April 20th 2022

Joaquin's Handbook

For Praxis II

Table of Contents:

1. Introduction

This handbook serves as a reflection of my experience in my first year of Engineering Science (2021 - 2022), as well as a learning tool for myself and others whenever we need guidance in engineering. Most importantly, this handbook will contain a set of tools that I used during my first year that I believe will be the most useful in my future engineering. Each tool illustrated will be explained, analyzed for its strengths and weaknesses and ultimately show how to use this tool based on a modified approach.

Most of this handbook will cover my experience in Praxis I and Praxis II but also touch on other course work from my first year as I believe it to be relevant to my future design work, engineering work, and engineering design work. However since this is being written during the second term of my first year, I cannot validate whether this statement will remain true. Addendums may be added on as I become more experienced in engineering and wish to document my ideas.

Most of my learning could not have been possible by my wonderful teachers, TAs, and peers so I would just like to take this opportunity to thank them for my experiences in first year. Thank you.

1.1 Structure of Handbook

The handbook will begin with a personal statement about myself that will outline who I am and how my identity impacts my engineering. This is done at the beginning to help guide the reader (and a future self) on the biases and skills this version of me has at this time as that will influence how I perceive the tools I have used this year. If in the future some of my statements in this handbook are proven wrong, I hope that the position statement helps reveal someone who is flawed and still learning engineering.

This handbook has two main sections that can be read exclusively apart or conjoined. Section One describes three engineering projects I did in this first year of Engineering Science. For each project, I will describe how engineering design was used to create the final product. Whenever an engineering tool is used however, it will briefly describe how that tool was integrated into the overall process, and then direct you to the corresponding section in Section Two.

Section Two will specifically describe the engineering tools I believe will be the most beneficial to me in the future and those that I wish to carry with me into future courses and future engineering work. This section will outline the tool in how it is used, describe how it was used in the specific context, and the strengths and weaknesses of the tool. Ultimately it will describe a modified approach to using the tool if required and explain in which contexts the tool should be employed. Section Two will also refer to Section One whenever a more specific context is required.

Although the two sections are not mutually exclusive, one could read one section without the other if there isn't any need to look at the other section. However I highly recommend reading both sections around a specific tool since seeing an example of how a tool was used could be more beneficial than reading any sort of description.

1.2 How to use Handbook

This handbook is designed to present engineering tools in a practical way that would help one learn how to use the tool and give an example of the context in which the tool was used this year. My hope is that a reader will wonder how *The Requirements Model* could be used in a project and simply turn to that section in the handbook. Maybe they'll flip to the corresponding engineering project that used the *The Requirements Model* to get more insights but overall it should be a fast process.

This means that every tool will be mutually exclusive and not require any prior reading to understand the ideas. You don't even need to read the introduction.

That being said, as stated above, one could benefit from reading multiple sections, not just the one they require at the time. Further context and examples is always beneficial when dealing with an engineering tool, as no engineering tool is that same and no one uses the engineering tool that same way. Inspiration can come from learning how someone else or a past self tried to do something.

1.3 Why this Medium?

I have chosen to create this handbook in this form for two reasons. The first is that this is aesthetically pleasing to me and since I am the primary stakeholder, I thought that catering to what I like seeing is an objective. While some may think long documents are boring and have too many words, I think that with enough heart and care, this handbook can be intriguing and educational.

The second reason is that the table of contents automatically links with sections when this document is in a doc file format or a pdf. One simply has to click the section they desire in the table of contents and the document will send them to where they wish to go. If I were to write this handbook on a powerpoint or slideshow, I would have to design the linking process myself.

2. Position

This section details how I perceive myself and how that influences who I am as an engineering student. I will explain my engineering Identity and then outline my skills, values and biases that help guide this handbook. At the beginning of Praxis II, the first assignment I did was the position statement. While I still agree with how I described engineering, design and engineering design in the assignment, I disagree with who I said I was. This is because I have changed overall during this term and I will describe that in the changes section.

2.1 Engineering Identity

A big theme around Praxis II was this idea of what engineering design was. Several lectures and tutorials were spent discussing this topic. The definitions I came up with in January are still the definitions I believe in at the end of the year. They are:

Engineering:	Engineering is the act of using science, math, and personal developed intuition, to learn the decisions needed to solve a problem and improve the human condition.
Design:	Design is the process of making a plan to create a product.
Engineering Design:	Making design decisions using science, math and a developed intuition, within a set of constraints in an iterative process consisting of design and the assessment.

These three definitions are at the core of who I believe I am as an Engineering Student. In this program I am learning how to be an engineer and perform engineering design. Not only does this require learning the math and science that I will use in my educational career but it also requires this innate desire to improve the human condition. Engineering is a profession with the power to almost do anything, and I think it should always be done to improve humanity somehow.

I originally wanted to be an engineer simply to create spaceships, but after going through one year of this program, I've realized there are so many other things out there that I can do beyond just making rocket ships. Although I don't know exactly what I want to do yet with an engineering degree, I know that I want to help people and improve their lives. When you have the skill to make technology and use science to do almost anything, why not use it to improve the lived experience of the people around you and around the world?

Design and specifically engineering design are big parts of this process. Throughout this past year I have had the opportunity to frame a problem, come up with solutions for it, and test these solutions out. I believe this iterative process to be engineering design; using science and math to iteratively create solutions. Although I wouldn't say I am very good at engineering design, much less the actual engineering, I have learned some new concepts and tools this year that I would like to take with me into the future. Thus most of this handbook will focus on those tools and concepts that I used in engineering design and describe my analysis of these items.

2.2 Skills

During this first year, I have had the chance to really examine my strengths and weaknesses in a program that really tests me and forces me to push past my limits, or at least the limits I thought I had. There have been moments where I've failed or faltered but the important thing is that I got up again and persevered through those hardships. I've only been able to do that by understanding where my skills lie.

Three skills that I want to highlight and that become important in the implementation of my favored tools and concepts are:

Ability to Learn

Ability to Understand

Ability to Listen

In this program I have first and foremost learned how much I don't know and how much of science and technology I need to learn by the end of undergraduate time. Even though it has been difficult to keep up with all the new information, I have found that I can pick it up pretty well. Specifically in lectures I have no problem understanding ninety percent of what is said and can replicate it easily with practice. This has allowed me to move through all my courses without falling behind as simply attending lectures is enough for me to understand the lessons on a conceptual level. Of course in order to be able to perform on an exam or midterm, I have had to study hard.

My ability to understand has been more highlighted in my design projects {3.}. Communicating with my fellow Engscis is an amazing experience but due to differences in background and education, it can be hard to understand what someone is saying at first. I have found however that I can understand in most cases what is being said, and if I don't I try to understand in other ways, like demonstrations or visualizations. I think being able to quickly understand what someone else is saying is important as it helps the conversation move forward in a timely manner without the stall of too many clarifying questions.

Another aspect of communication that I think is important to highlight is the two way street nature of most conversations. Listening to someone else is not only a passive skill but an active one requiring you to give visual or audible feedback to the speaker. Something I noticed in Praxis I and Praxis II was that the teaching team never outright rejected answers or responses. A lot of the time they would begin their phrases with agreement or restating the idea in their own words. For me I've never had an issue with giving a person 100% of my attention when they are talking to me, and I always seem to be interested in what they have to say, even outside of engineering. I think this skill has helped me be an amicable team member.

2.3 Values

Values are really what make us human. As objective as we want to be sometimes, a lot of our decisions are based on our perspective which is informed by our values. I myself am Catholic Christian and the philosophy of the religion informs my decision making. This is reflected in my core values, which are:

Compassion

Focus

Compassion is a core tenant of not only Catholic teaching but also my own life. I believe the best way you can help someone is by first caring and showing that compassion. When you really care about something or someone, it helps motivate you to give it everything you have. Compassion doesn't have to be about a person but can also be about an idea, a concept or even belongings. I think as engineers we have a responsibility to show respect for our fellow humans, the animals around us, and the things that do not belong to us. Compassion is the first step of making sure you only have everyone's best interests at heart, or to at least make sure you are considering everyone when you make choices.

My second core value is focus. I am of the opinion that focusing 100% of your energy on one thing is better than focusing 50% on two things. Thus I like to give my complete focus in a project or task. Of course due to the nature of the program this is not always possible, so I try to give 100% focus in pre-allocated time slots. This value of focus also informs my expectations of my group members. I expect my team members to be focused on the project when we are working together and I don't like it when one of us is clearly working on something else or not even paying attention. For my group projects, whenever the whole group was completely focused, that was when we had some of our best work.

2.4 Biases

Of course everyone has biases that affect and impair their decision making. Being able to identify your biases is important so that you can look beyond them and see everything in front of you. My main biases are:

I only accept ideas that I understand

I fall for confirmation bias easily

I prefer short-term fidelity options

These three biases will affect the handbook in the way that it is written and the information gathered. Although I believe that the information presented in the handbook to be factual and useful in certain contexts, I request that any reader use their critical thinking skills before blindly following the instructions in the handbook.

I personally don't like ideas that I don't understand. If there is a way for me to learn more about a concept or idea, then I will take the opportunity to ask for more information or further description. If there is no way to get further information, then I will disregard the idea. This is reflected in the handbook as I will only be addressing the tools I have used a lot of and I know I can make meaningful commentary about.

Another trait I've seen in myself this year is that I always move with a purpose. I don't want to do work unless I know the goal I hope to achieve. But that means I do things like research with a specific idea in mind, and thus I fall for confirmation bias. Because I know what I'm looking for, I often miss contradicting evidence to my preconceived notion. For example in Praxis I {3.1}, I thought that the shield concept would be the best for our opportunity because of its simplicity and ease of use. I spent a lot of time arguing for this even though our tests showed that the pillow concept was better. In the end my group was able to convince me that the pillow concept was better, which was clear from the evidence. My confirmation bias told me that the shield idea was better even though I didn't have the evidence to back up that claim.

My last bias is about low effort, high fidelity options. Another way to phrase this is that I like doing the least risky option, with the highest reward. I don't like spending the time to create a complicated presentation or prototype {7.1}, if I know that a simpler device is enough. This goes hand in hand with the fidelity of the device in question, Is it worth spending a large amount of time for something that may prove unnecessary? If something will take a lot of time and work, I need to know it will be worth it in the end or else I won't do it at all. An example of this bias is the fact that I prefer lower complexity prototypes over higher complexity prototypes even when the higher prototype is better, because I believe it is only marginally better and the lower prototype is simpler.

2.5 Changes

At the beginning of the second term, I was tasked to outline my personal position on engineering. In that assignment I outlined these values:

Learning

Analysis

At the time these two were the most important values to me as an engineering student. As stated above these values have changed.

The reason I focused on these values at the beginning of the term was because of what I learned during first year, and how much I realized I didn't really know. I thought that engineering was about learning and analyzing what you are learning. For example in CIV102 we learned all sorts of formulae about civil engineering and how they were all derived. Most of my focus then at the beginning of second term was to continue that pursuit of learning new topics.

During the second term however, we as a class were pushed more to apply what we had learned from the first term into real contexts. In Praxis II we took the basic concepts from Praxis I and applied them to real world problems in our *RFP* assignment and later the *Showcase* presentation. In my own project for Praxis II, we used the CIV102 knowledge to create one of our constraints as we dealt with tension and strings. In our other courses there were more examples of real world applications and how the topics we were learning could be applied in actual contexts.

I have learned that the value of an engineer is not about what they know, but more about what they are willing to do. Of course knowledge and skill is important in this field, but all of it becomes unimportant if you aren't willing to use it. Therefore in this handbook I focus on the why question. Why do I want to Engineer? The values of compassion and focus help answer this question {2.3}.

3. Section 1: Engineering Projects

In this section I will describe three engineering projects that I did this year and will describe how I integrated the engineering tools in the process. For a more detailed look at each tool, check out section 2.

