4.3 Solution

The following is a detailed list of Alternative Solutions used in section 3.

- Everything In the Basket
- Magnets do the Work
- BallPark Titrations
- According to Science
- High quality H_2O
- Ima pusher, not a puller
- Everything's Gone Gooey
- Foam If You Want To
- One Word: Plastics

4.4 Delphi Matrix

The Delphi Matrix is a number system shown in *Figure 4.1* that is based from the alternative solution found in section 3. The team numbered the alternative solutions accordingly so we could decide based on the scoring that would best fit Bethany Schmidt's wants and needs.

Criteria	Weight	Alternative Solutions (0-50 high)								
	0-10 high	Everything In The Basket	Magnets Do The Work	Ballpark Titrations	According To Science	High Quality H20	I'm a Pusher Not a Puller	Everything's Gone Gooey	Foam If You Want To	One Word: Plastics
Sustainability	4	10 / **40**	15 / **60**	40 / **160**	15 / **60**	45 / **180**	25 / **100**	15 / **60**	30 / **120**	40 / **160**
Mobility	9	40 / **360**	20 / **180**	50 / **450**	40 / **360**	40 / **360**	40 / **360**	20 / **180**	40 / **360**	40 / **360**
Size/Shape	5	30 / **150**	35 / **175**	35 / **175**	35 / **175**	5 / **25**	40 / **200**	5 / **25**	50 / **250**	50 / **250**
Cost	5	15 / **75**	10 / **50**	35 / **175**	25 / **125**	35 / **175**	5 / **25**	25 / **125**	15 / **75**	15 / **75**
Manufacture Time	2	35 / **70**	10 / **20**	35 / **70**	35 / **70**	35 / **70**	10 / **20**	40 / **80**	25 / **50**	20 / **40**
Disenfectability	5	40 / **200**	30 / **150**	25 / **125**	50 / **250**	50 / **250**	35 / **175**	5 / **25**	15 / **75**	30 / **150**
Time To Set Up	6	40 / **240**	35 / **210**	50 / **300**	45 / **270**	45 / **270**	25 / **150**	40 / **240**	45 / **270**	45 / **270**
Encouragibility	7	25 / **175**	25 / **175**	0 / **0**	35 / **245**	35 / **245**	35 / **245**	40 / **280**	35 / **245**	40 / **280**
Durability	10	20 / **200**	35 / **350**	20 / **200**	25 / **250**	45 / **450**	35 / **350**	30 / **300**	25 / **250**	40 / **400**
	Total	1510	1370	1655	1805	2025	1625	1315	1695	1985

Figure 4.1 DELPHI MATRIX

4.5 Decision

Based on the criteria that was used in making the Delphi matrix, as seen in *Figure 4.1* helped the team make a final decision that would best fit Bethany Schmidt's wants and needs for a mobile outdoor science lab.

5 Specification

5.1 Introduction

This section contains specifications of the Mobile Science Station. In the section is described the specifics of what was made and how it is intended to be used, as well as how to clean and maintain it.

5.2 Solution Description

5.2.1 Design specifications

The final design is an Ozark Trail brand collapsible utility Cart that is fitted with a removable wooden tote and includes additional wooden storage. The removable tote is constructed from upcycled wood with a hollow frame to keep it as light in weight as possible. Constructed design and assembly is specified in Appendix 6.2 Drawings Specification. The lid of the removable tote doubles as a workspace with a wooden lip to prevent materials from falling during use. The lid is raised to a comfortable work height with folding wooden legs attached to the tabletop with piano hinges. The legs fit into runners installed into the removable tote for added stability. The removable storage is a rectangular open topped box that fits snugly inside of the removable tote. Inside of the storage box there is installed adjustable dividers so that glassware of all sizes is able to fit inside of the removable storage for transportation.

Figure 5.2-1 Mobile Science Station Converted into Workspace

Figure 5.2-2 Removable Storage

5.3 Cost analysis

5.3.1 Design Cost (hours)

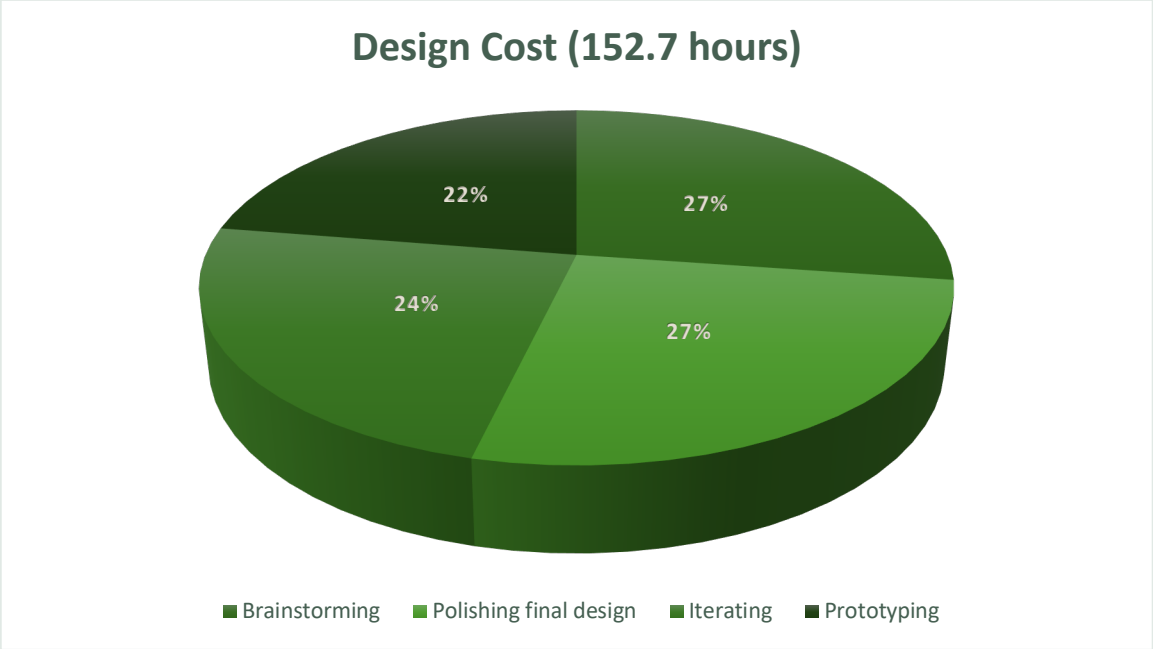


Figure 5.3-1 Design Cost as Percentages

5.3.2 Implementation Cost

Materials Cost			
Quantity	**Materials**	**Price**	**Cost**
1	collapsible wagon	$73.78	$73.78
2	hinges	$5.77	$11.44
24	cabinet screws	$0.08	$1.92
32	sheet metal screws	$0.08	$2.56
12	wood screws	$0.08	$0.96
24	finishing nails	$0.04	$0.96
apx 35 lbs	upcycled wood	donation	$0.00
		Total Cost	$91.62

Table 3 Materials Cost

5.3.3 Maintenance Cost ($)

Projected O&M costs are quite minimal. The main thrust of maintenance budget will be purchasing sanitizing products in order to clean the Mobile Science Station before and after every use. Any spillage or additional mess will also have to be cleaned as well as a periodic cleaning of the tires to guard against mud and detritus buildup.

5.4 Prototyping

5.4.1 Introduction

This section demonstrates the prototype iterations that went toward the final design decisions of the product. When presented with the prototypes, the client gave the team feedback about elements she liked and those she did not care for. Throughout the process the team was able to pin down the need for: Removable storage, an adjustable or removable lid that doubles as a work surface, collapsibility and mobility or ease of transport.

5.4.2 Prototype 1 Solid Cart With Removable Storage

TSNs first prototype was a noncollapsable solid cart to be made of wood or plastic. The lid hinged on and off to reveal removable adjustable storage for glassware. The resulting prototype was not preferred because of the amount of space that the cart took up as a whole, though the client did respond well to adjustable removable storage.

