Engineering Design Handbook

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What to Expect?

This handbook consists of my design process and design work from my first year of engineering. I have also included important tools, models and frameworks which I used during the design process. The first section of the handbook will allow you to better understand my position regarding engineering and you will be able to see 3 personal engineering design products that I have worked on. The second section shows an in-depth analysis of my personalized engineering design process, which is based on my experiences and values. Lastly, I will share my experience using various tools and frameworks. Throughout the handbook you will see embedded checklists, charts, images and tips where appropriate. The handbook is organized in a manner where everything related to a topic is found in one place, such as important links, charts and images in order to increase the useability.The main purpose of this handbook is to be a personal reference for future design work.

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About Me

I am an engineering student who is passionate about technology and learning about how “things” work. What really gravitated me to this field was the ability to integrate my passion for technology and help improve the quality of life of people by applying my knowledge to create impactful products. Over the past year I have tried to integrate my personal values in my design work, learned more about myself and developed important soft skills.

I am a big fan of the theory of “ the marketplace of ideas”, which entails that under the correct environment, the best ideas come to the top. I have tried to apply this theory to my design work by creating an inclusive team environment where members are not afraid to share their ideas and have respectful discourse. This has intern allowed the fruition of unique ideas and important rebuttals while comparing designs. One simple way I try to create an inclusive environment is by asking less represented/spoken members about their opinion on a topic, which has become a key component of my design process.

Throughout this year, I have really enjoyed the journey of seeing my engineering products from start to finish. This has allowed me to gain a bit of interest in roles such as project management and work for smaller companies where I would have the opportunity to oversee a project from start to finish. I have also learned to mitigate risk while working on projects by asking clarifying questions to various stakeholders, making fewer assumptions and integrating various tools and frameworks in the process. Furthermore, I had the privilege of working with talented team members, from whom I was able to learn various skills including using 3D modelling tools. These skills and lessons will be helpful for future projects.

Through my design work, I am not only trying to solve problems, but also developing my own skills. A major skill that I have developed over the past is my ability to work effectively in a team, stay organized and work hard. According to my team members I had a “ worth ethic and your ability to get things done on time”, and I should “continue to show amazing teamwork skills"(TELS 2). In a design team it is vital for me to ensure deadlines are met, group members feel valued and ensure I give my time and energy to ensure the best design work comes out of the process.

Overall, I would consider myself as a passionate engineering student who is always willing to learn and leverage his strengths to maximize the productivity of the team. Although, I do catch myself sometimes falling in the trap of confirmation bias, where I gather information in a manner which supports my existing ideas, rather than taking a holistic point of view. I have tried to reduce this bias by intentionally researching opposing points to my idea, and inviting team members to challenge me as well.

1. Personal Engineering Design Products

1.1 CIV 102 Matboard Bridge Design

Project Background/Requirements

My team(Chris Lansdale, Grace Gloade, Navin Vanderwert) and I were responsible for designing a conceptual bridge using which could span 950mm and support two 600N point loads. One of the biggest constraints to the project was that we only had 1016mm by 813mm of cardboard to work with. Throughout the project, my team applied the knowledge that we learned in CIV 102 regarding the dynamics of a bridge. Overall, the final design(Figure 1) was successful due to the implementation of specific tools/techniques.