3.1 Praxis I: Smudging Opportunity

For Praxis I, I was in a design team with Isabelle, Paige, and Kevin. We worked on designing a solution for preventing smudging in writing. This topic was especially important to me personally because my dominant hand is my left and I smudge a lot of my writing.

The first step in our process was framing and to do that we applied the requirements model {6.1}. Since there was already a requirements model from the original opportunity, we simply modified it to be more detailed and removed the objectives we didn't think we needed.

Objective	Metric	Criteria	Constraint
1 Avoid smudging on paper	Time after writing for ink/lead not to smudge on paper (seconds) [17]	Less time is preferred	Must be less time than when using a standard pen and paper set-up. [17]
2 Avoid smudging on hands	Time required before smudging stops occurring on hands (seconds) [17]	Less time is preferred	Must be less time than when using a standard pen and paper set-up. [17]
3 Cost Efficient	Cost per month of usability (dollars)	Cheaper is better	Should be no more than $5 per month
4 Usable by both left and right handed students	Does it satisfy Objective 1 and Objective 2 for both left-handed students and right-handed students? (Yes/No)	-	Must be yes
5 Usable by different hand sizes	Range of hand circumferences accommodated (mm) [16]	Larger range is prefered	-
	Range of hand lengths (distance between the wrist and the tip of the middle finger) accommodated (mm) [16]	Larger range is preferred	-
6 Comfortable	Average rating given by a test group that rates how comfortable the design is on a given scale. (1-10)	More comfortable is preferred	-
7 Usable for different types of writing utensils	Number of writing utensils that satisfy Objective 1 and Objective 2	More utensils are preferred	-

Alpha Requirements Model for Praxis I [4]

Once we had framed the problem in a way we thought was good, we diverged on different ideas using a 6-3-5 brainstorming tool {5.1}. This allowed us to get the ideas we initially had and that we presented in the alpha presentation [4].

Prototypes, general design, pros cons, main aspects

1. Wristband / Bracelet

- Light, easily adjustable
- Moves along while writing in an intuitive/easy way

2. Scaffolding

- Provides best support for arm
- Clunky, not carried easily everywhere (stationary artist)

3. Pillow Arm Brace

- Focused around support and ergonomics
- A little clunky

4. Hand shield

- Really easy, and cheap
- Restrictive / not comfortable to write with, not the best at stopping smudging

5. Compass / art easel

- Easy to employ, keeps hand off the page
- comfort??

6. Marionette Utensil contraption

- No surface area touches the paper
- Complicated desk setup, hard to have controlled actions

List of design concepts for Beta

Moving from beta we created a measurement matrix and comparison matrices {5.3} to converge down to our best idea. From the data in those matrices, we found that our pillow concept was the best one as it smudged the least and provided the most comfort. This was not the idea I thought we would go with but since the data pointed towards it, we chose it.

Pillow Prototype

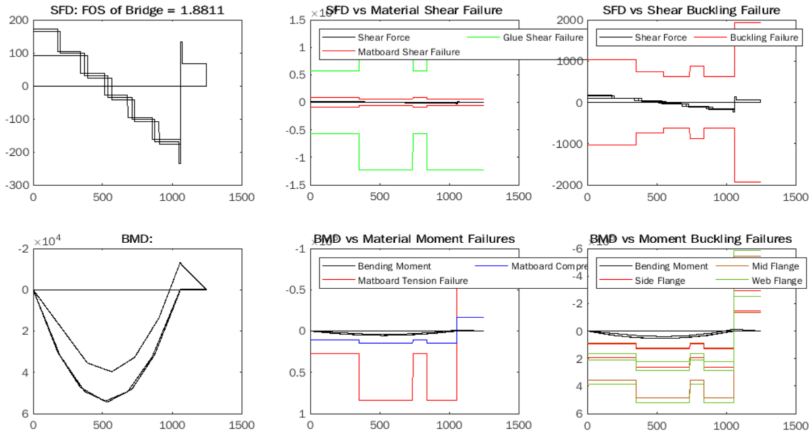
3.2 CIV102: Matboard Bridge Design Project

For CIV102, our final project involved designing a bridge out of matboard that would be tested in the civil engineering lab. It had to pass two load situations, a train with dynamic loads and a press at two points. For this design project I worked with Yina and Grace. We designed a bridge predicted to fail at 1286N by my code and experimentally it buckled at 1280N.

Bridge team standing on our creation.

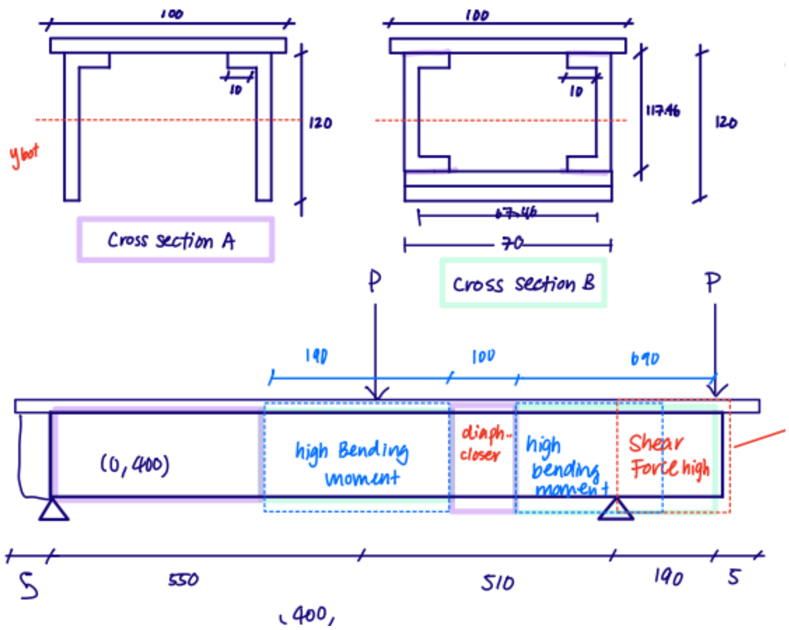
The key components around this project were designing the bridge itself, writing code to perform the force calculations and representing them with graphs, and then actually constructing the final design. These different tasks were done with different tools with different levels of success.

The first task was to actually design the bridge and that was done by using a morph chart based technique {5.2}. We started by separating the different forces on the bridge and thought about which points needed adjustment to make it last longer.



Graphical representation of the forces we are dealing with and where they are located across the bridge. [3]

By doing this we saw where a different cross section was necessary, one where the structure was stronger to resist the higher forces.



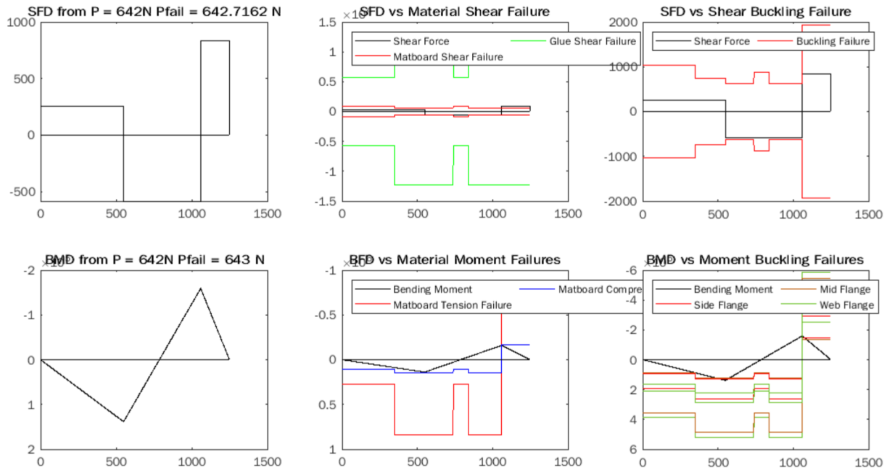
Cross section plan. Cross section B is more suited for more intense force. [3]

We created a sketch of the bridge we wanted to make similar to the hoover dam model {6.2} and then began constructing the bridge to make it a reality. The construction process had some issues with gluing, sketching, and cutting so the bridge itself is not exactly as the way we theoretically designed it.

The other part of this project was around Matlab {7.2} and creating a math prototype to test the bridge theoretically {7.1 B}. From the math prototype and matlab code, we could see where and at which force the bridge would break theoretically.

```
%% Train Load: 6 points for the 6 wheels

TLocation = 1; %Train at Start

[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation, P, x, SFD_TrainLoad,
locationA, locationB);

[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176, P, x, SFD_TrainLoad,
locationA, locationB);

[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176 + 164, P, x,
SFD_TrainLoad, locationA, locationB);

[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176 + 164 + 176, P, x,
SFD_TrainLoad, locationA, locationB);

[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176 + 164 + 176 + 164, P,
x, SFD_TrainLoad, locationA, locationB);

[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176 + 164 + 176 + 164 +
176, P, x, SFD_TrainLoad, locationA, locationB);
```

Sample of the matlab code. [3]



Graphs formed by the math prototype to show the forces on the bridge [3]

All of this data came together when during the testing day, the bridge survived until a load of 1280N, only 6N less than its theoretical value. The bridge also made the kilonewton club, a club of bridges that passed 1KN.

3.3 Praxis II: Accessible Guitar Opportunity

For Praxis II, my design team of Nadia, Lisa, Malek and I, were tasked with creating a more accessible guitar. Although the RFP was originally hard to work with, by the time we got to showcase we had a great concept and some excellent prototypes to prove that the concept worked.

One of the first things we did after reading the RFP was modify the requirements model created by the authoring group {6.1}. We changed most of it as a lot of the requirements were too complicated like how to measure grip strength, or made no sense for musicians like the metric of number of songs that can't be played (which doesn't make sense since there are basically infinite songs). We changed the requirements model to really only focus on three objectives:

Reduce key pinch strength required to play the guitar

Allow for the user to play basic as many chords as possible

Be Authentic to the guitar experience

Objective	Metric	Criteria	Constraint
Primary Objectives:			
Minimize strain on fretting hand	Force to press down on a string (N)	Less force is better	Less than 6.05 N (based on tension calculations) Current force required to press down on string)
Authentic to guitar playing	Qualitative Scale out of 8	Higher number out of 8 is better	
Allow play of common chords	Number of chords able to be played	More chords is better	Must have the following chords: - Tonic - Subdominant (IV) - Dominant (V)
Allow play in common keys	Number of music keys that can be played in	More keys is better	Must have the following keys: - C major - A minor - G major - E minor - Eb major - C minor - F major - D minor

Praxis II Requirements Model [1]

This modified requirements model helped frame our future solutions in an effective way of tackling this RFP. Idea generation was done by a modified 6-3-5 brainstorm {5.1} done by combining our group with another guitar group in the same studio. This 8-3-5 allowed us to generate plenty of ideas that would lay the foundation of our beta concepts.

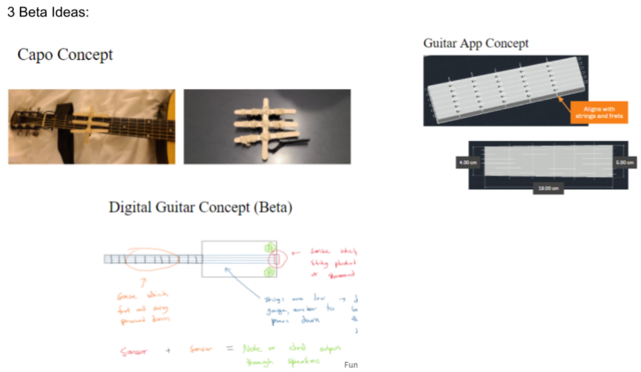
Another tool used to help form our ideas for beta was a morph chart {5.2} used to separate the different functions of a guitar and focus on the one that really affects stakeholders with low key pinch strength: strumming. The combination of the 8-3-5 and the morph chart helped us diverge our solution space. We converged down to three concepts for beta.