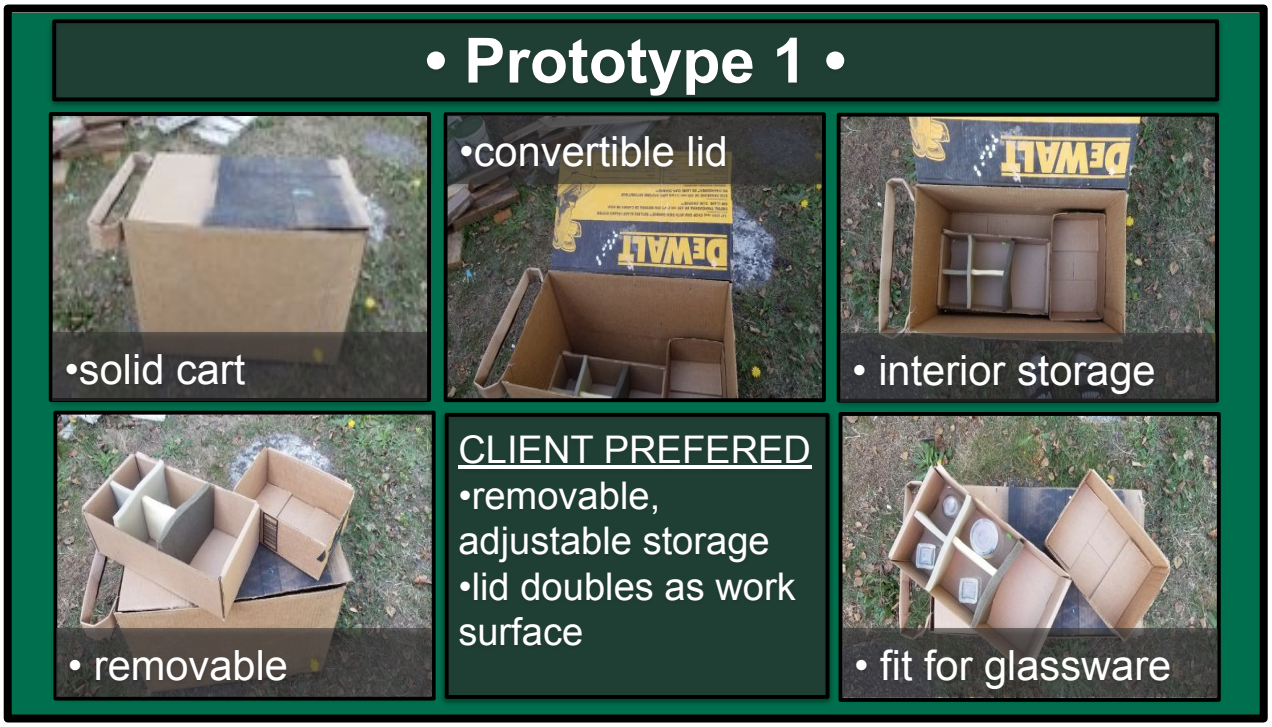


Figure 5.4-1 Prototype 1

5.4.3 Prototype 2 Collapsible Frame With Lid And Removable Storage

Figure 5.4-2 Prototype 2 was generated by TSN to experiment with collapsible cart designs with a canvas interior. TSN found that this design led the storage to be too deep to be convenient, though the client responded well to the collapsabillity of the design and the lid doubling as a workspace.

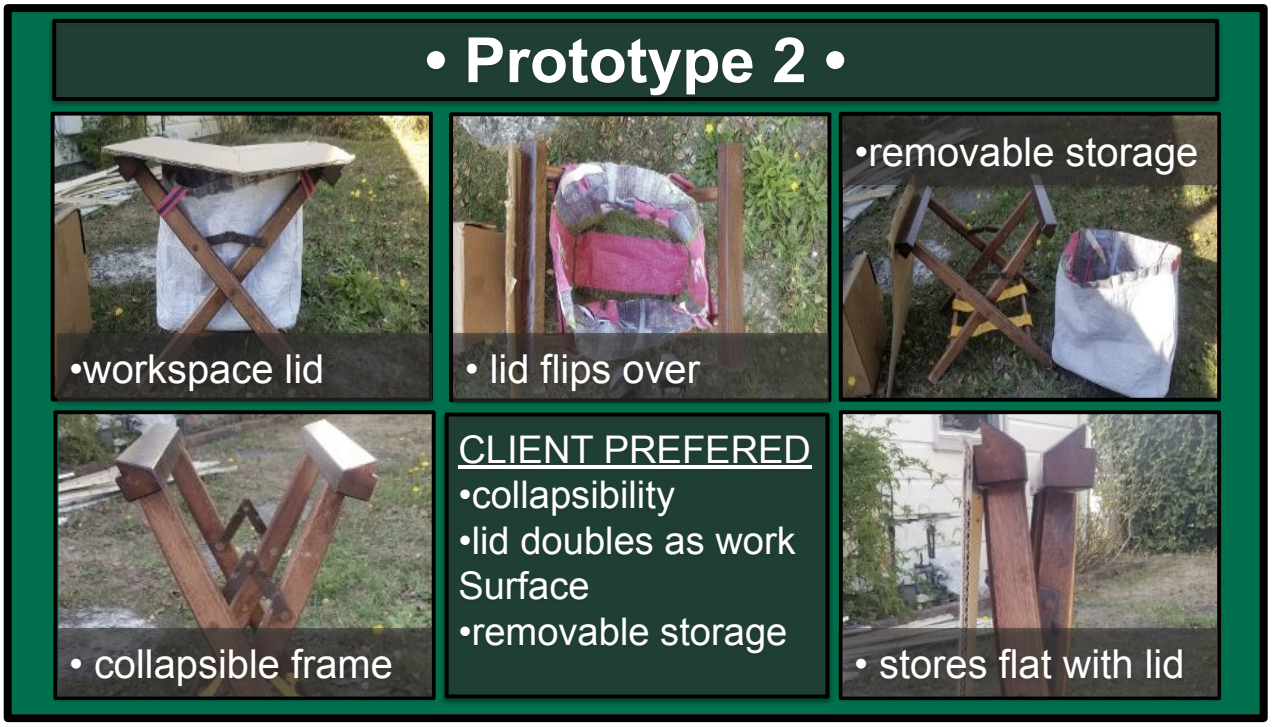


Figure 5.4-2 Prototype 2

5.4.4 Prototype 3 Collapsible Cart With Articulating Lid And Interior Storage

The third prototype TSN designed was a multicollasable cart that was rectangular in deth and had a multihinge collapsible frame. Testing showed that this was the preferred build and set up for the client, and TSN then determined that buying a premade cart with a similar design would ultimately lead to the most cost effective product.

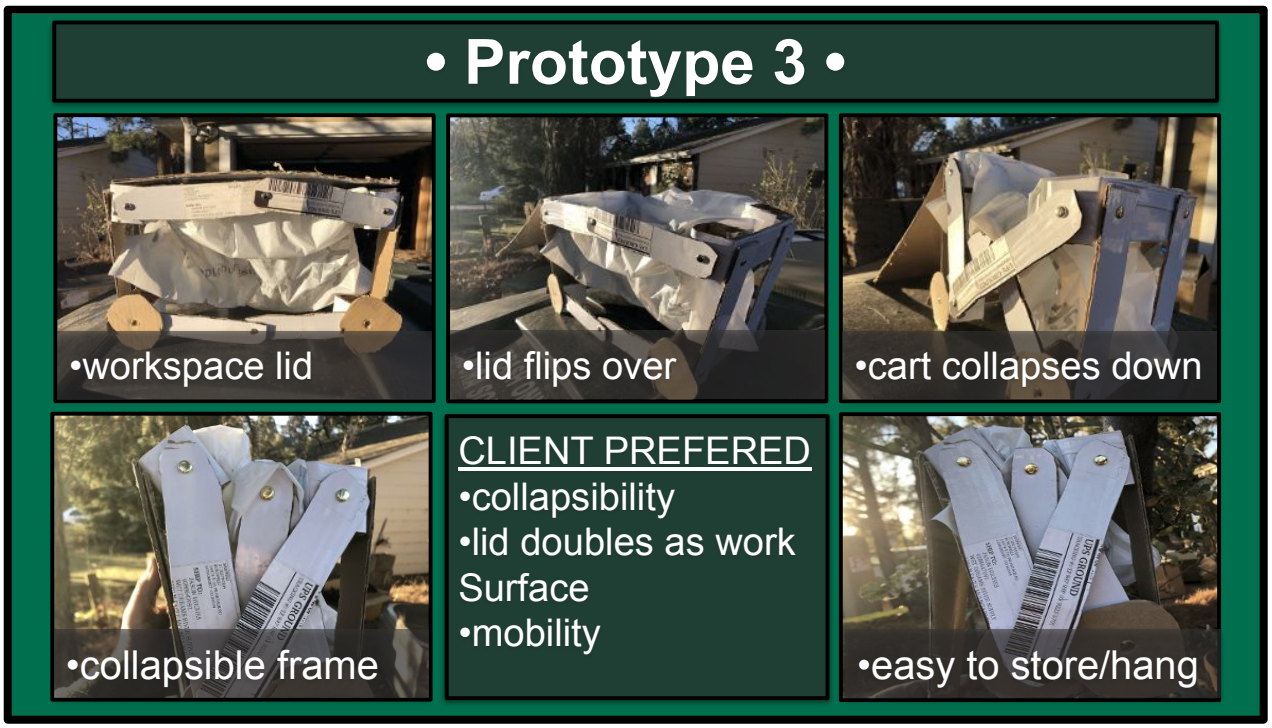


Figure 5.4-3 Prototype 3

5.5 Instructions for Implementation and Use

Illustrated in Figure 5.5-1 Set Up Procedure below are the simple instructions on how to convert the Mobile Science Station from transportation to lab demonstration mode. What is not shown but should be implicit is the need to wipe down and sanitize the Station before and after use. Cleaning the Station guards against the spread of COVID-19 and also prolongs the lifespan of the product. Follow this link to YouTube for a video of a basic demonstration in the use of the Mobile Science Station.