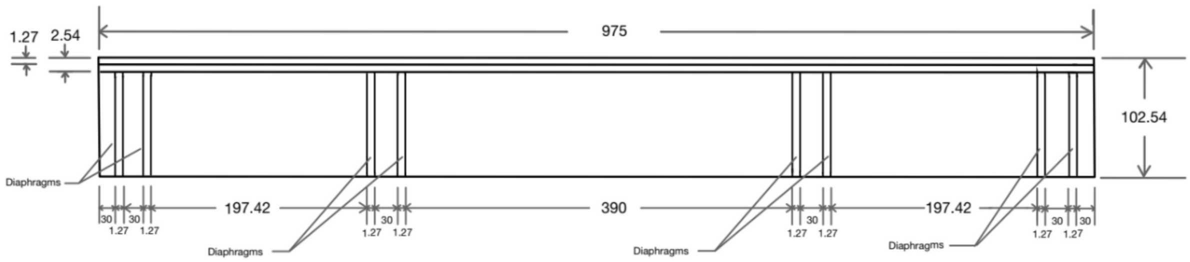


Figure 1: Longitudinal Cross Section View of Final Design

Application of Iterative Design Process

My group wanted to create the "most" safe design. This would mean the bridge would be able to carry loads above the required load. Therefore, we tried to optimize the cross section of the bridge. In our **first iteration** (Figure 2) we created a design which could not support the given load. Hence, in our **second iteration,** we had to alter our design, which was done by making the design more thicker, as seen in Figure 3. This new design passed all the constraints, but we still had material left over, and decided to optimize the cross section even further in order for the bridge to be more safe. Finally through our **third iteration** we were able to come up with a cross section which could support much more weight, leading to our final design (Figure 4). The iterations helped us modify and improve subliminary design to create the "best" final design.

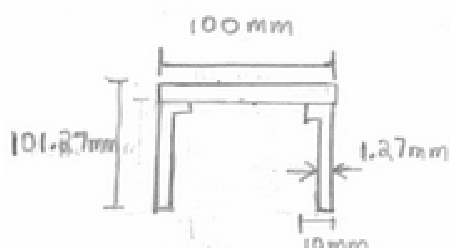


Figure 2: Failed Design

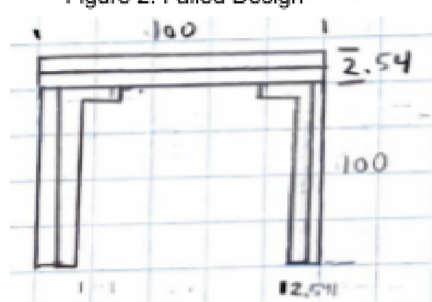


Figure 3: Unoptimized Design (meets constraints)

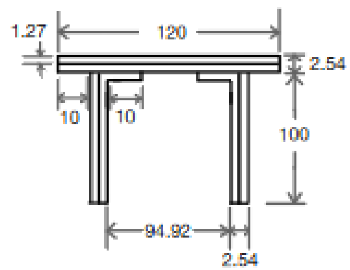


Figure 4: Final Design

Tools/Representations Used

MATLAB

My team used MATLAB inorder to calculate forces and to make the calculation process more **efficient** and **accurate**. You are able to easily change variables and do not have to re-calculate the formulas. Figure 5 shows a snippet of our script.

Flexural Failure:

```
ybot = h/2;
P1 = (6*I)/(45.675*ybot)
```

```
P1 = 1.6568e+03
```

Shear Failure:

```
b = 2*t2;
Q = 2*t2*(h/2 - t1 - t2)*(h/2 - t1 - t2)/2 ...
+ 2*t2*f*(h/2 - t1 - t2/2) + w*t1*(h/2 - t1/2);
P2 = (4*I*b)/(0.3909*Q)
```

```
P2 = 1.2146e+03
```

Glue Shear Failure:

```
b = 2*f;
Q = w*t1*(h/2 - t1/2);
P3 = (2*I*b)/(0.3909*Q)
```

Figure 5: Snippet of MATLAB Script

Sketches

A quick simple sketch allowed my group members to convey their ideas, and also quickly **visualize** any major flaws in an idea. A sketch, as seen in Figure 6 also enabled my team to do preliminary **calculations** by noting down important dimensions on the sketch.

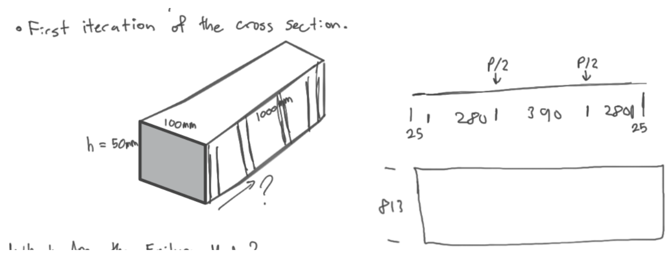


Figure 6: Cross Section Sketches

Engineering Drawings

Engineering drawings such as the ones shown in Figure 7 enabled the team to **clearly/accurately capture all geometric features** of the final design in a manner which a manufacturer can turn the design into a reality. The engineering drawing also showed **professionalism** and dedication of the team towards the project. The drawings could have been improved by adding a scale, so the reader can easily visualize proportions.