Our concepts for beta were:

Capo Concept

Guitar App concept

Digital guitar concept



Three beta ideas for Praxis II [1]

From beta we used a measurement matrix and comparison matrices {5.3} in order to converge further down into our one concept we would focus on and present at beta.This concept was the digital guitar.

Pugh Charts

Pugh Chart: Guitar App as Reference

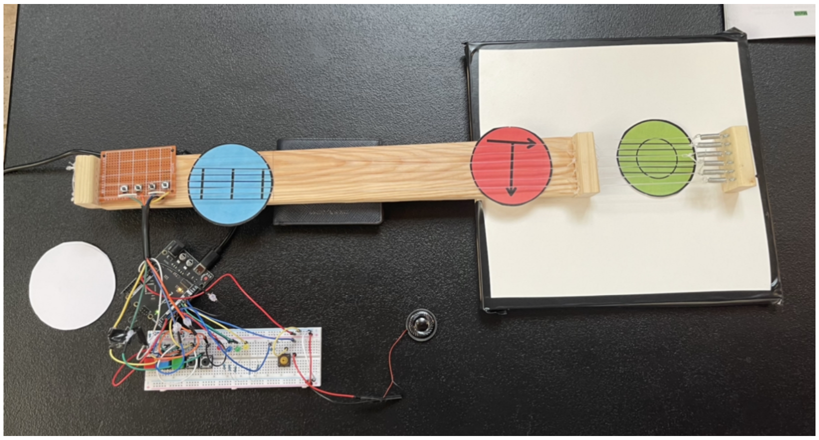
	Capo Concept	Guitar App	Digital Guitar
Key Pinch Strength Reduction	-1	0	-1
Number of Chords that can be played.	-1	0	+1
Authenticity	+1	0	+1

Pugh Chart: Digital Guitar as Reference

	Capo Concept	Guitar App	Digital Guitar
Key Pinch Strength Reduction	-1	+1	0
Number of Chords that can be played.	-1	-1	0
Authenticity	-1	-1	0

Comparison Matrix used to converge down to digital guitar [1]

For the digital guitar I created a functional prototype {7.1 C} out of an arduino and some circuitry in order to demonstrate the core part of our design, the way the sensors interact together to produce a sound. This prototype was vitally important during showcase to demonstrate how the guitar would work and prove that the concept is viable. Despite the initial setbacks with this RFP, the final product turned out great and I am very proud of the work I did in this design project.



Functional Prototype of Digital Guitar [1]

4. Section 2: Engineering Tools

Engineering tools are at the heart of this handbook. In these next few chapters I hope to describe, demonstrate, and analyze the tools I used in first year and how I would use them in the future. Since these are all the thoughts of myself as a first year engineering student, a lot of these ideas may become outdated or become ones that I no longer agree with. These are simply the ideas and tools I wish to carry with me into my future.

The tools are separated into three types of tools, *Functional Tools, Conceptual Tools,* and *Representational Tools.* It is organized in this fashion because each tool has a specific goal in one of these three aspects, whether it be used to further design, teach and illustrate engineering concepts, or to represent thinking in more clear and concrete ways. These tools can be used in other contexts outside of these topics, but I recommend using them for their specific purpose.

In the sections below, each tool will be explained, give an example of how it was used in my first year, analyze how effective it was, and finally explain how it can become more effective. Based on my experience with the tool, each will be measured under two qualitative scales designed to focus on the tool's practicality:

Practicality Chart:

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

In the end everything is used to answer the question:

Do I recommend it to be used again?:

4.1 Functional Tools

Functional Tools are tools that were used to further thinking and develop concepts or ideas during the year. These tools were essential for work to be done and the project to develop further and further. Simply put these are "doing-tools" since they do something. They generate ideas, help clarify aspects of a concept etc. Functional tools are applicable in many different situations, but should be modified in different contexts to increase the effectiveness of the tool.

4.2 Conceptual Tools

Conceptual Tools are tools that help explain or illustrate a concept. These tools don't "do" as much as the functional tools but help develop a vocabulary that a team can use to communicate ideas. They can help quantify exactly what you want to say into useful ideas that everyone will get. All the tools selected in this category are models from Praxis I and Praxis II that I used to understand engineering design as a whole and help communicate my ideas into expressions my team members could understand. Rather than be "done" these tools should be kept in mind when working with engineering design.

4.3 Representational Tools

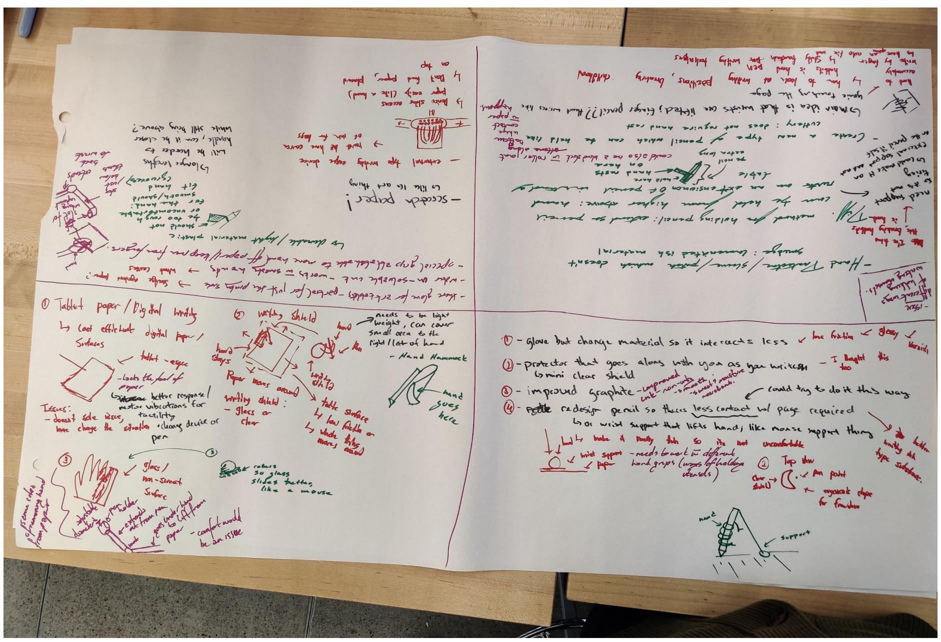
Representational Tools are tools that help represent and display ideas. Generally representational tools are visual as visual stimulus is the best way to convey information; For example: advertisements, youtube videos, etc. These tools help explain ideas that otherwise but be stuck in an engineer’s head. They also translate vital information about a design in a simple way so that audience or team members easily understand. *Representational Tools* are the most applicable in other contexts as not only can engineers use them but other fields as well.

5. Functional Tools

5.1 6-3-5 Brainstorming

5.1.1 Description

6-3-5 Brainstorming is a **Diverging** technique that hopes to capture the same ease of use that traditional brainstorming has, while allowing all voices to be heard. In a team, each member is given the task of brainstorming three possible ideas in a limited time. This can include writing down words, but more importantly should have some sort of sketch or visual component to help illustrate the idea. After the time has been spent, the group either rotates themselves or rotate's their work around the group so that the next person can read and add on to the ideas. This can involve writing down questions they have, or adding further detail to the ideas. This happens for an equal amount of time as the last part. Then this is repeated again and again until enough people have seen the ideas.



Praxis I team conducting 6-3-5 brainstorming technique on a chart paper [4]

In the document, *27 Creativity Tools for Divergent and Convergent Thinking* [6], provided by the Praxis I teaching team, the specific instructions is to have a group of **6** team members, create **3** ideas each, and rotate the ideas **5** times, hence the name 6-3-5. However as not all groups can cater to this specific set, it can be modified to include four team members as seen in the above image, five team members, or even eight people. The time for each rotation is also stated to be 10 - 15 minutes, but in my experience that is too long of a time and it's better to have closer to five minutes so that more rotations can be conducted.

This technique should be used for any sort of idea generation. This can include finding solutions but may also include finding different lenses to look at a problem, or even something as simple as name generation (although for a task as simple as this, the technique should be reduced in time as it is unnecessary to spend a whole five minutes on just names). Overall it is a good diverging tool that can be used in multiple different contexts.

5.1.2 Examples

In Praxis I, my team used this technique to generate possible solutions for our opportunity of reducing smudging in handwriting {3.1}. This was done by a group of four where we divided the chart paper into quarters and rotated ourselves around the table. This technique helped us generate our five possible solutions that we presented in the Alpha presentation. As seen in the above image, we each had a different color so that our individual thoughts were easily reflected in each comment. We used illustrations to highlight the components of our ideas. This technique helped us see everyone's ideas as if we went with a verbal brainstorming activity, some voices would've been drowned out by others.

Another example of this technique was in Praxis II this time with two groups working together on the same RFP {3.3}. Both groups started out pretty lost in where to begin scoping the guitar RFP and solution development so it was thought that this technique could not only generate possible ideas, but also help find what direction either group wanted to pursue in solving this RFP.

8-3-5 Brainstorming between two groups

This brainstorming session allowed us to see a lot of different ideas but also see the ideas that were similar or the same. Both groups now had a lot of solution possibilities and also a set of possible solutions to actually help frame the opportunity based on what everyone thought of. While I cannot speak to the other group, this specific brainstorming helped point in the direction of a full mechanical solution and the framing around key-pinch strength {3.3}.

5.1.3 Analysis

The main improvement this technique has over traditional brainstorming techniques is that it helps every voice be heard. Because everyone writes down their ideas and everyone looks at them at least once, voices aren't silenced like they might be in group discussion or any full collaborative divergent technique. Another good aspect of this technique is that the time limitation forces you to be both concise in your idea generation and also stay focused on the task. It also helps remove any bias towards your own ideas since you spend just as much time working on other people's ideas as you do your own initial ones. In my experience, the ideas generated from this technique can range from useful to unrealistic but the wide variety gives you a lot to work with.

The main issue with this technique is that on its own it's hard to organize the ideas. As you can see in the above images, the writing and sketches go everywhere and it's hard to come back to just a photo of the scribbles when you want to further develop ideas. Another issue is the repetition of the ideas that occur. If the team doesn't think beyond their initial "inside-the-box" answers, you won't get many unique ideas but rather just repeated ones.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

As a tool it is pretty easy to implement and the results of it can be very useful. There are of course other diverging options out there but since this is the one I know the best, this is the one I will be using in the future.

Do I recommend it to be used again?: **Yes**

5.1.4 Modifications

The modifications I believe should be implemented for this tool are the ones my group made during our work in Praxis I and Praxis II. The first is the use of different colors. It isn't explicitly stated in the documentation [6] but having different colors really helps convey the work each person is doing. In terms of assessment, it helps make sure that every team member is clearly contributing to the process, and for the team itself it helps us know who to ask for clarification when we need it.

The second modification is the use of sticky notes for comments and questions. The sticky notes weren't implemented in the 6-3-5 brainstorming I did with my teams but I saw other groups use it. Allowing the ideas to be moved around helps separate the initial ideas from the future comments, as well as help connections to be formed between separate ideas. Once could move the sticky notes around to connect ideas with similar designs but different concepts, or if the comment is unnecessary, easily remove it from the thinking space.