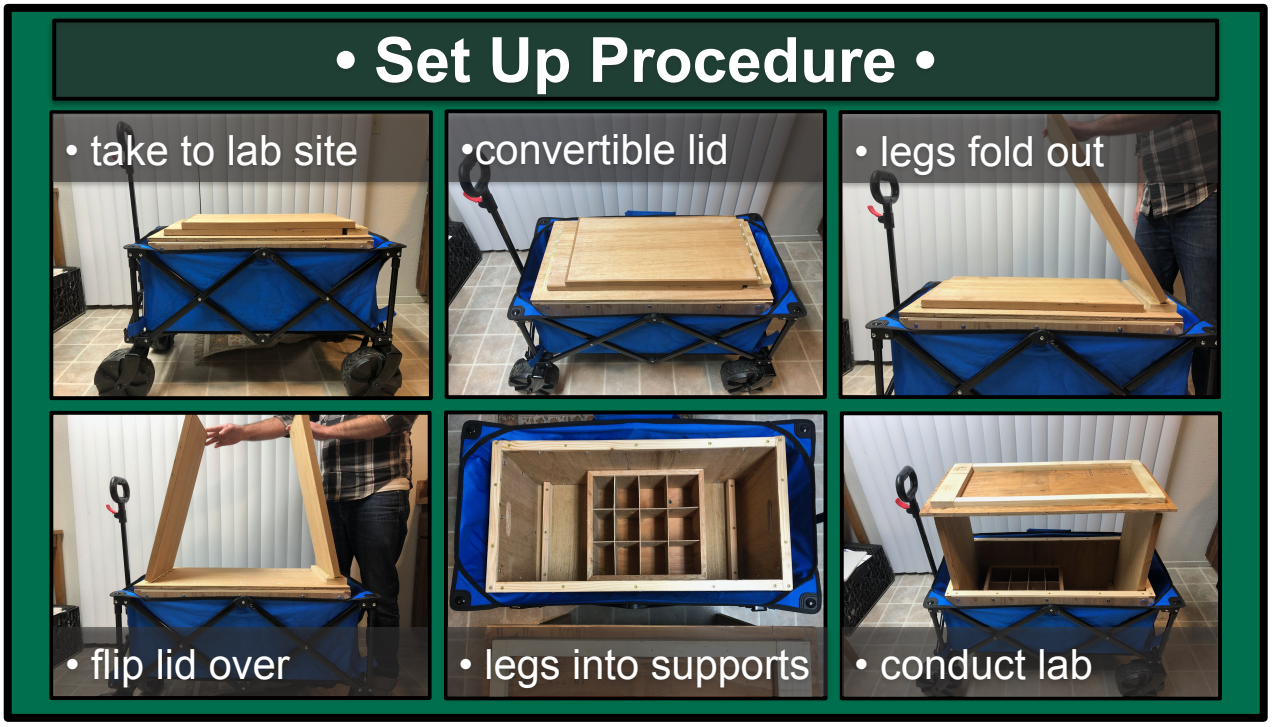


Figure 5.5-1 Set Up Procedure

5.6 Results

The results from testing showed that the cart is durrible and can be pulled over required terrain. The removable storage is able to hold glassware to be transported so the glassware does not spill or break. Set up time for the lid to be converted to a workspace is approximately 30 seconds. There is a hazard for finger pinching if in the way while assembling the product. There is also the possibility of the converted table to wobble if heavy force is exerted on it. The station is easily sanitizable and fully enables safe socially distanced outdoor science education.

6 Appendices

6.1 References

Barton, T., and Parekh, A. (2020). "Reopening Schools: Lessons from Abroad". *Commonwealthfund.org*, <https://www.commonwealthfund.org/blog/2020/reopening-schools-lessons-abroad> (Oct. 4, 2020).

Burke, M., and Xie, Y. (2020). "How schools across the globe are reopening amid the coronavirus pandemic". *EdSource*, <https://edsource.org/2020/how-schools-across-the-globe-are-reopening-amid-the-coronavirus-pandemic/634739> (Oct. 4, 2020).

CDC. (2020). "Coronavirus Disease 2019 (COVID-19) – Prevention & Treatment". *Centers for Disease Control and Prevention*, <https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html> (Oct. 4, 2020).

Chaudhry, Raj. “Everything You Ever Wanted to Know about Wood Glue.” *Cottage Life*, 24 Sept. 2019, cottagelife.com/design-diy/everything-you-ever-wanted-to-know-about-wood-glue/.

Cohen, Jon. (2018) “Could Ultraviolet Lamps Slow the Spread of Flu?” *Science*, 2018, doi:10.1126/science.aas9109.

Dowling, Stephen. (2018) “Is a 20-Second Handwash Enough to Kill Covid-19?” *BBC News*, BBC, 20 Aug. 2020, www.bbc.com/future/article/20200818-covid-19-has-handwashing-been-forgotten.

<http://https://formlabs.com/> (Oct. 4, 2020)

Hartley, C. (2020). *The Road Ahead*. Humboldt County Office of Education, 6-15.

Horne, R., and Hausman, K. (2017). 3D printing for dummies. John Wiley & Sons, Inc., Hoboken, NJ.

Koley, T., and Dhole, M. (2020). *COVID-19 Pandemic*. Routledge, 1-10.

LOCKER, A. (2019). "Formlabs Form 2 Review: Great Resin 3D Printer | All3DP". All3DP, <https://all3dp.com/formlabs-form-2-review-price-sla-3d-printer/> (Oct. 4, 2020).

Ozark Trail, 2020, “Ozark-Trail-Folding-Camp-Multipurpose-Wagon-Black,” https://www.walmart.com/ip/Ozark-Trail-Folding-Camp-Multipurpose-Wagon-Black/670509406, Dec. 10, 2020, Walmart.

“Personal Protective Equipment for COVID-19.” *World Health Organization*, World Health Organization, 11 Aug. 2020, www.who.int/medical_devices/priority/COVID_19_PPE/en/.

Perry, R. (2020). Email.

Schmidt, B. (2020). Email.

Schmidt, B. (2020). Zoom.

Sidell, J. (2020). email.

Schneider, R. (2020). "UPDATE: Most Humboldt County schools closed for rest of March; Eureka schools closed til April 20 – Times-Standard". *Times-standard.com*, <https://www.times-standard.com/2020/03/15/ferndale-schools-st-bernards-to-close-for-the-next-two-weeks/> (Oct. 4, 2020).

"Senegalese engineering students fight coronavirus with inventions." (2020). *Aljazeera.com*, <https://www.aljazeera.com/features/2020/05/13/senegalese-engineering-students-fight-coronavirus-with-inventions/?gb=true> (Oct. 4, 2020).

Study International Staff. (2020). "These ingenious student inventions in Jamaica and Morocco can help fight COVID-19". *Study International*, <https://www.studyinternational.com/news/student-inventions-fight-covid19/> (Oct. 4, 2020).

Took, J. (2020). "Newark private schools find creative ways to reopen this fall". *Newark Post*, <https://www.newarkpostonline.com/news/newark-private-schools-find-creative-ways-to-reopen-this-fall/article_fd0b3a3f-8abc-5486-87f1-dda1ad694c99.html> (Oct. 4, 2020).

UltraBoard. (2020). "COVID-19 Protective Barriers for Schools and Public Spaces Now Available from U.S. Sign Foam Manufacturer UltraBoard". *Prnewswire.com*, <https://www.prnewswire.com/news-releases/covid-19-protective-barriers-for-schools-and-public-spaces-now-available-from-us-sign-foam-manufacturer-ultraboard-301099155.html> (Oct. 4, 2020).

“Using Personal Protective Equipment (PPE).” *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention, 19 Aug. 2019, www.cdc.gov/coronavirus/2019-ncov/hcp/using-ppe.html.