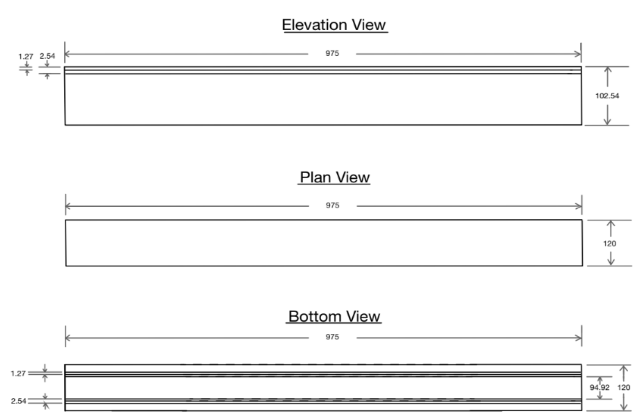


Figure 7: Engineering Drawings
(main contributor: Grace Gloade)

1.2 ESC101 Sheet Music Display Apparatus

Project Background/Requirements

My team(Armita Doost, Spencer Hofstes, Arielle Zhang,Jaden Bulteel) and I were responsible for brainstorming various unique solutions to this opportunity. The opportunity was to create a design which would help musicians to prevent the music sheets on their stands from flipping over due to the wind while performing. The design would also enable them to flip pages quickly(within 2 seconds) when necessary. I worked on two of the brainstormed ideas, and I will quickly go over the tools and process of how I reached to both of the designs

Design: Magnetized Stand

The magnetized stand is designed to withstand wind speeds up to 14 km/h with the usage of a magnetic back accompanied with magnets to hold the music sheets in place. This design contains these new additions and one major change to the traditional stand K&M 10065 Music Stand (K&M, 2020). The magnetic design includes a magnet handle to ensure ease and speed when flipping between pages. The musician will remove the magnet using the handle, flip the page normally and place the magnet back on the stand. The time it takes to conduct this action is below the recommended 2 seconds as limited steps are added into the regular page flipping procedure.