5.2 Morph Chart

5.2.1 Description

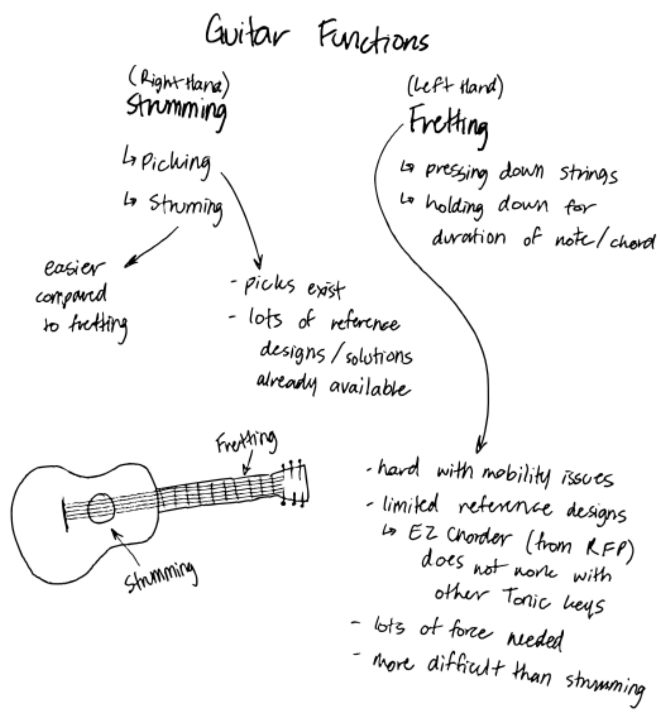
The *morph chart* is a tool that can be used for both **diverging** and **converging**. Its main purpose is to quantify different aspects of a design and brainstorm the possibilities for those individual components. The first part is to decide on what the different goals the design is trying to achieve. Once you list them down, you can use a different diverging tool to brainstorm solutions for each goal.

Another way to use the morph chart is to use it like a checklist and check whether your possible solutions are meeting those goals. If there is no component in a solution addressing one of the goals, then you can either add a component to it, or throw out the idea completely.

This tool helps clarify what exactly you are trying to design for by simply stating the aspects of any possible design. This helps further brainstorming and idea generation which will be described in the examples.

5.2.2 Examples

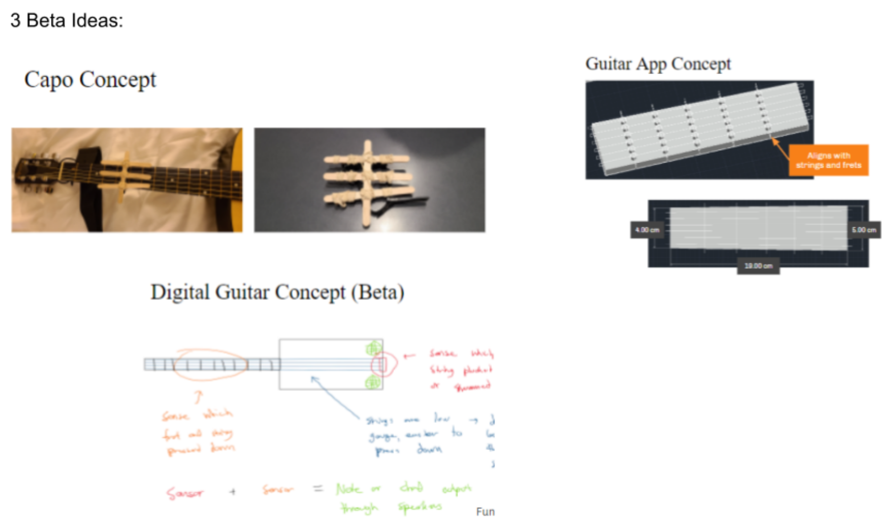
In Praxis II, my group was tasked with creating an accessible guitar {3.3}. After our initial brainstorming with the 6-3-5 (see above), we created a morph chart of what our design might incorporate based on the real components of a guitar.



Morph Chart for guitar functions. Written by my colleague Lisa [1]

From this chart, we were able to look into possible solutions for both fretting and strumming and discovered that there are already plenty of ways to reduce the force required for strumming, from picks to a "foot action guitar strummer" [1]. This let us rescope away from strumming and focus primarily on fretting.

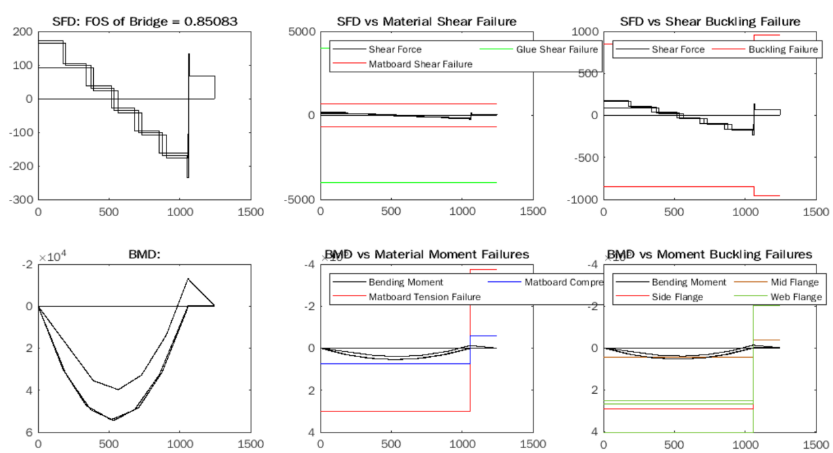
From that we developed more ideas surrounding just fretting which led us to our three beta ideas. {3.3}.



Beta Concepts. Prototypes created by colleagues Lisa and Nadia

Each of these concepts addressed the fretting component from the morph chart and the digital guitar would go on to be our concept for *Showcase*.

In CIV102, a similar idea would be used to find the material dimensions for our Matboard Bridge {3.2}. Since the bridge was known to be put under bending, shear stress, and plate buckling, we considered these components separately and brainstormed how we would protect the bridge against all these stresses.



Graphs displaying failure stresses for design 0

The graph above presents the stresses that the bridge would be put under and how the basic design fairs against those forces. In order to tackle the most dangerous forces on the bridge, my team decided to change the cross-sectional design to increase the second moment area of our bridge as well as have specific parts of the bridge reinforced with more Matboard where it would undergo the largest amount of stress. By separating these different forces, we could see what changes would have to be made in order to counteract the different forces, instead of being overwhelmed with all the considerations at once.

5.2.3 Analysis

As seen in the matboard bridge example, a morph chart is good at clarifying and defining what you want your design to do. Instead of just thinking, "I want the bridge to survive", you can separate it to, "I want the bridge to survive bending stress" and "I want the bridge to survive shear stress". This helps point your brainstorming in a specific direction, instead of being random and not that useful.

In the Praxis II example, we were able to rescope our entire framing in order to focus on what really matters. This is important so that you don't waste time thinking about something that you don't need to solve or design for. By clearly indicating what you think the goals of the design are, you can clear up what is important and what can be ignored.

Morph charts require a level of abstraction that might not initially be enticing for a team. It also requires a good imagination or a good way of representing the ideas around the morph chart so that every team member understands the goals of the design. If the team already has a good idea of what their solutions are or have no idea where to begin, the morph chart might not be the appropriate option.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

Based on the scale, the morph chart is a useful tool in the right contexts but it is harder to implement than one might be expecting. It requires a large amount of knowledge into possible solutions or the opportunity being addressed. In the end the morph chart might not have been necessary if the opportunity is clear or if the possible solutions aren't complex.

Do I recommend it to be used again?: **Yes**

5.2.4 Modifications

One modification I would make is to use multiple morph charts at different levels of abstraction. The first morph chart should be specifically designed around the requirements of the opportunity, while future iterations focus on detailing the functions that would meet those requirements. This would speed up brainstorming as you no longer are developing full ideas in your head without quantifying what the idea is actually doing. With multiple morph charts you can form more focused ideas since you understand all the components you are looking for and how it traces back to your original framing.

A good place the morph chart could be used, but I did not do this year, is in Detailed Design Decision making. One could describe the different components of their selected solution through a morph chart to better organize the details they need to further develop. For example for the guitar RFP {3.3}, once we had selected our digital guitar design for showcase, it was immediately clear that we needed to research which sensors we would put for strumming and fretting. What wasn't obvious by would've been with a morph chart, was that we also needed to consider the computer within the device, and how we would power it. Without these two considerations, we could never have fully developed the device.

5.3 Measurement Matrix and Comparison Matrix

5.3.1 Description

The *measurement* and *comparison matrices* are **Converging** tools used to compare different solutions against each other to see which is the best. The important thing to note is that neither matrix easily shows the correct or best solution. An engineer still has to use their critical thinking to decide the best option.

The measurement matrix is simply a chart comparing each solution by the metrics of the requirements {6.1}. It organizes the information but doesn't clearly explain how to use the information to make a decision.

Measurement Matrix

Measurement Matrix	Wristband	Pillow	Scaffolding	Shield
Comfort (level of comfort)	9.75	10	8	12
Affect writing (s)	7.8125	1.82	10.5025	4.7125
Smudge Distance (cm)	8.9	7.3	8.3	7.9

Measurement Matrix from Praxis I [5]

From the image above, you can see that the matrix uses the metrics set in the requirements and lists the values (for the case of smudge distance) or scores (for the cast of comfort). It is important that the matrix uses the metrics existing from the requirements as the comparison matrices will then use the criteria for those metrics.

The comparison matrix is a chart similar to the measurement matrix, with the same headers, but instead of values it simply scores whether or not the solution is better, worse or the same. A comparison matrix will have one compared solution to which the others are put against.

Pairwise Comparison (Wristband)	Wristband	Pillow	Scaffolding	Shield
Comfort	o	better	worse	better
Affect Writing	o	better	worse	better
Smudge Distance	o	better	better	better

Wrist Band as Base Line

Pairwise Comparison (Shield)	Wristband	Pillow	Scaffolding	Shield
Comfort	worse	worse	worse	o
Affect Writing	worse	better	worse	o
Smudge Distance	worse	better	worse	o

Shield as Base Line

Comparison Matrices from Praxis I [5]

The better or worse is based on the criteria of the requirements and metrics. If the solution is more aligned with the criteria than the baseline, then it is better. If it is less aligned with the baseline then it is worse.

In the images above, the compared solution is the one marked in gray, while better/worse is denoted with green and red. Since only one of the solutions is being compared against all the rest, multiple matrices are required for a decision to be made.

5.3.2 Examples

In Praxis I, for the smudge opportunity, a measurement matrix and comparison matrices were used to converge down to the final solution of pillow {3.1}. The measurement matrix was based on the three requirements from the requirements model: comfort, affect on writing, and smudge distance. The values of the solutions were put into a measurement matrix:

Measurement Matrix

UPDATE

Measurement Matrix	Wristband	Pillow	Scaffolding	Shield
Comfort (level of comfort)	9.75	10	8	12
Affect writing (s)	7.8125	1.82	10.5025	4.7125
Smudge Distance (cm)	8.9	7.3	8.3	7.9

The values of this measurement matrix were then used to compare the different solutions against each other. These comparisons were made based on the criteria set in the requirements model.

Four matrices were made to easily compare each solution against the others.

UPDATE

Pairwise Comparison (Wristband)	Wristband	Pillow	Scaffolding	Shield
Comfort	o	better	worse	better
Affect Writing	o	better	worse	better
Smudge Distance	o	better	better	better

Wrist Band as Base Line

UPDATE

Pairwise Comparison (Shield)	Wristband	Pillow	Scaffolding	Shield
Comfort	worse	worse	worse	o
Affect Writing	worse	better	worse	o
Smudge Distance	worse	better	worse	o

Shield as Base Line

Pairwise Comparison (Scaffolding)	Wristband	Pillow	Scaffolding	Shield
Comfort	better	better	o	better
Affect Writing	better	better	o	better
Smudge Distance	worse	better	o	better

Scaffolding as Base Line

Pairwise Comparison (Pillow)	Wristband	Pillow	Scaffolding	Shield
Comfort	worse	o	worse	better
Affect Writing	worse	o	worse	worse
Smudge Distance	worse	o	worse	worse

Pillow as Base Line

Because the other solutions were worse than the Pillow solution, indicated by the color red, the pillow option was seen as the best option. Specifically it beat the second place solution, shield, in effect in writing and smudge distance which were the primary objectives of the opportunity.