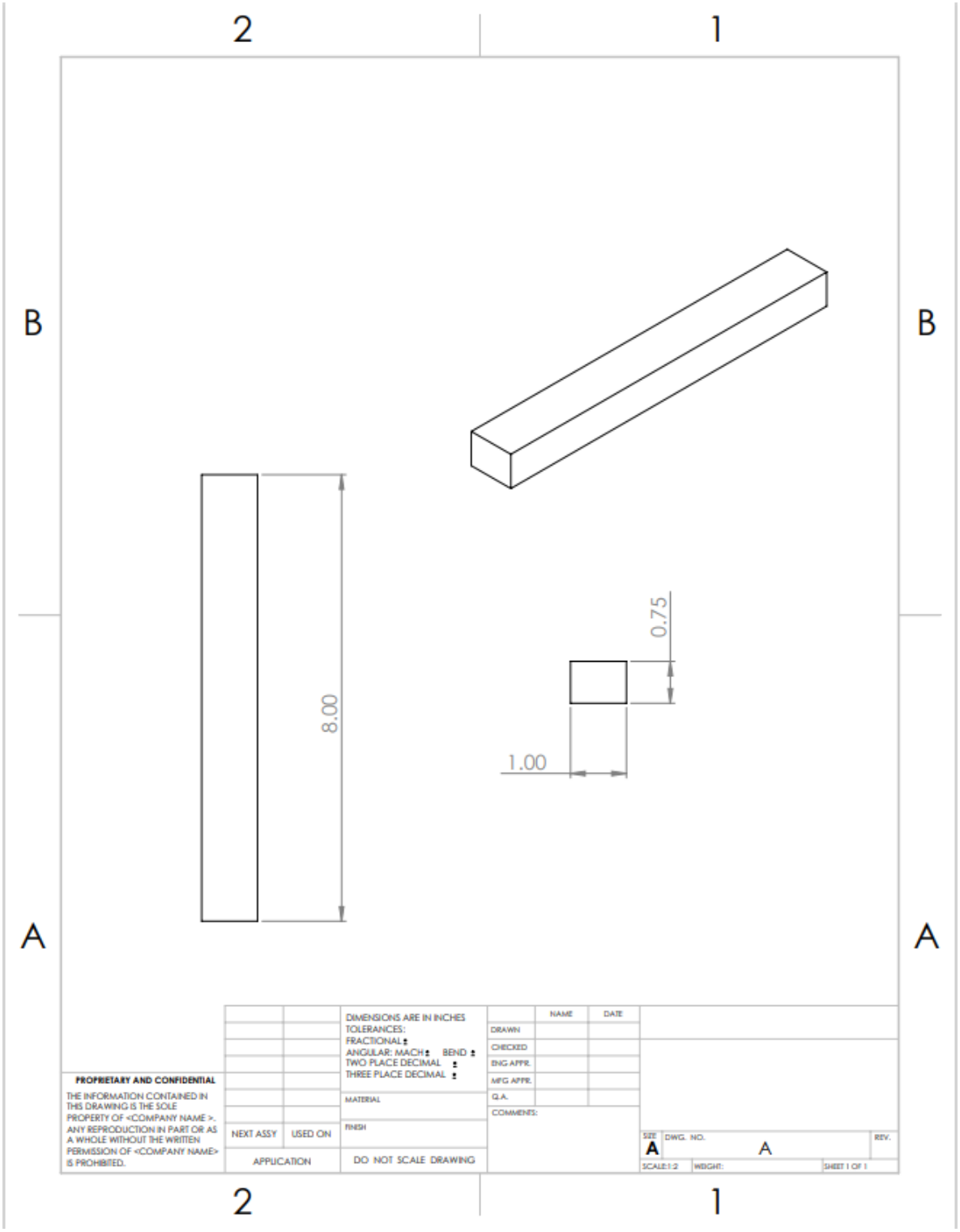
Viner, R., Russell, S., Croker, H., Packer, J., Ward, J., Stansfield, C., Mytton, O., and Booy, R. (2020). "School Closure and Management Practices During Coronavirus Outbreaks Including COVID-19: A Rapid Narrative Systematic Review". *SSRN Electronic Journal*.

Woodford, Chris. “Wood - An Introduction to Its Structure, Properties, and Uses.” *Explain That Stuff*, 11 Dec. 2019, www.explainthatstuff.com/wood.html.

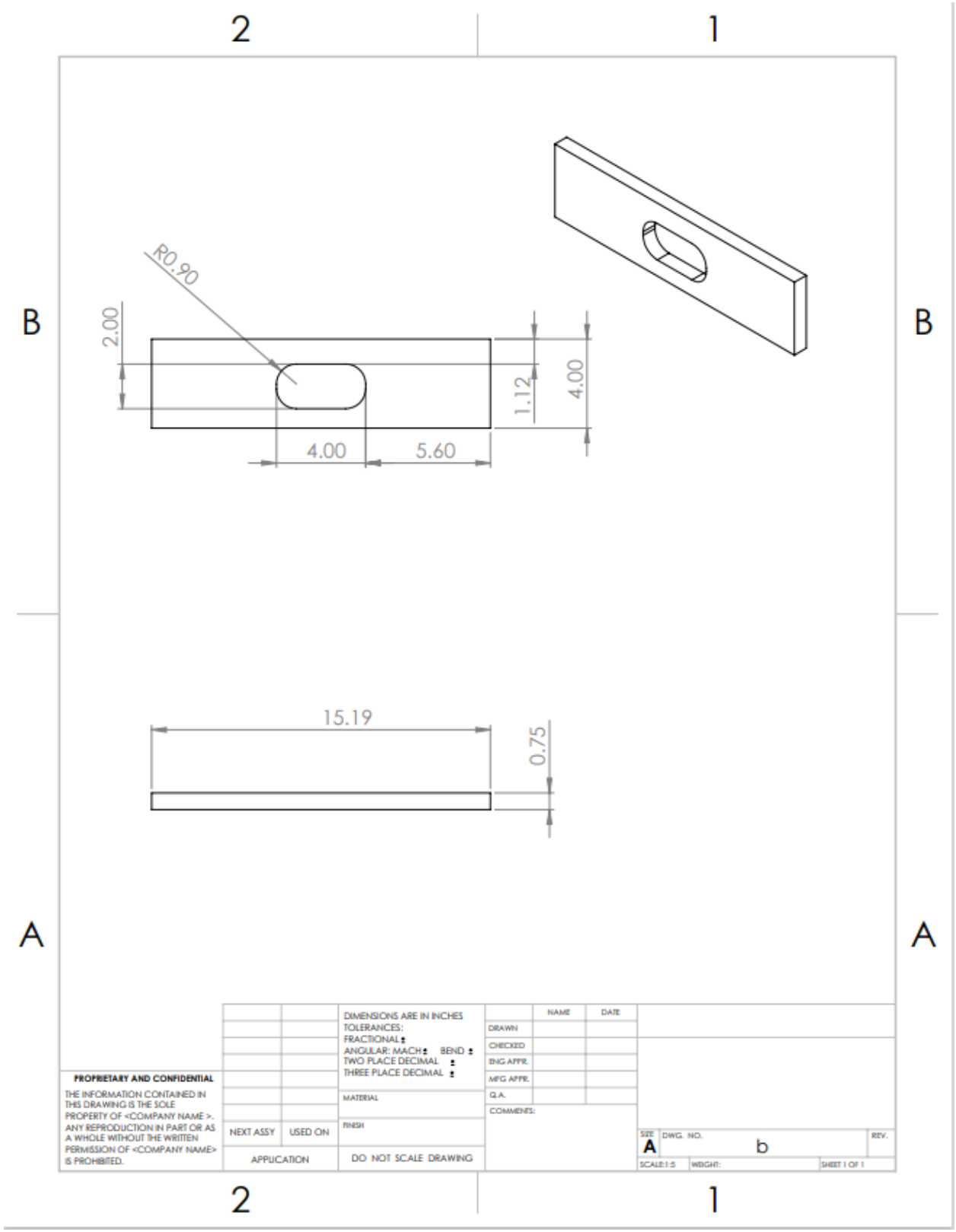
“Woodworking.” *Learn About Woodworking | Discover a Hobby*, 2019, www.discoverahobby.com/woodworking.