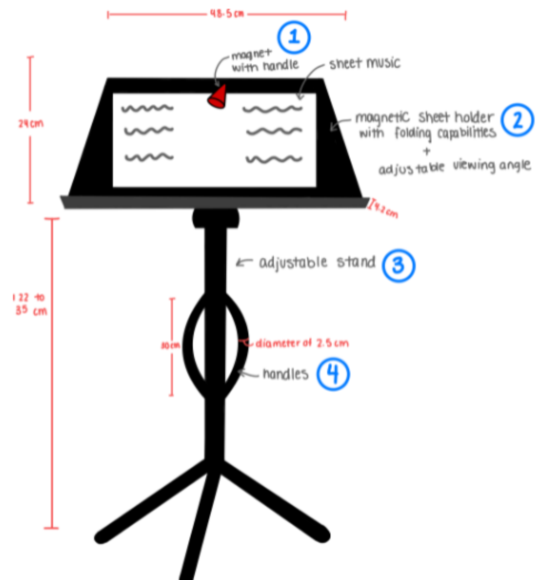


Figure 8: Cross Section Sketches

Application of SCAMPER for Magnetized Stand

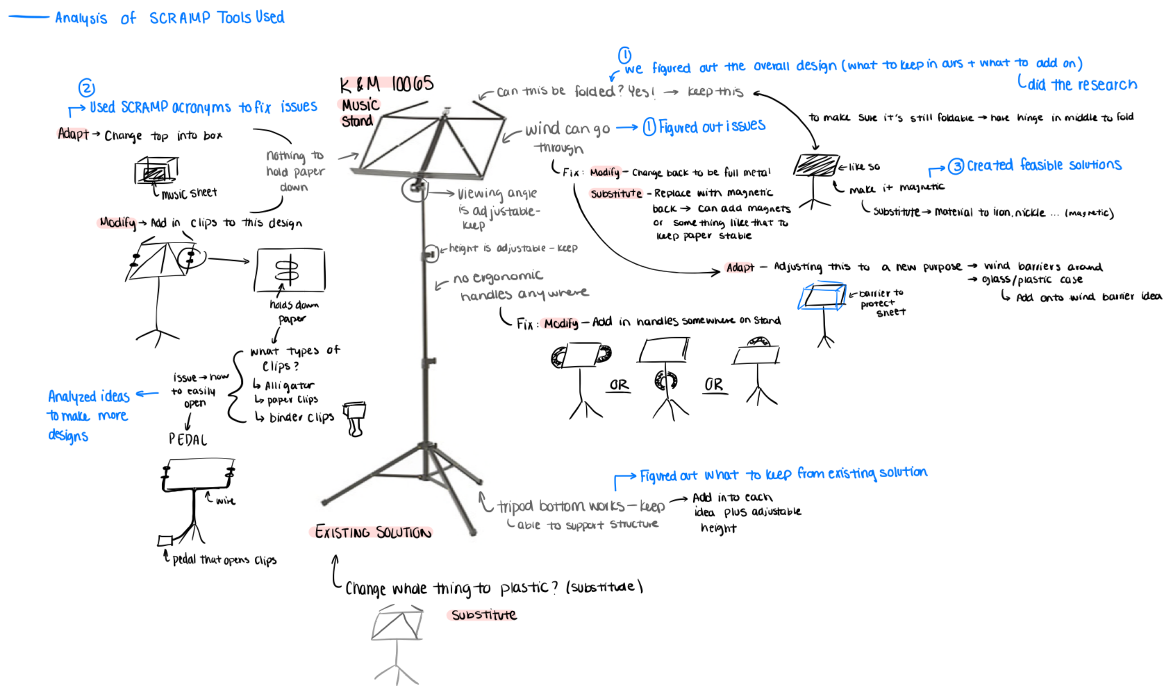


Figure 9: Scamper Outline Which Led to the Creation of Magnetized Stand

SCAMPER is a tool which helps in creating new designs out of existing designs by modification, substitution and other means.My team and I applied SCAMPER to a regular music stand(reference design), as seen in Figure 9.From previous divergence tools, we had gained enough information about the parts within the music stand that were causing unusability during high wind speeds. Therefore, we were able to break down the existing solution provided and understand the issues. From there, as can be seen in Figure 9, we used the specific acronyms to solve these issues. For example, we used “substitute” in order to replace the back of the original stand with a magnetized plate to make the stand magnetized. The idea generation from the tool allowed the team to think deeply and innovatively about solutions that would serve the needs of the stakeholders in the brief. It opened discussion within the group allowing for more perspectives and ideas to be integrated within the designs. Therefore, this tool not only supported the creation of the magnetized stand but helped to better understand the flaws of the reference design and develop other ideas to solve the issues presented in the brief.

1.3 ESC102 Assisted Zipper Tool

Project Background/Requirements

My team(John Wolf, Riddhiman Roy, Liam Bessey) and I were responsible for creating a product which would **make the process of zipping a jacket quicker and easier for individuals who lack fine motor skills**. My team decided to break down the process into two distinct functions (initial zipper alignment and pulling zipper up). We decided to create two different designs which would address each function individually. Our major requirements were to decrease the time of the process and reduce the amount of dexterity required to operate the product. Through this product we aimed to improve the quality of life of our stakeholder. Figure 10 shows the final two designs and Figure 11 shows the primary objectives of the opportunity.