5.3.3 Analysis

The measurement and comparison matrices are effective converging tools. As long as the requirements of the opportunity are properly formed and effectively describe what would make a better solution, the measurement and comparison matrices should be the first things made for convergence.

In Praxis I, the hardest part about implementing the matrices was the actual proxy testing, as a test had to be made for each objective. Conducting the tests themselves also took some time. The actual comparison however didn't take that much time since the best option was pretty obvious. If the comparison hadn't been obvious, then one would have to use critical thinking and prioritize certain objectives.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

This is a very good converging tool and should be used in most engineering design projects.

Do I recommend it to be used again?: Yes

5.3.4 Modifications

The only modification I would make from how I used this tool in Praxis I is changing the colors for better and for worse. In the image above, having more red meant that the solution was better than its competition, which goes against our intuition as humans.

5.4 Group Meetings

Group meetings were a pivotal part of the three projects I did this year. Whether it was online meetings at 10 pm, early morning meetings at 9:30, or even midnight bridge meetings, group meetings were essential for the completion of work and communication of ideas. Meetings can be about anything from discussing next steps and delegating work for the week, to being an actual work period where the team spends the hour doing their respective jobs.

Online meetings were necessary this year mainly because of COVID and a lack of access to facilities where meetings could be conducted. Online meetings were also done to accommodate commuter members of my teams since they couldn't stay on-campus for the entire day.

Since there were big differences in how group meetings were conducted depending on whether it was online or in-person, I will be analyzing them separately. The practicality chart will also not be used since no matter how easy or hard the meetings were to implement, they were vitally necessary and the project could not have been done without meetings.

5.4. A. Online Group Meetings

5.4.1 Description and examples:

Group meetings conducted online are often through Zoom, or Discord. These meetings last anywhere from a few minutes to five hours. This year because of online schooling, everyone has a good set up to attend a zoom meeting, however this might not always be the case and should be considered when planning a meeting. Scheduling a meeting remains the same no matter online or in-person.

In Praxis II, the majority of our meetings were online because one of my team members was a commuter student. In the online setting, most of the meeting was done in silence, with the only group discussions having all that much talking. We did not turn on our cameras. Frequently someone would ask another team member to read their work but other than that it work time was mostly done in silence. This was an efficient system as we did finish all of our work on time.

When we did have group discussions, I tried to always write down what was being said and record the ideas. This was to ensure we remembered what was being said.

5.4.2 Analysis:

Despite the success of our online meetings in Praxis II, it wasn't an environment I particularly enjoyed. A lot of the time you don't actually know if your team members are working with you unless you track what they were doing. Since no one really talked, you can't be sure if someone stepped out or if they were doing something entirely different.

Certain tasks were also impossible to do online such as validation tests or construction of prototypes. Thus, the online meeting was best for creating and researching evidence, creating documents and presentations, and practicing scripts.

Writing down everyone's ideas was very helpful, especially when we needed to remember what was said. I found that it was easier to remember information from in-person meetings than virtual meetings so having a written record was good.

In a non-COVID setting and if every team member could attend, **I would not recommend doing online meetings**. They are impersonal and don't create a good team dynamic. However if even one member can only make the meeting online, I think that every member of the team should be online so that the one person is not left out of discussions and has equal say in the process.

Do I recommend it to be used again?: **No**

5.4.3 Modification:
If you are to do an online meeting, I think that camera's being on should be tried. Not everyone may be comfortable having their cameras on for one reason or another, which should be respected, but if possible, online meetings should have their cameras on. Both out of respect, and for focus.

5.4. B. In-Person Group Meetings

5.4.4 Description and examples
In-Person meetings are important for any team. Although online meetings can be used to get work done, in-person meetings help a team bond or to at least get to know each other. Although in-person meetings aren't always on task or extremely productive, they help the group grow together and learn how to interact with each other.

For all three design projects, we conducted in-person meetings, mostly to get work done but sometimes for discussions. In either case off-topic conversations were bound to happen but they should be allowed. In-person meetings are the best way to get work done I think because everyone is there to keep each other focused. What would've taken a person alone 1 hour might only take the group 30 minutes because everyone will stay on task longer.

Punctuality is important but depending on the team may not be a requirement. Some team members may let a few minutes slide while others may get really upset about their groupmate wasting their time. Overall I recommend trying to be on time as much as possible.

5.4.5 Analysis
In-person meetings were better than online ones because it helped the team dynamic better. Having good team dynamics is important for future work in that team. Although they may not be as focused or on task all the time, you become more comfortable with your team and this improves your work output later. In general I believe it's important to have those moments of un-productivity with your team members so that you bond and truly become a team.

In-person meetings are productive when you want them to be and are vital to working in any group or team. Learning to communicate in a group setting is a skill that I will continue to develop and grow in my scholarly career and my work career.

Do I recommend it to be used again?: **Yes**

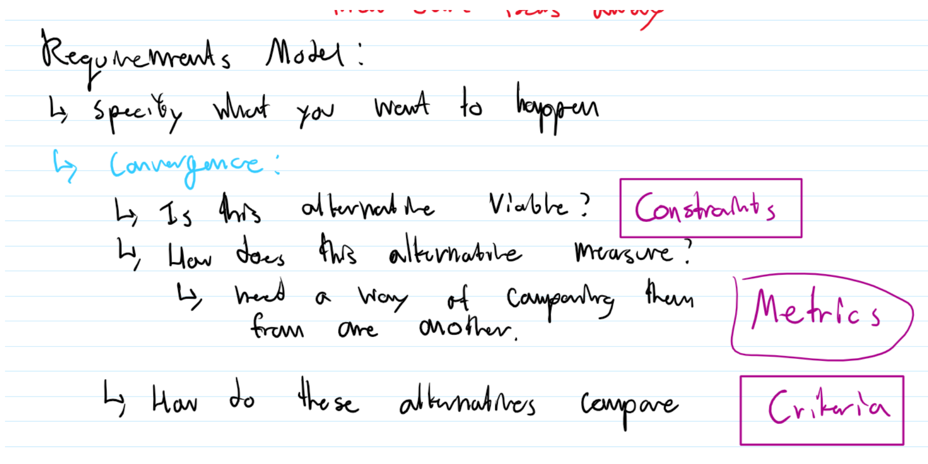
5.4.6 Modification
I don't think In-person meetings can be improved further in the context of engineering design. Since most meetings are work based meetings, you don't have to document every word someone says. The important thing is to take photos to show the process of your design.

6. Conceptual Tools

6.1 Requirements Model

6.1.1 Description

The *requirements model* is a **Framing** model designed to help quantify the characteristics of a possible solution to a problem. This model can be used in all sorts of applications from engineering design to which courses you should take in your upper years. Its high applicability is the reason I used it so much this year in both Praxis I and Praxis II.



My notes on the requirements model from Praxis I

The requirements model focuses on four things, in this order: Objectives, Metrics, Criteria, and Constraints. Each is important to the model and should be greatly integrated together.

Objectives are those phrases that one might find from stakeholder statements. They are the goals of a design or solution in nearly plain english. They should be the easiest to understand independently but on their own it's hard to measure whether or not you are completing the objective. An example may be, “Reduce damage done to guitar”.

Metrics are the characteristic and unit used to measure the objective. It is most helpful if it is in a numerical form so that it is easily comparable but qualitative metrics may be used when a number doesn’t capture the metric completely. The metric alone does not tell you whether a design is good or bad. Every objective must have a metric. An example of a metric is “Volume in meters cubed”

Criteria and Constraints are the qualifiers of the metric and show whether a design is good or bad. One does not necessarily need to have both a criteria and a constraint but every metric should have at least one.

Criteria describe how a metric can be compared. Often in phrases like, “More is better” or “Less is worse”, criteria are the heart of the requirements model as they quantify exactly how a design can be seen as better or as worse.

Constraints are hard cut offs for the metric that a design cannot fall under. If it does then the concept is not viable. Constraints will have a specific quantified value based on the metric associated with it and essentially return a binary result of “Is viable” or “Is not viable”. Constraints must be justified whether it be by researching a specific code or by logical steps. Arbitrarily choosing constraints is not wise as you may be overconstraining yourself.

6.1.2 Examples

The requirements model was used in both Praxis I and Praxis II. In Praxis I {3.1} we used it to frame how our smudge designs should be compared. This specific requirements model was not fully made by us but modified from the original.

Objective	Metric	Criteria	Constraint
1 Avoid smudging on paper	~~Time after writing for ink/lead not to smudge on paper (seconds) [17]~~	~~Less time is preferred~~	~~Must be less time than when using a standard pen and paper set-up. [17]~~
2 Avoid smudging on hands	~~Time required before smudging stops occurring on hands (seconds) [17]~~	~~Less time is preferred~~	~~Must be less time than when using a standard pen and paper set-up. [17]~~
3 Cost Efficient	Cost per month of usability (dollars)	Cheaper is better	~~Should be no more than $5 per month~~
4 Usable by both left and right handed students	Does it satisfy Objective 1 and Objective 2 for both left-handed students and right-handed students? (Yes/No)	-	Must be yes
5 Usable by different hand sizes	Range of hand circumferences accommodated (mm) [16]	Larger range is prefered	-
	Range of hand lengths (distance between the wrist and the tip of the middle finger) accommodated (mm) [16]	Larger range is preferred	-
6 Comfortable	Changed to Qualitative Test	More comfortable is preferred	-
7 Usable for different types of writing utensils	Number of writing utensils that satisfy Objective 1 and Objective 2	More utensils are preferred	-

Praxis I requirements model for Alpha [4]

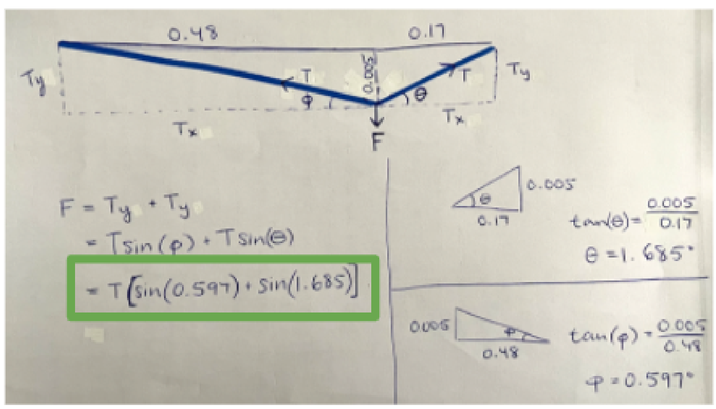
This requirements model was used to form the measurement matrices that helped with converging. The metrics directly tied into how the proxy tests were conducted and the criteria was used to compare the different ideas.

For Praxis II {3.3}, my group and I changed the entire requirements model from the RFP as we believed a lot of it was either unnecessary or poorly researched. Our requirements model is directly tied to how we converged to one design.

Objective	Metric	Criteria	Constraint	
		Primary Objectives:		Force on string
Minimize strain on fretting hand	Force to press down on a string (N)	Less force is better	Less than 6.05 N (based on tension calculations) Current force required to press down on string)	
Authentic to guitar playing	Qualitative Scale out of 8	Higher number out of 8 is better		Authenticity
Allow play of common chords	Number of chords able to be played	More chords is better	Must have the following chords: - Tonic - Subdominant (IV) - Dominant (V)	Diatonic Chords
Allow play in common keys	Number of music keys that can be played in	More keys is better	Must have the following keys: - C major - A minor - G major - E minor - Eb major - C minor - F major - D minor	Tonic Keys

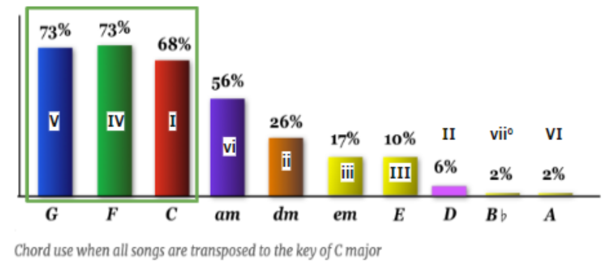
Praxis II Requirements model from Evidence Folder [1]

For this requirements model, justifying the constraints was an important process since we wanted to make a device that could at the very minimum play basic pop songs. Chord research was done to create the constraint around diatonic chords, and string tension calculations were done to find the force required to press down on a string.