6.2 Drawings Specification

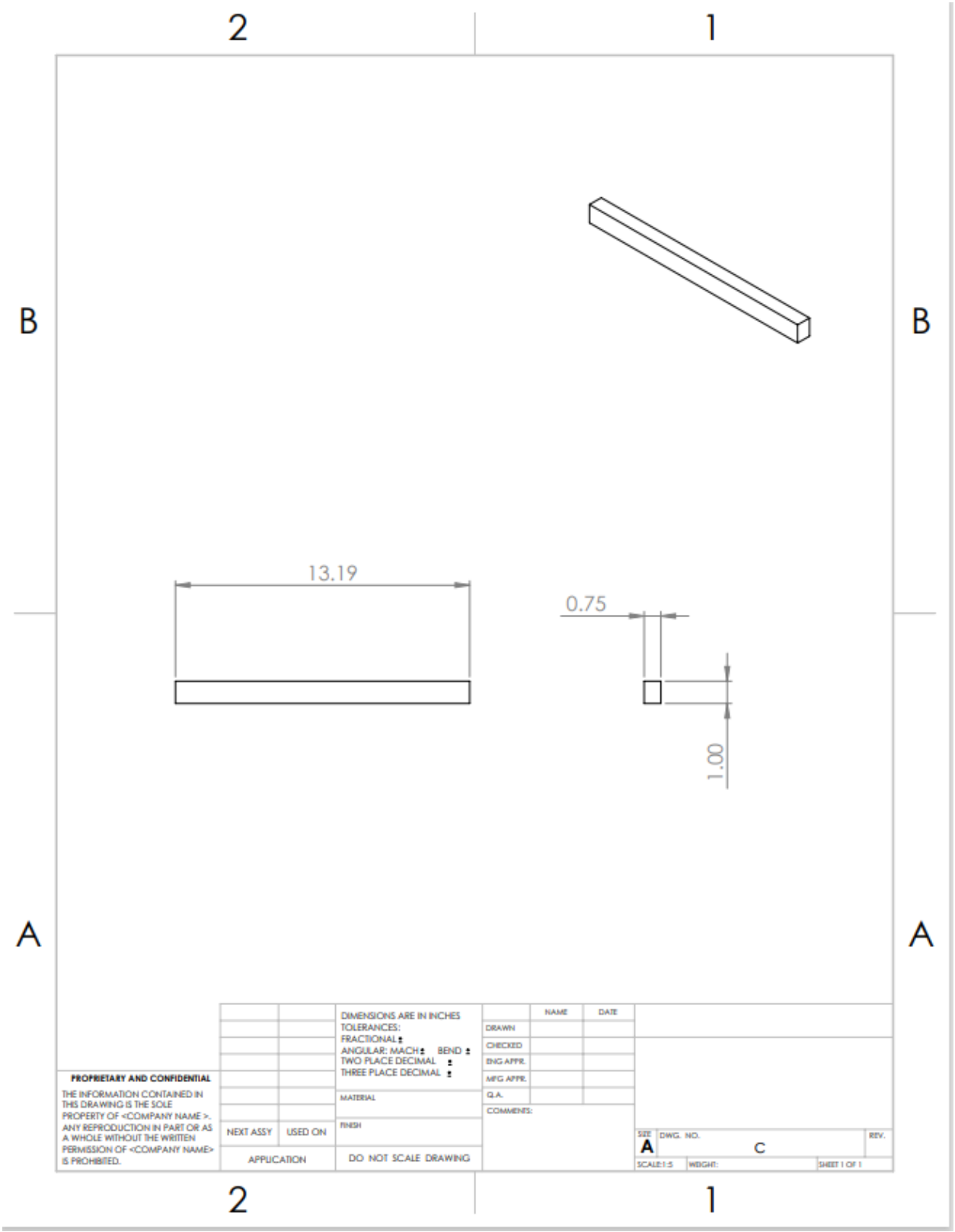
6.2.1 Individual Part Specifications



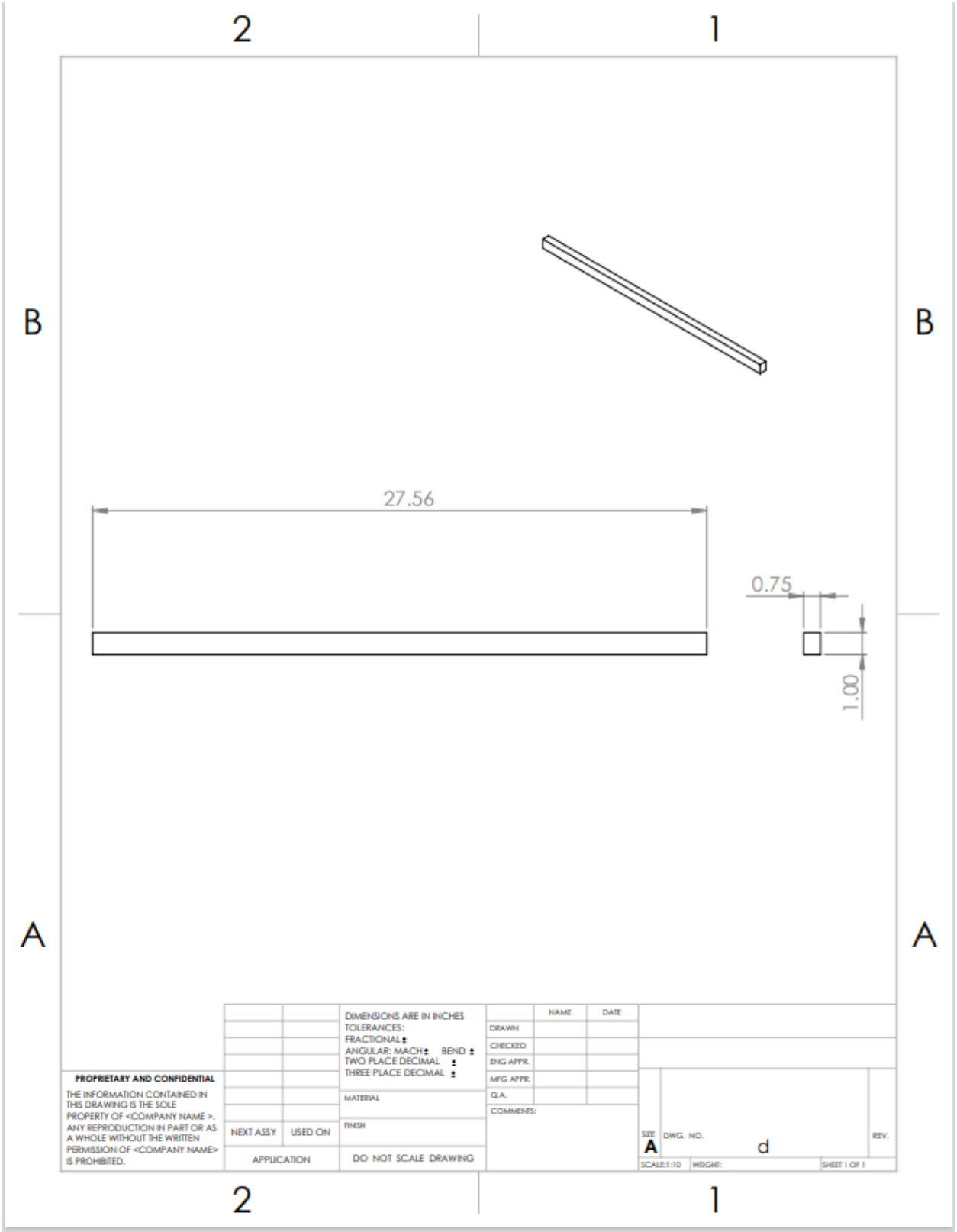
Individual Part Schematic 1



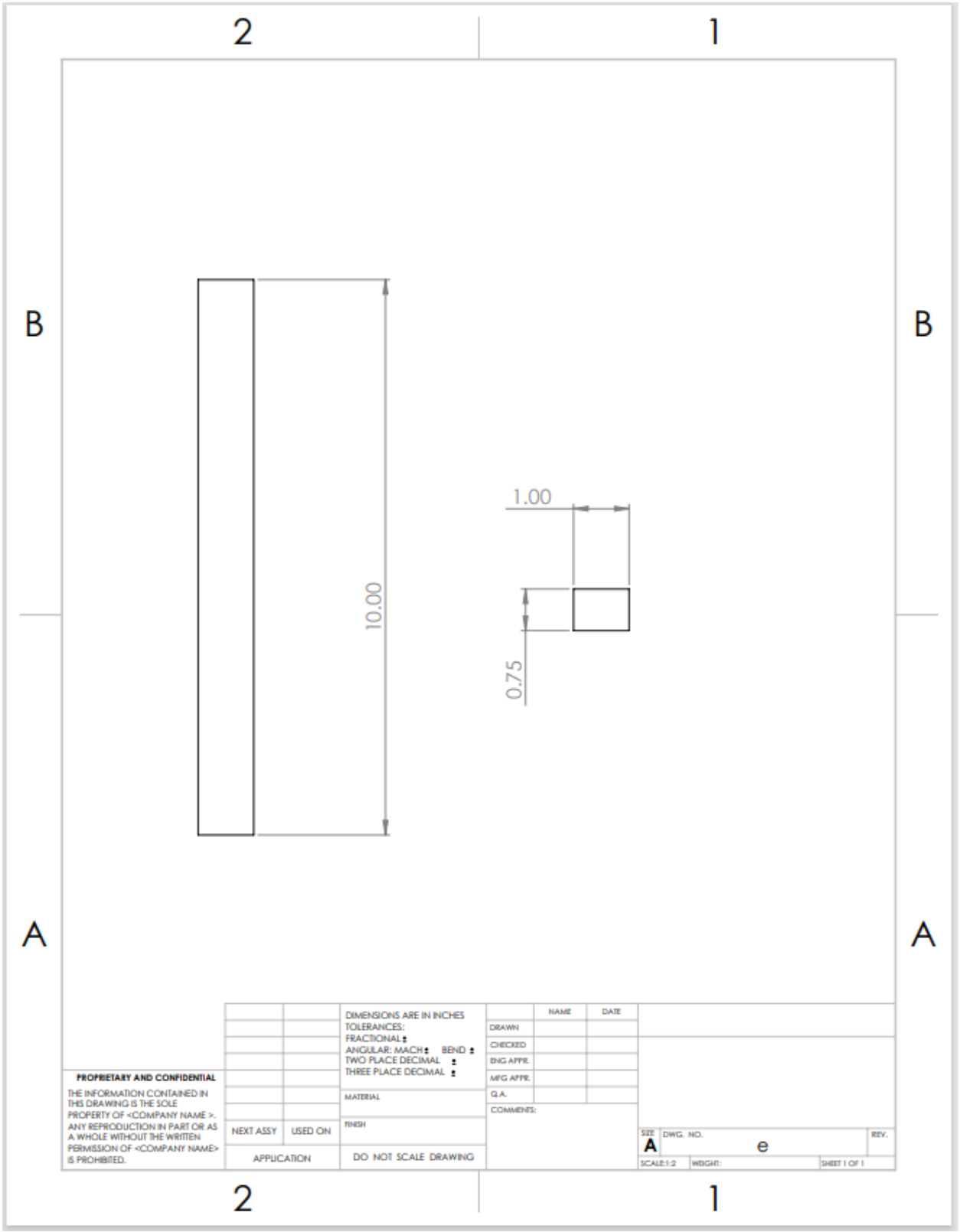
Individual Part Schematic 2



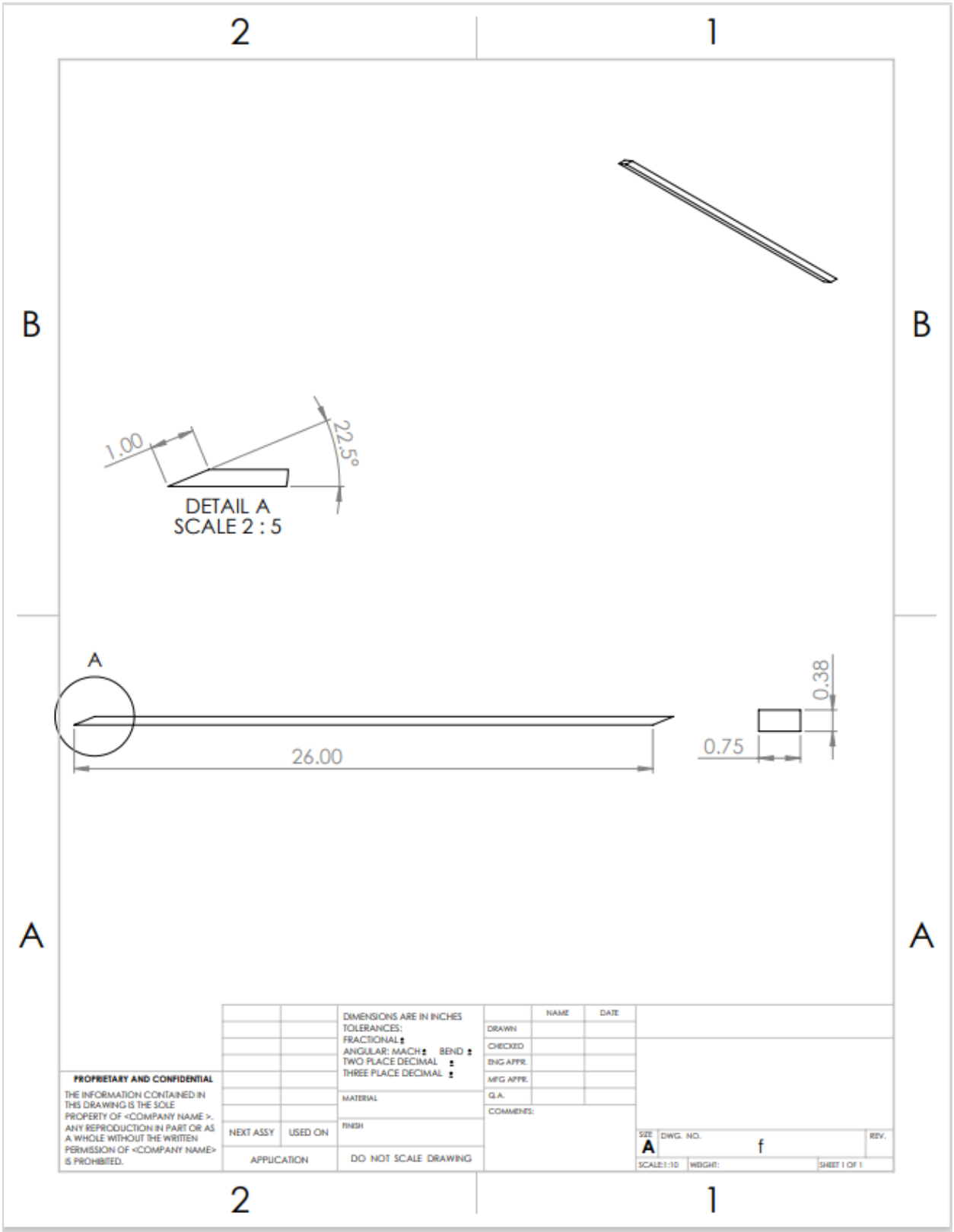
Individual Part Schematic 3