Figure 10: Zipper Tool Aid Design

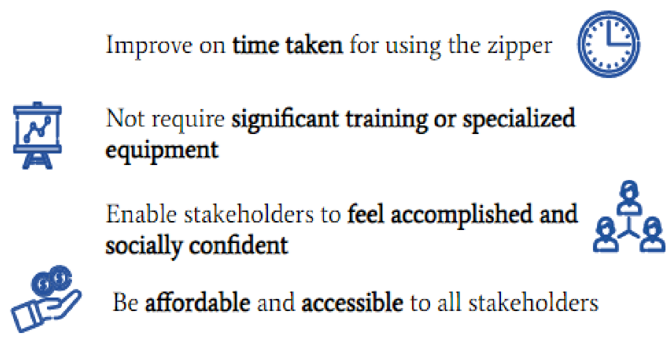


Figure 11: Primary Objectives

Main Tools Used to Create Design

The initial idea of the alignment aid tool came from the wishing tool (information about the wishing tool can be found on page 13). A group member said "I wish I do not have to align the zipper in the retaining box", as seen in Figure 12. I decided to bring this wish into a reality by developing the alignment tool. The alignment tool creates a larger external insertion slot to make the alignment process quicker to accomplish. I also decided to apply SCAMPER and magnified the size of the insertion slot to make it easier for users to align the tool. This tool was tested and through multiple rounds of iteration, it became the final design. Through the iterations, we added grip pads, changed the dimensions and shape. Creating a 3D printed prototype allowed my team to effectively test and support our claim that the product is usable. For more information about the prototyping process of this design, visit page 23.

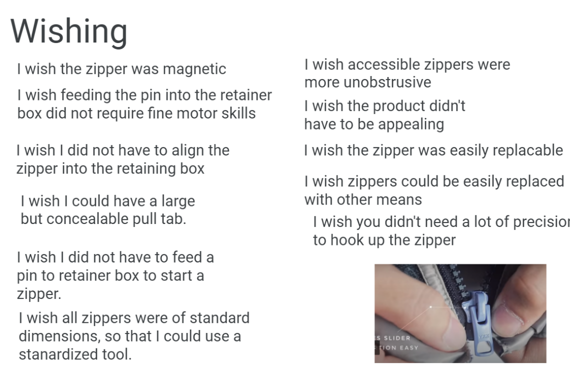


Figure 12: Wishing Tool

2. Personal Engineering Design Process (PEDP)

"An iterative decision-making algorithm/process which is used to find the solution to an opportunity which best meets the needs of the stakeholders."