Sample calculation for force to press down on a string [1]

Justification of "Play Common Chords" Objective



1300 pop songs transposed to C major were analyzed and relative frequency of diatonic chords was measured. Dominant, subdominant and tonic were the most played chords, and are therefore constrained in the requirements model.

Chord research to justify constraint [1]

6.1.3 Analysis

The requirements model is vitally important for framing a problem, as shown by the fact that it was used in both projects. In both instances the requirements model was used beyond just framing the problem, serving as the foundation behind the converging process.

In terms of how I and my groups used this model in our work, I think that the biggest mistep was not using codes to justify constraints or to select metrics. That is definitely something I will need to work on in future engineering design work.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

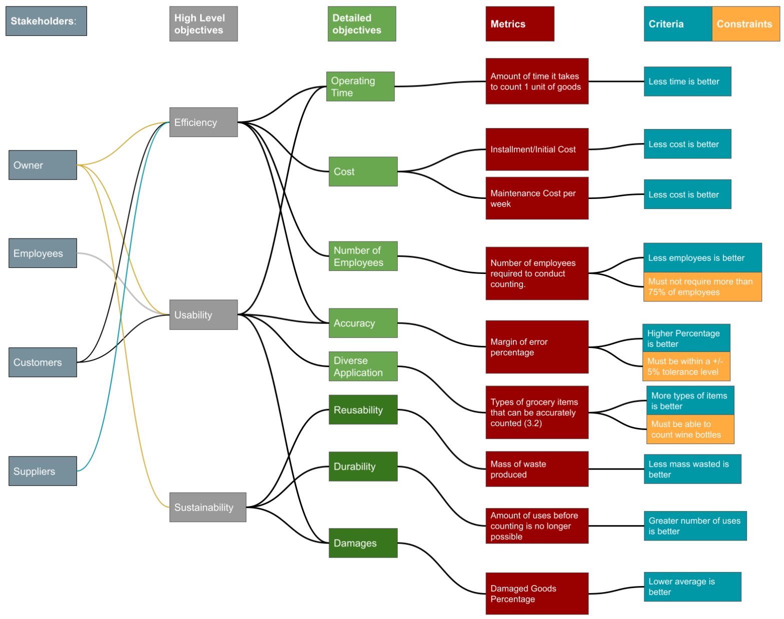
The requirements model is not too terribly difficult to implement at face value. However just because you intuitively understand how to measure your possible solutions, doesn't mean that the constraints or criteria are justified. The difficulty in implementation comes from the fact that you need to justify every idea on the model.

Do I recommend it to be used again?: Yes

6.1.4 Modifications

I think that a better design for the representations of the model could be developed to demonstrate the relationship between the four components better. The best version was the flowchart version from the

RFP design. Using similar representations helps audiences understand the nature of the requirements model and how it is all connected.

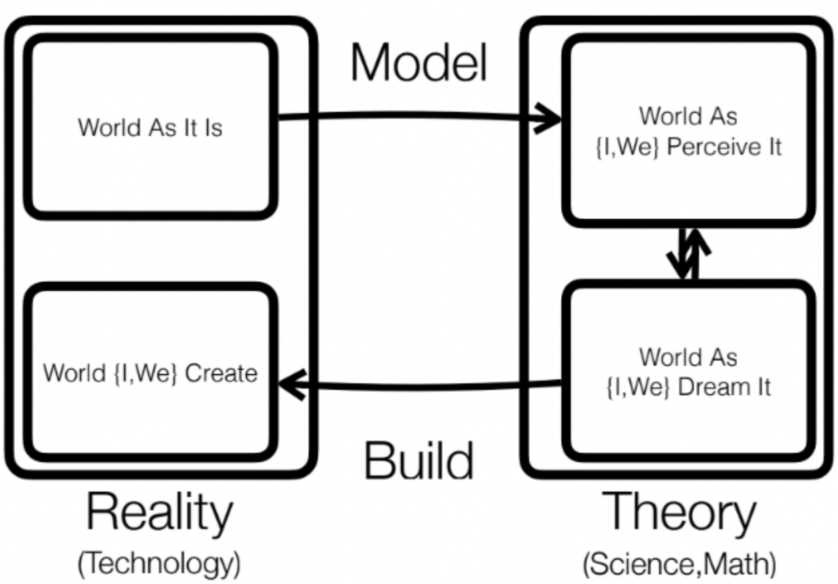


Flow chart representation of my Praxis II team's RFP requirements model

6.2 Hoover Dam Model

<u>6.2.1 Description</u>

The *hoover dam model* is a model that describes the difference between perception and reality in regards to engineering. It specifically illustrates how we create the reality around us from perceiving it first and then dreaming about what it could be. All four ideas are separate even though to our brain, they might initially seem the same.



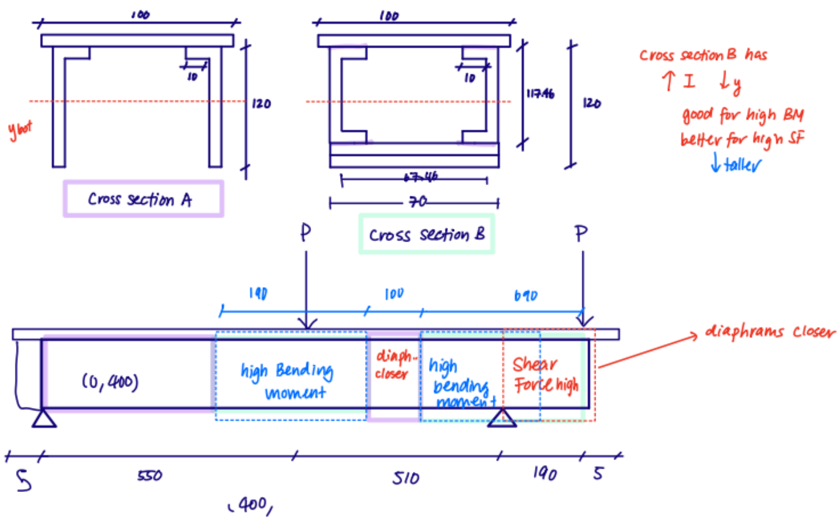
Hoover dam model from lecture slides [2]

The model describes how we must first perceive the world and dream it before we create it. The world as we perceive and the world as we dream fall under this theoretical space of science and math where we can explain every natural phenomena and everything is simple enough for our scientific models. This however is not the world as it actually is.

Using this model involves understanding that although math and science is complex enough to represent the world, it isn't always going to be completely accurate. Its using theory and science but allowing for errors or some unexplained phenomena to change the outcome you thought would happen.

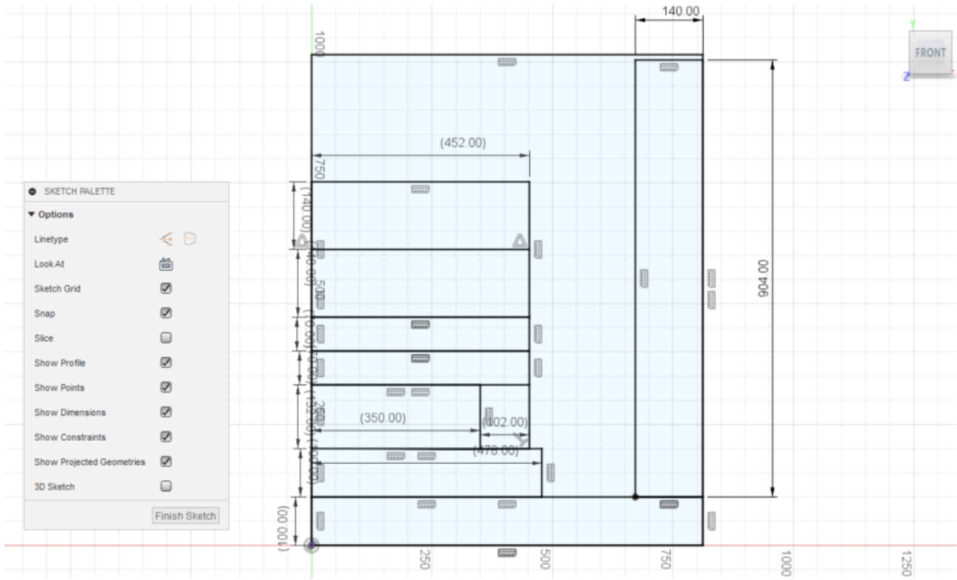
6.2.2 Examples

My bridge group used this model in order to build our bridge {3.2}. When we started out designing the bridge, we started with sketches of possible cross-section designs based on what we saw in previous years. Our perception of previous bridges influenced the world we dreamt for our own bridge.



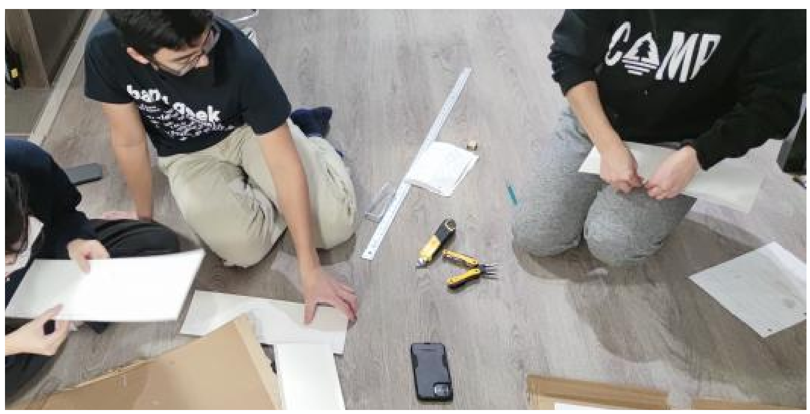
Initial sketches of bridge as drawn by Yina [3]

These sketches were not enough however to actually start construction so we pushed the world we dreamt into a more realistic world with limited resources and made a plan for how the bridge parts would be cut from the matboard.



Plan for how to cut Matboard [3]

Now that we had the plan to cut the Matboard and the plan of how the bridge would be put together, we were able to begin construction and start creating a world formed by us.



Cutting the Matboard [3]

Constructing the bridge [3]

Because of things like construction errors, the bridge we dreamt was not necessarily the same as the bridge we created but it was pretty similar. Knowing this, we knew that the bridge might not survive up to its theoretical limit, so we set our expectations lower than expected.

6.2.3 Analysis

This model is a great reminder of how what we engineer cannot fully be described by math and science calculations. During the construction process, we had many errors and mishaps that we had to let go of. The bridge wasn't exactly as we had envisioned it.

However the main ideas of the design were still there as the bridge was only shy 6 N of its theoretical limit which means the math and science was pretty accurate to our bridge.

Planning your theoretical plan before starting was very helpful for the project and should be done in all design based projects, even if the understanding that it won't be perfect is there.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

I do believe the bridge project could've been done without this model and without making the theoretical numbers and sketches first. However without the world as we dreamt, I don't think we would've been nearly as successful in the testing.