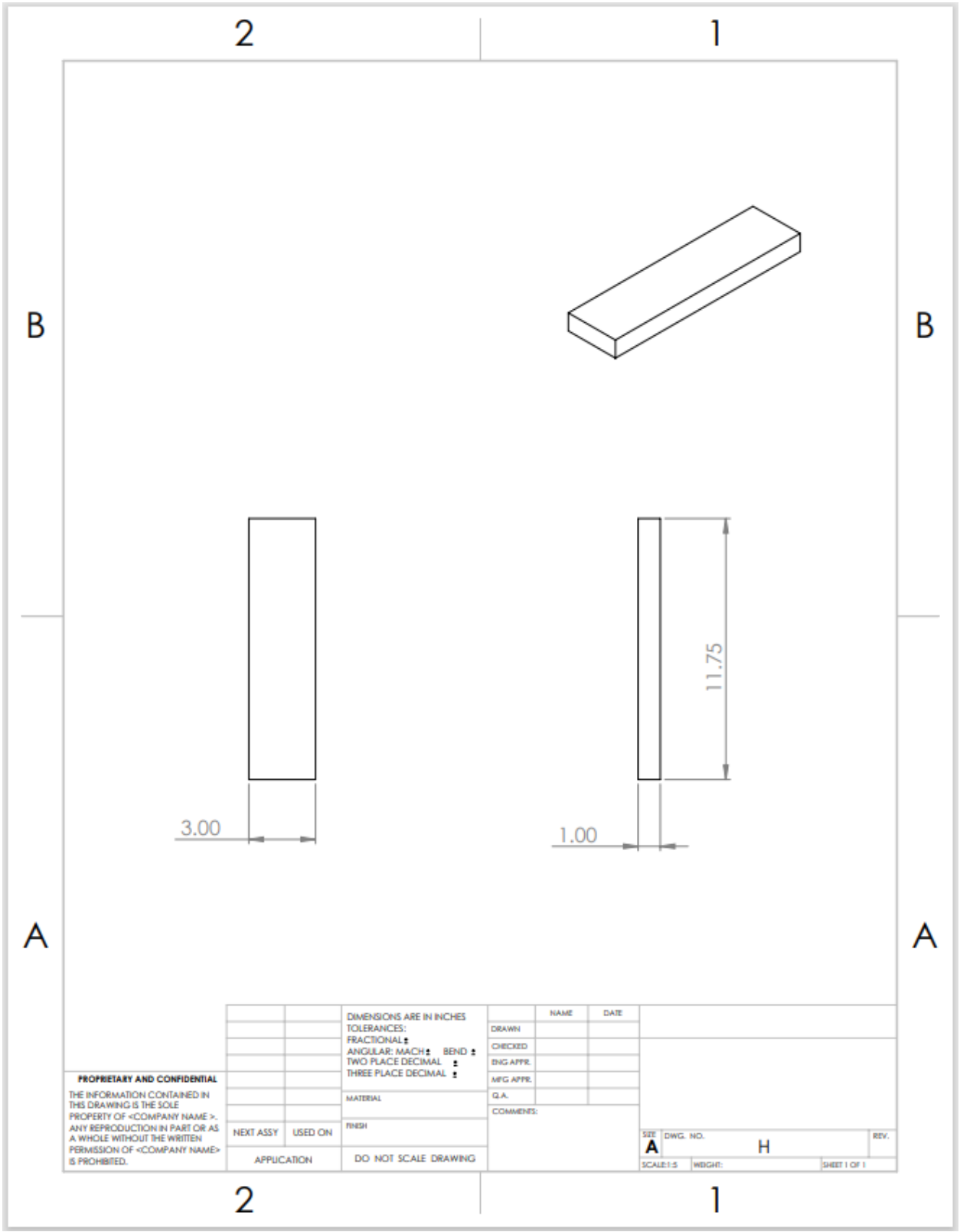
Individual Part Schematic 4



Individual Part Schematic 5

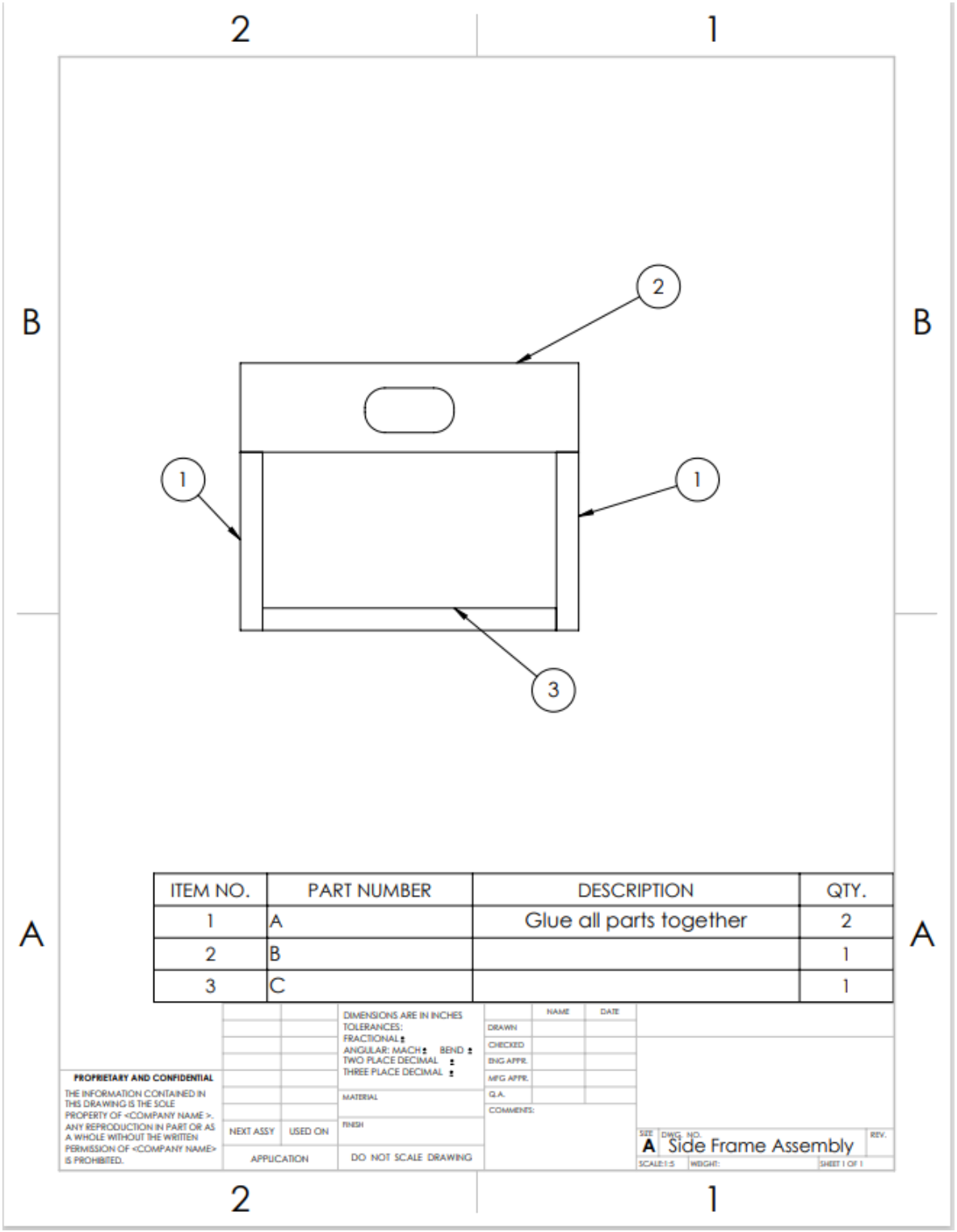


Individual Part Schematic 6



Individual Part Schematic 7

6.2.2 Assembly Specifications



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	A	Glue all parts together	2