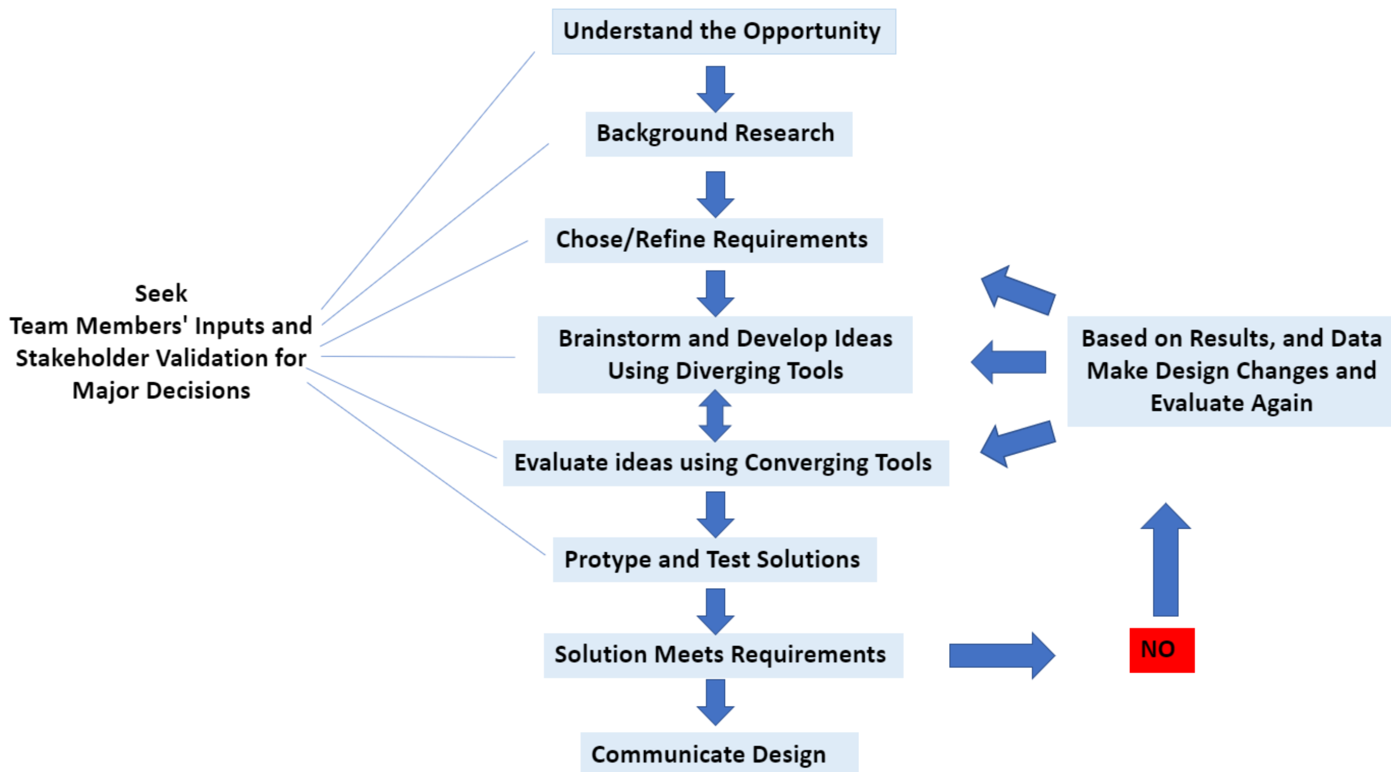


Figure 13: PEDP Flowchart

To better internalize the design process, think of the PEDP flowchart in Figure 13 as a dynamic programming **algorithm**. Essentially, you want to find the most **optimized** solution, which is achieved by a combination of solving sub-problems. These sub-problems are the various steps in the design process. You want to ensure that these steps are taken with **intention**, since if you do not complete them effectively, you may not achieve a solution which best meets the stakeholders' needs. Lastly, think about the design process as a while loop (**iterative process**), where the exit condition is that the solution meets the requirements and there is no room for improvement. You will have to go through a step multiple times to ensure you tried to make improvements to the original idea.

2.1 Framing

<u>Purpose</u>

Framing is the first 3 steps of the design process. You want to frame the opportunity in a way which **constricts/constrains potential solutions**, which can lead to a poor solution.

Understand the Opportunity

It is important to ensure that you and your team clearly **understand the experiences of the stakeholders** and how the stated opportunity would make an improvement. You can think of this step as understanding the **“bigger picture”** of the whole opportunity.

Background Research

Find **flaws** in reference designs, and do research to fill in gaps of **knowledge** regarding the opportunity. This may include, surveys, learning more about the stakeholders’ lived experiences through interviews, and scientific research for technical constraints/metrics. **A great resource for technical values pertaining to the human body is the MILT-STD handbook.**

Chose/Refine Requirements

In a real-world context, the primary stakeholder would have given some requirements regarding the opportunity. These requirements can be **refined** as you do more research based on data and facts. You may also want to **add** in additional requirements as you may see fit. Although, after all requirements have been finished, ensure you check with your stakeholders one final time. Constraints and criteria in the requirement should be generated based on higher level objectives. **More about the requirements model can be found on page 19.**

Common Pitfalls Experienced

- Used non credible sources for research, which later turned out to be false
- Made up unrelated metrics/criteria without ensuring if they related back to a higher objective
- Not ensuring each teammate had a similar understanding of the opportunity before moving on

Quick Framing Checklist

- [ ] Objectives/Criteria/Constraints are based on stakeholders’ needs
- [ ] Design team and primary stakeholder have the same understanding of the “problem”
- [ ] Flaws of reference designs are integrated into constraints/criteria
- [ ] Research is done to fill gaps in knowledge and create specific metrics/constraints/criteria

Here is an example of framing done for my team's Request for Proposal in Praxis 2. Key Feedback received for RFP pertaining to framing:

Strengths

- "well use of reference designs to identify flaws"
- " tabular format with numbered metrics/criteria/constraints were good"
- "healthy mix of quantitative and qualitative metrics (with the inclusion of usable rubrics)"

Improvements

- "more detailed analysis of stakeholder habits/experiences"

2.2 Diverging (Let the Creativity Flow)

Purpose

The goal of diverging is to ensure that you are able to develop **multiple unique solutions** to the opportunity. It is important to note that diverging may come after

Brainstorm and Develop Ideas Using Diverging Tools

In order to ensure that **unbiased**, and **unique** ideas are brainstormed, I used multiple diverging tools, which can be found in section 3(pg.13). Converging tools may also help gain insight on certain aspects of a design and diverge from then on.There may be a specific manner in which you want to diverge. For example, in the image to the right, my team diverged based upon each functional objective of our given opportunity. Another possible way to diverge could have been based on specific DFXs.