Do I recommend it to be used again?: **Yes**

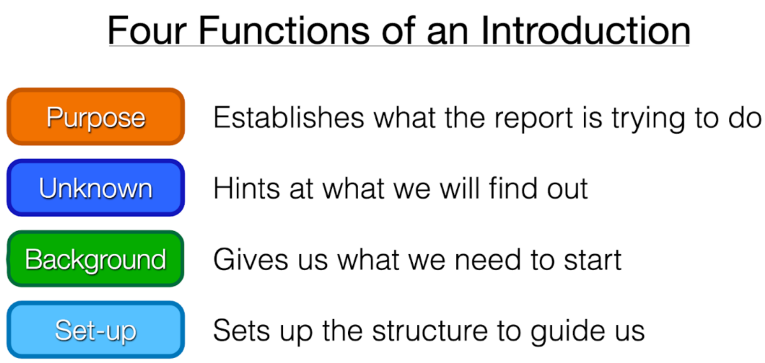
6.2.4 Modifications

More emphasis should be made in this model about what the differences are between reality and theory, beyond just the fact that theory is just perception. There are some things in the world we cannot account for in our calculations and those forces may be the reason a design passes or fails.

6.3 PUBS Model

6.3.1 Description

The PUBS model is an acronym designed to help create good introductions to engineering texts. Each letter in the acronym describes a theme that the introduction must cover.



PUBS slide from Praxis I [2]

As shown in the image above, P represents the purpose of the document and describes what is the main goal or purpose of the document. U represents the unknown or the information that will be revealed in the document. B represents the background information that needs to be given so that the reader can understand what is happening. S stands for the set up, which helps create the structure that will guide us through the document.

6.3.2 Examples

During Praxis I, each strand analysis was a small writing assignment for reflecting on what was done in the particular strand. The introduction to each of those documents was written with PUBS in mind.

Analysis Of Idea Generating Strategies Used In The Diverging Process

The most important part of the Diverging process is generating ideas that will solve or fulfill the requirements of the design brief. When the team generates ideas, everyone should be included so that every voice is heard and everyone has a stake in the overall project. This report will analyze the actions done by myself and the members of my team to include everyone in this process.

Diverging Strand analysis introduction [8]

This diverging strand analysis reveals the purpose in the phrase, "This report will analyze the actions…", sets up the background in "The most important part of the diverging process…" and sets up the unknown by referring to the actions that will be later described.

Frame Strand Analysis

Introduction:

The three strands of Praxis are vitally important in engineering work, especially when working in a team. The framing process involves deciding the characteristics of the 'splartz'. Without a thorough framing process, one could not do the next two strands, as the requirements and objectives are major aspects of any further process.

The subject of this paper is the framing process conducted by our praxis group as we framed a possible method of cleaning conveyor belts in grocery stores. This analysis will outline what the group did during the framing process, analyze what may have gone wrong, and then give possible solutions to problems addressed. Specifically, this will address the Stakeholder selection and objective creation and the overall process in the creation of the Design Brief.

Framing Strand analysis introduction [7]

This wordier introduction shows the purpose at the start of the second paragraph, sets up the structure in the next sentence, and paints the background in the first paragraph. The unknown is not explicitly shown.

6.3.3 Analysis

Both examples are poor representations of the PUBS model, missing things or being really way too long. They don't really highlight the main ideas of the introduction.

This happens because I don't believe in introductions like this. I have found that the best introductions are the ones that introduce you to a topic and give enough information for you to read and understand the rest of the sections. While PUBS has merit in its emphasis on purpose, I think that focusing on set up and unknown is unnecessary for an introduction. The introduction should paint the background of the paper and then state the purpose of the entire document.

This conflicting idea of introduction is the main reason why I wouldn't use the PUBS model in the future. It also is a lot of effort to think about the best way to answer these four ideas.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

I think there are other models for introductions out there that I could possibly use instead of this. One that I would like better. Because of this, I don't think I should use this tool again.

Do I recommend it to be used again?: **No**

6.3.4 Modifications

As stated above, I don't think the set up or unknown is necessary for an introduction. The purpose and background should be the core focus of an introduction as it is meant to preface and frame the rest of the document.

7. Representation Tools

7.1 Prototypes

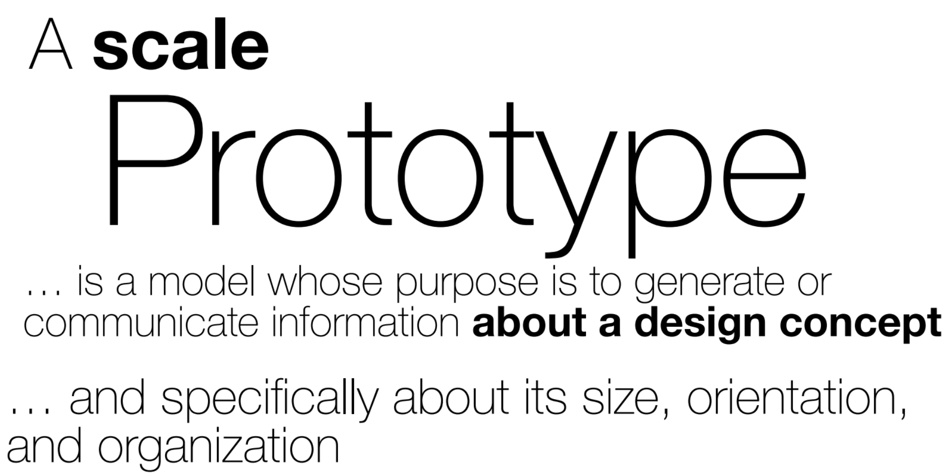
Prototypes are the most important representation tool an engineer has. They are the best way to convey information from size, functionality, and purpose. You can't really say you are designing a product unless you have a prototype for it. Prototypes don't have to be the fully functioning type you see in movies and industry presentations. Other prototypes exist that help convey the information you need to show.

For this handbook I will highlight the three prototypes that I used throughout this year to represent my and my group's ideas for our engineering projects: Scale Prototypes, Math Prototypes, and Functional Prototypes. These prototypes focus on different aspects of a concept but each one helps communicate a concept to someone else, whether it be a member of the group or an outside viewer.

7.1 A. Scale Prototype

7.1.1 Description

A *scale prototype* is a prototype that represents a design concept's size and how it is organized. The scale prototype helps viewers visualize the concept. The scale prototype can also help see whether the size is appropriate for the concept. For example with our guitar prototype, we used our scale prototype to help represent the orientation of the components of the concept, but also for us to try carrying and see if it is the correct size for a guitar.



Scale prototype slide from Praxis I Lecture [2]

The scale prototype can be used to generate ideas of how a concept should be orientated and how all the components would fit together. By developing the prototype, the designer will learn about problems surrounding location and size and be able to highlight and hopefully solve them.

7.1.2 Examples

In Praxis II, for the accessible guitar opportunity, my colleague Nadia created a scale prototype of our digital guitar concept.

Scale Prototype of digital guitar created by Nadia

This prototype allowed us to visualize how the different components of the digital guitar would interact, from the tactile sensors at the frets, to the strain sensors by the bridge. For presentation purposes, it allowed us to communicate the fact that our strings were weaker by having those exact weaker strings, and later on helped us show the tactile sensor's functionality when we combined it with a circuit.

7.1.3. Analysis

I think the scale prototype used in our Praxis II project was useful to begin with, but only became really useful once paired with the two functional parts: the low tension strings and the fret sensors. Combined the prototype really took shape and helped explain the concept without needing a lot of words.

A scale prototype on its own is only good for helping an outside viewer visualize the concept but once you begin attaching functional parts to it, then it does a lot more to describe the concept. A big theme of Praxis was "Prototype the most unbelievable thing" and most of the time the most unbelievable thing won't be how big the concept is, or how the components are orientated. In earlier stages it might be useful to scale ideas, but once you're in detailed design decisions, I think that you need functional parts.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

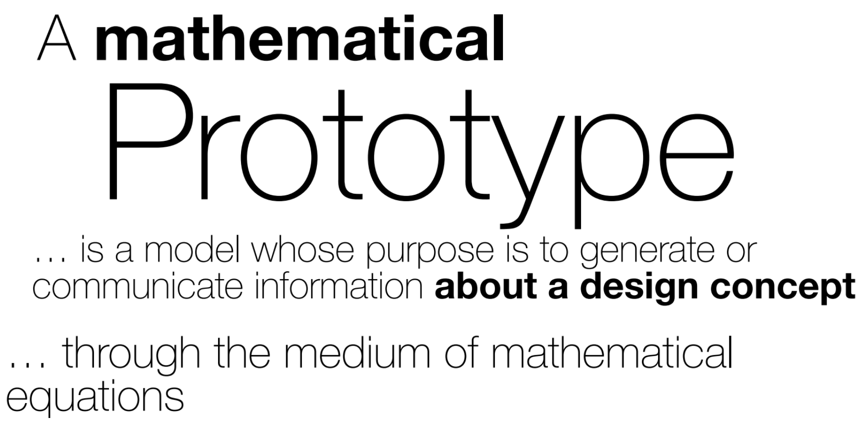
In terms of implementation, the scale prototype has a variable implementation difficulty. The digital guitar was made out of wood and required Nadia to buy some materials from a hardware store and cut the wood with power tools. Other scale prototypes can be made just out of cardboard and paper. For a good prototype I think that it should be made out of a material like wood or metal and that means it will be difficult to make if you don't have the knowledge or resources.

At the bare minimum the scale prototype is necessary for any concept. A good visual prototype helps illustrate the core components of the concept. In future design work, I think a scale prototype will be necessary to explain concepts and ideas.

Do I recommend it to be used again?: **Yes**

7.1.4 Modifications
Since scale prototypes are pretty unique I don't have any modifications that you can universally apply to all. I strongly recommend however that you develop any scale model further to become some form of functional prototype to help explain more things than just size and orientation.

7.1 B. Math Prototype
7.1.5 Description
A *mathematical prototype* is used to convey how science and math interact with a design concept. It can be used to prove feasibility or describe the behavior of a concept. Mathematical prototypes shouldn't be used to describe a concept directly as complicated math usually isn't digestible by an audience. Instead the information should be translated into a medium that's easily explained.



Mathematical prototype slide from Praxis I Lecture [2]

7.1.6 Examples
In the CIV102 Matboard bridge project {3.2}, we used math to calculate whether or not our bridge would fall under the applied load. This information helped us predict what would happen when we tested our bridge. Based on our calculations, the bridge would break at 1286 N and when we tested it in the lab, it lasted until 1280 N. So the calculations helped us accurately predict the behavior of our bridge.

Function:

```
function [ ShearBuckle ] = VBuck( I, t, b, height, E, mu, y, a, Qcent )
% Calculates the Shear Buckle capacity at every x value

    %pi
    pi = 355/113; %Pi approximation

    for i = 1:length(I)
        ShearBuckle(i) = ((5*E*pi^2)/(12*(1-mu^2))) * ((t(i)/height(i))^2 + (t(i)/a(i))^2);
    end

end
```

Sample Call:

```
VBuck(415.684*10^3, 1.2700, 2.5400, 75, 4000, 0.2, 41.7018, 550, 6248.5)
```

Code Result:

```
ans = 5.0045
```

Hand Calculation:

$$\sigma = \frac{5\pi^2 E}{12(1-\mu^2)}\left(\left(\frac{t}{h}\right)^2 + \left(\frac{t}{a}\right)^2\right)$$

$$= \frac{5\pi^2(4000\ MPa)}{12(1-0.2^2)}\left(\left(\frac{1.27\ mm}{75\ mm}\right)^2 + \left(\frac{1.27\ mm}{550\ mm}\right)^2\right)$$

$$= 5.004535044\ MPa$$

$$= 5.0045\ MPa$$

Sample calculation of bridge

7.1.7 Analysis

The mathematical prototype is a very powerful tool that when used accurately can help you understand your concept's feasibility or behavior. In the way we used it in the bridge, it helped us show that the bridge would pass the load requirements.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

Actually making the calculations was very difficult but making them was necessary to see if the bridge would fall. Although the math and physics were difficult, I went in knowing the concepts and understanding exactly what I had to calculate. I think that if I didn't and I had to figure that all out then implementing a math prototype would've been next to impossible.