2	B		1
3	C		1

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY | USED ON

APPLICATION

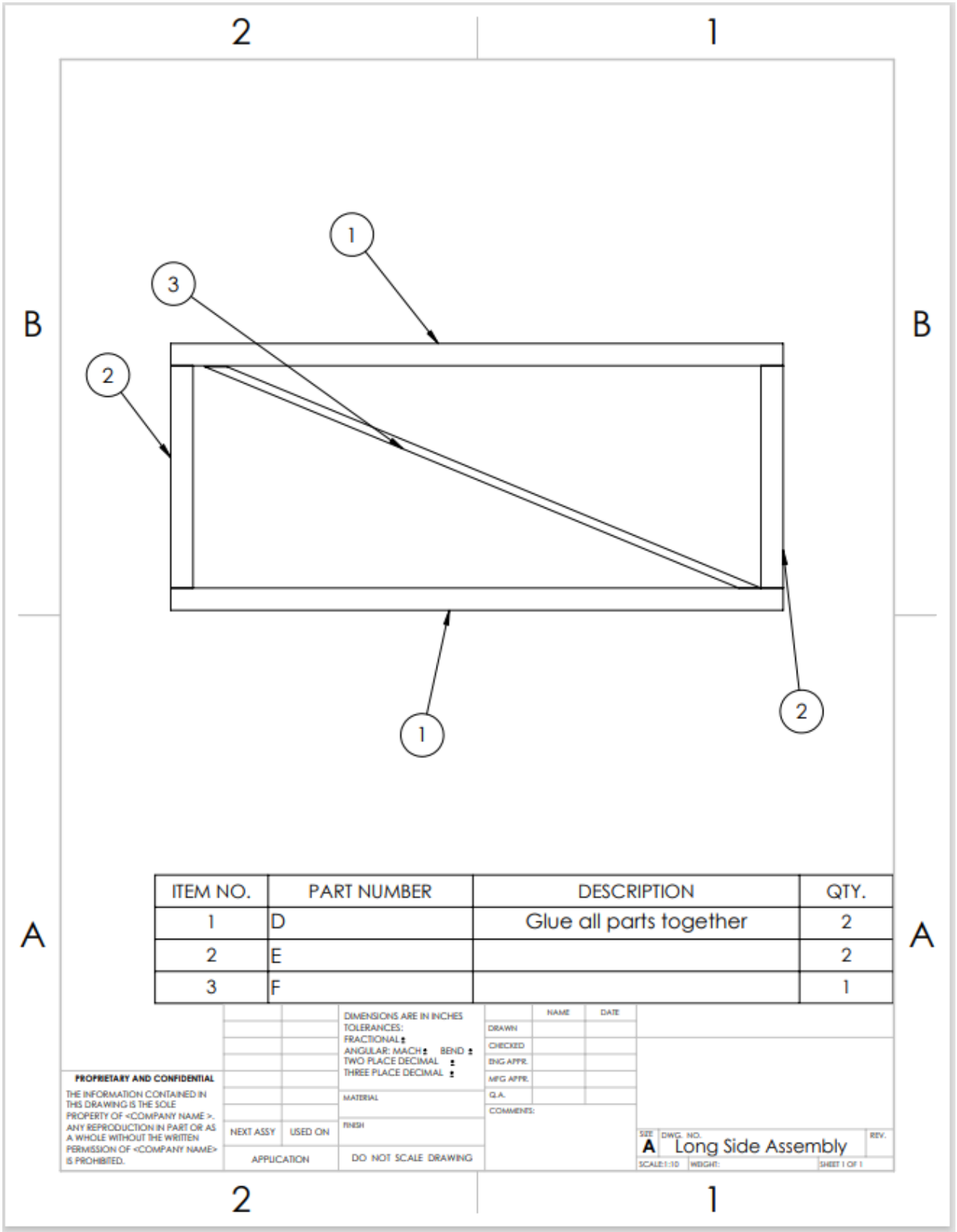
PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <COMPANY NAME >. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <COMPANY NAME> IS PROHIBITED.