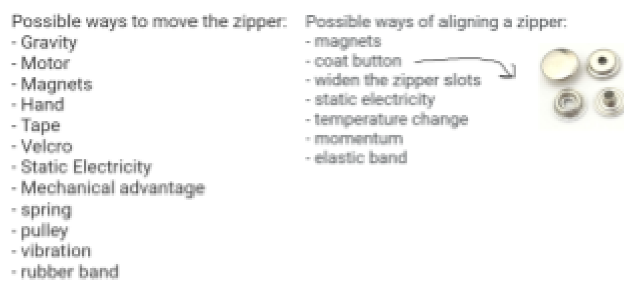


Figure 14: Praxis 2 T25's initial divergence process. Diverging based upon different primary functions and brainstorming different methods to fulfill each function.

Common Pitfalls Experienced

- Being **anchored** to a reference design(wishing tool can come in handy)
- **Converging** while diverging(can limit the ability to find unique solutions)
- Quickly shutting down ideas that are thought to be **"off the wall"**, which in the future could have been integrated into a different design

Quick Diverging Checklist

- [ ] Implemented **at least 2** different diverging tools for initial divergence
- [ ] If working in a team, ensured **everyone's** ideas were heard
- [ ] **Representing** ideas through a quick sketch, words or verbally

2.3 Converging

Purpose

The converging process allows one to converge from multiple designs to one or a set of potential designs based on how well each design meets the requirements.

Evaluate ideas using Converging Tools

There are multiple different ways to compare design ideas and narrow down to a specific set of designs. Depending on the stage of convergence you are at, you may decide to employ different tools, and how many designs to narrow down to. For initial convergence, I would have a larger set of designs to narrow down to, so you can test, and learn from the designs. **Beneficial converging tools can be found in section 3 (pg.13).**

Protype and Test Solutions

Prototyping is a great method to convey the most “**unbelievable part”** of the design to other teammates in a manner to convince them of your idea. Also, testing is a great tool to **learn** more about your designs, generate useful **data** and use the data to make **comparisons** between different designs. **More about prototyping can be found on page 23 and more about testing can be found on page 18.**

Common Pitfalls Experienced

- Getting rid of certain ideas **too early** in the converging process can hinder your ability to find integrated solutions in the future
- “Wasting” time trying to prototype a very detailed high fidelity prototype, rather than slowly building towards a high fidelity prototype while gaining **validation/verification** from colleagues and tests

Quick Converging Checklist

- [ ] Implemented **at least 2** different converging tools
- [ ] Converged upon designs meet the **constraints**
- [ ] Convergence is done through a rigorous process, where **requirements** are taken into account
- [ ] Designs are tested under **uniform conditions**

2.4 The Human Component

Seek
Team Members' Inputs and
Stakeholder Validation for
Major Decisions

Purpose

While going through the design process, you will be interacting with other people, such as **teammates and** your **primary stakeholder.** Potentially in a real engineering project, you would be interacting with people from **multidisciplinaires**, such as finance or manufacturing. Therefore, I decided to include the need to **intentionally** interact with your team and stakeholders at every stage of the design process. I have personally found human interactions to be a vital part of creating an appropriate design.

Seeking Team Members' Inputs

Inclusivity remains to be a trait that I highly value while working in teams, as each individual has a unique perspective and this impacts the team's ability to find unique solutions. Try to create an **inclusive environment** by asking less represented members of the team of their opinion. Also, employing tools such as wishing, can be impactful in creating an inclusive environment. More about the wishing tool can be found on page 13. Another benefit of asking a members' input is to ensure that the team "is on the same page" and there isn't a team member who doesn't know what the rest of the members are currently discussing or working on.