Do I recommend it to be used again?: **Yes but only in specific contexts**

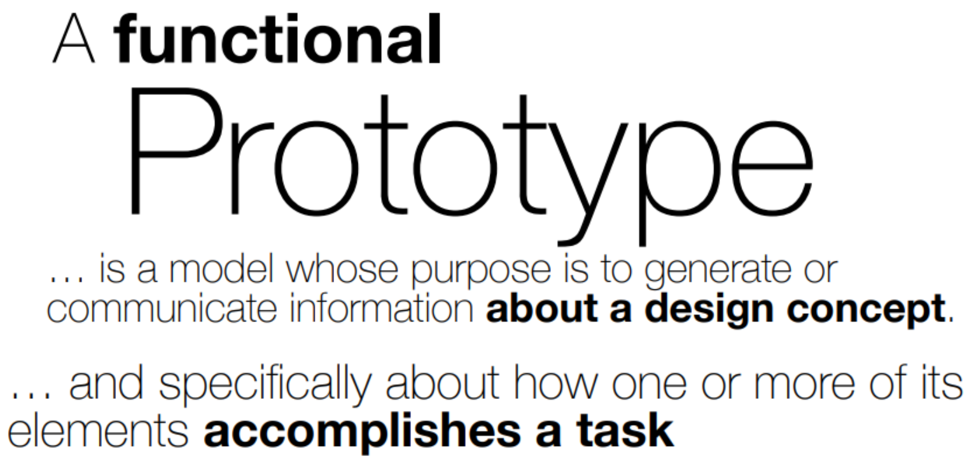
7.1.8 Modifications

In terms of using mathematical prototypes in design work, the main improvement I think is to make the calculations more clear for people that don't know how the formulae work. In the end people only really want to know the result of the calculations rather than how it all came together. In terms of our bridge project, I simply tell people I calculated it to fail at 1280 N and it failed at 1280 N.

7.1 C. Functional Prototype

7.1.9 Description

A *functional prototype* is a prototype that demonstrates one or more of the key functions of a solution or design. It is the prototype with the highest fidelity and use since nothing can explain an idea better than a device that actually does it. Functional prototypes are very important in engineering as they can serve as a proof-of-concept and immediately demonstrate the feasibility of a design.

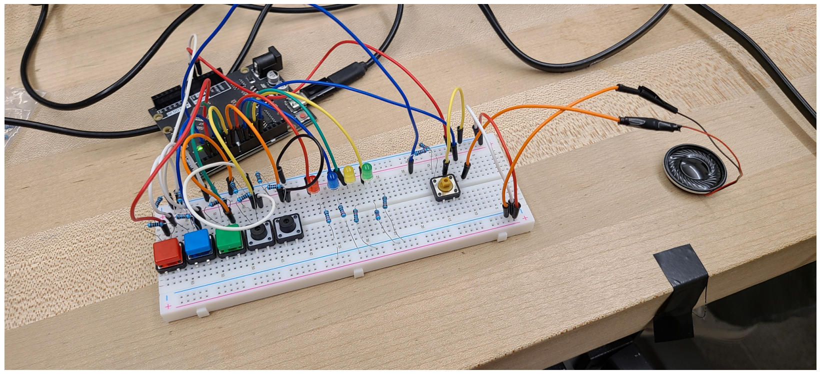


Functional prototype from Praxis I Lecture [2]

A functional prototype is focused on answering the question of how. How will your device accomplish the task? How is it possible for your device to do this? If the prototype can accomplice the task then it becomes really easy to see how the final concept could do it too. Functional prototypes are the best way to prove that your concept or design can work.

7.1.10 Examples

In Praxis II, for the accessible guitar opportunity {3.3}, I designed a circuit to prove the functionality of the sensors and how they would interact to produce sound. Although my group and I did not have access to the specific tactile and strain sensors we wanted to use for the full concept, I used buttons as proxy substitutes since the important thing was to demonstrate the sound generation.



Arduino circuit used to demonstrate sensor to speaker relationship

In the image above, the colorful buttons on the left proxied the fret sensors, while the brown button on the right proxied the strumming. The speaker on the right was where the sound came from. But interacting with the sensors just like how one would with the digital guitar concept, one could make the speaker output the corresponding note. This functional prototype was key in illustrating our digital guitar idea since it illustrates both how the sensors interact with each other, and the type of sound the guitar might make.

Later on for the *Showcase*, a second attachment was made, one that could be placed on our scale prototype of the digital guitar. This attachment contained buttons that could be pressed from underneath the strings, therefore demonstrating clearly the use of the sensors.

7.1.11 Analysis

The circuit functional prototype I created was very effective at proving the functionality of the digital guitar, especially once it was integrated with the other prototype. The ability to make sound was the most unbelievable part of the digital guitar and being able to proxy the effect with a functional prototype was a key component to our *Showcase* presentation.

In general the functional prototype is another necessary part of any design. It's one thing to say that your design would work. It's another to be able to prove it by having a similar device do the exact task you want your design to do. Functional prototypes could also be used to measure and evaluate certain factors on a design. For example, designing the mapping of the sensors to the note revealed that a case needed to be considered where multiple sensors of the same fret were being activated. When that happens multiple notes would play while on a regular guitar, only one note can be heard.

The only difficulty with the functional prototype comes from the fact that the prototype has to work. Sometimes the skill level required to make a functional prototype is too high for an engineering student to do. In those cases more research and a different type of prototype has to be used to prove the concept.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve anything (1)	It was good that it was used (2)	Was extremely necessary to be used (3)

Despite the difficulty in implementing a functional prototype, I do believe it is necessary to have a functional prototype prove the most unbelievable part of any design. Since in engineering we make plenty of claims that a device will work, having a physical device may be needed to justify those statements.

Do I recommend it to be used again?: Yes

7.1.12 Modifications

If a functional prototype is impossible at one's current skill level, I think that it first should be asked whether the design is too complex. Simplifying a design is always important but it is most important for creating functional designs, since functional designs should eventually become the backbone of your entire concept. If you can't make a functional design of the concept then the concept is effectively stuck at that level until it can be done. No amount of further planning or next steps will take away from the fact that you cannot build the concept.

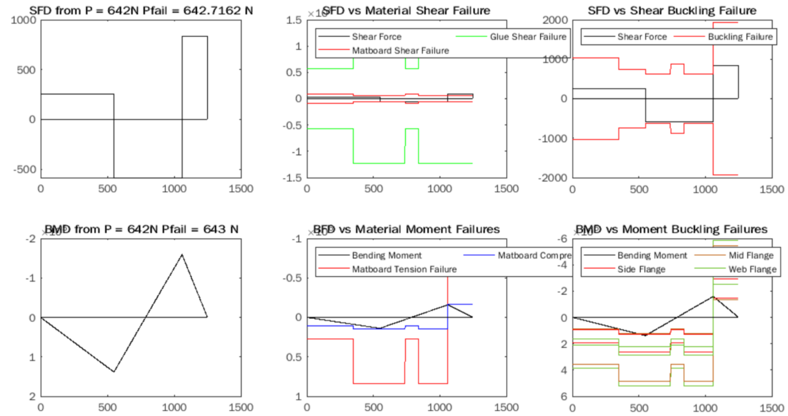
7.2 Matlab

7.2.1 Description

Matlab is a programming language designed for calculations and data representation. I learned about it in ESC103 but didn't really use it until the bridge project in CIV102 {3.2}. Using Matlab requires knowledge about the programming language that I cannot teach in this handbook but resources can be found online to learn the language. The main purpose of it being in the handbook is to explore how it was used in the CIV102 project and how it can be used in future projects.

7.2.2 Examples

In the CIV102 Bridge project, Matlab was used to do all the calculations on the bridge since doing them all by hand would've been tedious and time-consuming. There are two many aspects to the implementation of Matlab. The first is specifically the coding aspects and how one would translate the values from the bridge in a way for the program to manipulate. The second is representing all that information in graphs so that it is clear what the calculations are actually doing. While the coding aspects of the project are outside the scope of the handbook, the graphical representations will be described.



Matlab graphs from bridge projects. Please note that the failure force of 643N is half of the actual failure force.

Using Matlab I showed a graphical representation of the calculations surrounding the bridge {see 7.1 B}. This was used to demonstrate that the bridge would fail at 1280N and fail due to a plate buckle failure. These specific graphs were put in the bridge report to illustrate those two pieces of information.

7.2.3. Analysis

Matlab is a powerful tool that allows for both fast calculation and also good representation of those calculations. My code for the bridge project was accurate to +/- 6 N and I only had to do a few hand calculations. Presenting this data is also really simple because of the functions I designed to display the data. It is very customizable to whatever you need as long as you have the knowledge to design it.

```
function [ ShearBuckle ] = VBuck( I, t, b, height, E, mu, y, a, Qcent )
% Calculates the Shear Buckle capacity at every x value

    %pi
    pi = 355/113; %Pi approximation

    for i = 1:length(I)
        ShearBuckle(i) = ((5*E*pi^2)/(12*(1-mu^2))) * ((t(i)/height(i))^2 + (t(i)/a(i))^2);
    end

end
```

Sample of a function I designed using Matlab to calculate the shear buckle stress

The biggest flaw in it was the fact that I didn't know enough about Matlab to program what I wanted quickly. I spent a lot of time in trial and error trying different things until I got the program just right. In the future I think a better understanding of the programming is required before I try to use Matlab for engineering design again, or else I might once again spend too much time trying to code it.

Ease of use:	Was extremely difficult to implement (1)	Implemented with some difficulty (2)	Easy to implement (3)
Quality of outcome:	Didn't improve	It was good that it was	Was extremely

	anything (1)	used (2)	necessary to be used (3)

That being said, I think it would've taken longer to do all the hand calculations. So I think that for the specific project it was necessary. For similar projects requiring repetitive calculation I think that it should be used as well, or at least another computer based coding method of doing the calculations so that you are accurate and time efficient.

Do I recommend it to be used again?: **Yes in specific circumstances**

7.2.4 Modifications

As stated above the biggest modification is to learn more about the programming language before trying to make a complex program using it. The learning curve was the biggest time sink of the entire process.

8. Conclusion

Reflecting on my first year experience and what I have learned from this year has been an interesting task. I really hope that everything that I have stated here does not get forgotten and that I do indeed use this handbook in my future.

More important however is my own personal growth and reflecting on that. One of the first things Prof. Allan Kuan told us in our first lecture of CIV102 that “By the end of this year you will be very different people.” He then followed it up with “Look to your left and look to your right. One of you is not staying in this program.” These two facts have carried me through this year and will continue to carry me for as long as I remain in the engisci program. I really am a different person than when I was coming out of highschool. Not only have I been humbled by the course work but I’ve also seen and experienced so much more. I have created RFPs and solved real engineering problems. Within the context of a classroom setting of course.

I can only hope for what the future has in store for me. I can only hope that the lessons I have learned in these courses have prepared me enough for second year. If they haven’t then I guess I got some more learning to do. Learning that I can hopefully do quickly.

In the end the only thing I can do is do my best with the time and resources I have. As long as I keep doing that, and continue learning from these experiences, I can only go more and more up.

10. Embedded Extracts

10.1 Information and Image Sources

[1] Praxis II Evidence Folder || Nadia, Lisa, Malek, and Joaquin (Link)

[2] Praxis I and Praxis II Lecture Slides || Prof. Kinnear, Prof. Irish, and Prof. Sheridan

[3] CIV 102 Course Project Report || Yina, Grace, and Joaquin (Link)

[4] Praxis I Alpha Presentation || Kevin, Isabelle, Paige, and Joaquin (Link)

[5] Praxis I Design Crit Presentation || Kevin, Isabelle, Paige, and Joaquin (Link)

[6] 27 Creativity Tools for Divergent and Convergent Thinking pdf || Praxis I and Praxis II resources. (Link)

[7] Framing Strand Analysis || Joaquin (Link)

[8] Diverging Strand Analysis || Joaquin (Link)