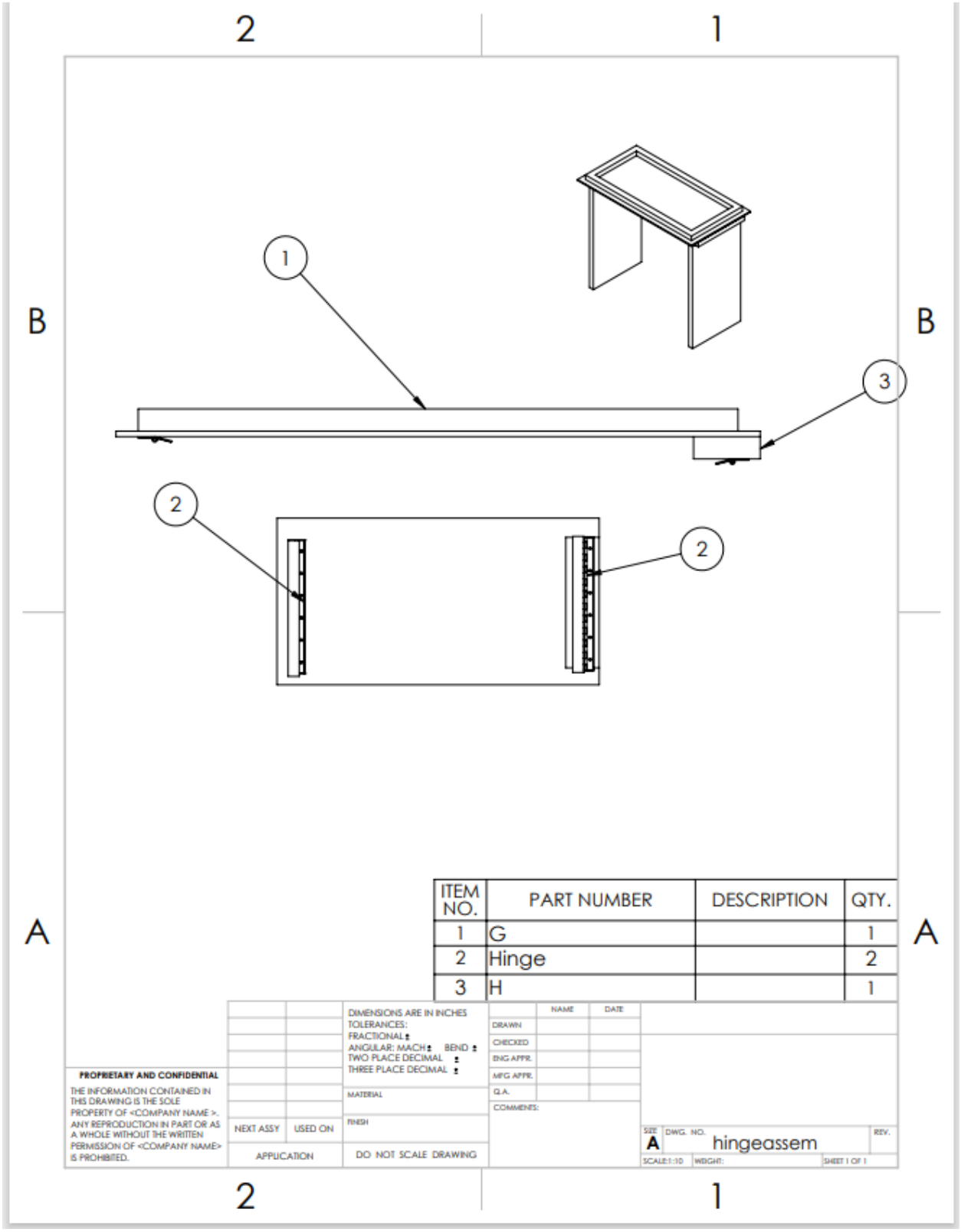
SIZE A | DWG. NO. Side Frame Assembly | REV.

SCALE:1:5 | WEIGHT: | SHEET 1 OF 1

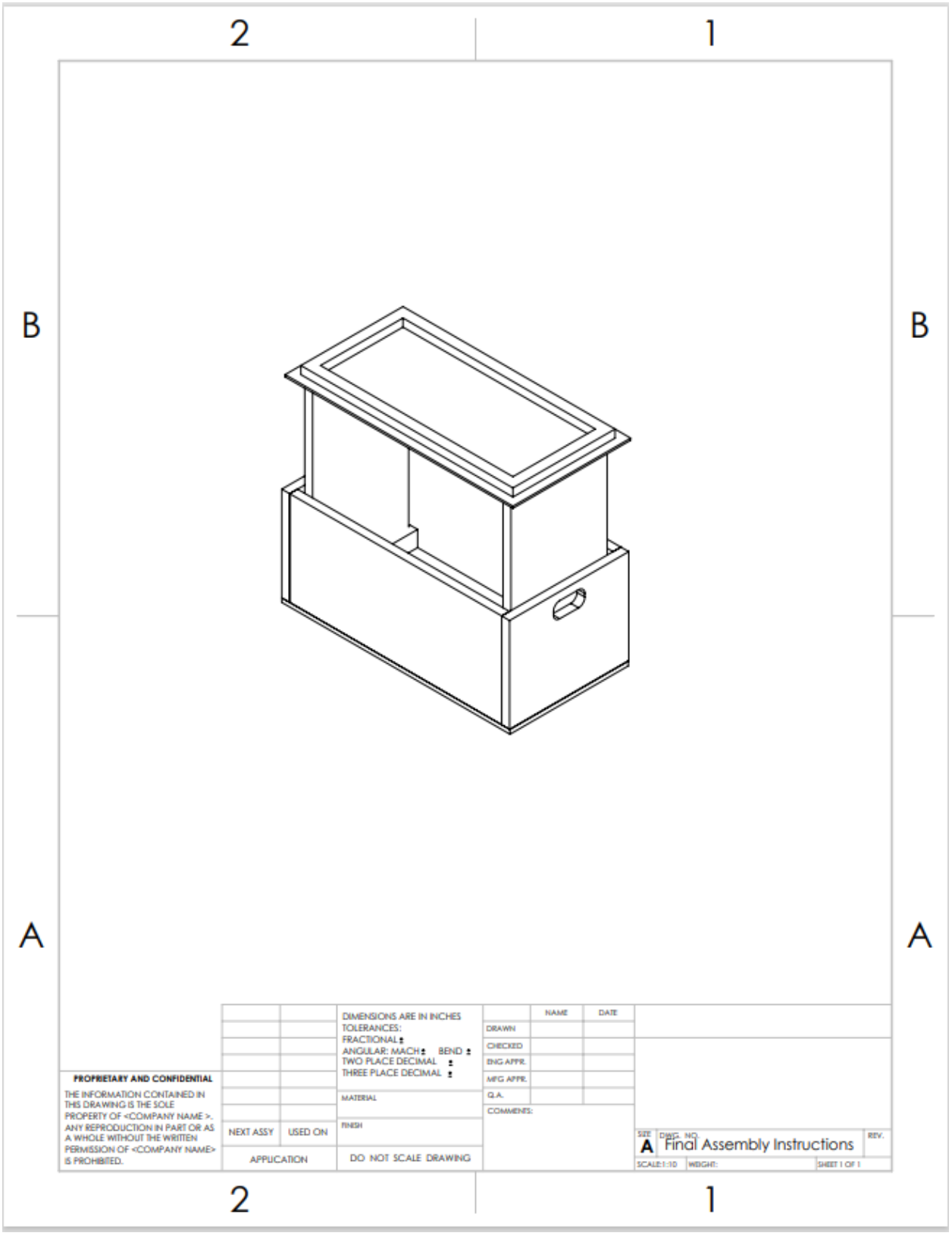
Assembly Specifications 1



Assembly Specifications 2



Assembly Specifications 3



Assembly Specifications 4