Seeking Stakeholder Validation

Whenever you feel like there is a bit of confusion regarding understanding the opportunity or making a contentious design decision, it is always safe to consult your primary stakeholder. For example, during the final project of Praxis 2, my team was a bit confused regarding some aspects of the opportunity. Therefore, we decided to contact the stakeholder through our shepherd (Kenny), as seen in the image below. For example, we weren't sure how the term "adaptive clothing" was interpreted by our stakeholder. Hence, we had to **validate** if a potential design met the adaptive metric. One way we could have more **effectively communicated** was by sending a sketch or visual image of the design. Nonetheless, this interaction with the stakeholder **reduced the risk** of my team creating a poor design. Figure 15 shows the interaction.

Hi Kenny,

Could you forward the following questions to Dr. Kerr please:

Do you have any limitations/challenges with arm and wrist motions?

Do you have trouble with pinching and pulling motions?

Would you consider an apparatus that attaches to the entire zipper line for your choice of adaptive clothing? Why or why not?

Figure 15: Asking important questions to our stakeholder regarding the final opportunity in Praxis 2.

2.5 Iteration

Purpose

The design process is not a linear process, but rather a cyclic process. You will have to converge and diverge multiple times to make adjustments to designs based on testing or due to the implementation of a tool such as scamper, where multiple ideas can be combined to generate more ideas. Furthermore, your testing data may incline you to change certain metrics or rescope the opportunity and you may have to diverge/converge all over again.

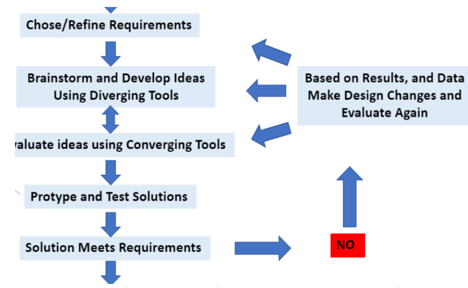


Figure 16: Snippet of Iterative Process from the Engineering Design Process Layout

2.6 Communicating the Design

Purpose

The last stage of the design process is to compellingly **communicate** the design to your **client, colleagues** or **primary stakeholder.** This is a key step in gaining the **trust** of investors, your company, manager, or client to accept that your design will solve the opportunity effectively. Articulating key design decisions and features backed up with research in a compelling manner increases the credibility of not only the design, but also the designer- you. Through my experience in praxis, I can say that at times **communicating about the design was more important than the design itself**. Here is a quick list of important **tips** to ensure you present the design effectively:

1. Ensure you use appropriate **jargon** depending on your audience.
2. Understand the **motivation of your audience**. Ex. You may want to focus more on the business objectives of the engineering project if presenting to the director of finance.
3. Choose the **right medium** depending on your audience and goal of the presentation. i.e presenting the idea to an investor may be better suited for an in-person conversation.
4. Note down **feedback** from interactions to make improvements (take them positively).
5. Have an idea of **evidence** that you may be asked to provide (figures, data, research).
6. **Rehearse** the presentation and think of potential questions that the audience might ask.
7. Be **CONFIDENT** to show you believe in the design!

The above list comprises lessons learned through presentations in Praxis, as well as some important communication strategies summarized from an article[1]. More information about communication strategies can be found here: [https://www.toptal.com/designers/ product-design/effective-design-communication-strategies](https://www.toptal.com/designers/product-design/effective-design-communication-strategies). **See Toulmin's Model on page 20 to make an effective claim and for effective prototyping practices to better communicate the design, refer to page 23.**

3. Tools

3.1 Wishing

Purpose

The premise of the tool is to say a wish which would make the opportunity easier to solve. Wishing enables each person to contribute ideas without having the fear of being judged [2]. This tool **legitimizes a statement that in other situations people might consider to be 'foolish'** and which they may covertly fear will cause others to laugh at them or degrade their social position. This tool lifts the barrier of self doubt and allows everyone to openly participate.

How and When to Use It?

To **maximize** the effectiveness of the tool, use it at the beginning of the diverging process to allow everyone's "jitters" out and to create an **inclusive environment**. Other times when I found using the tool helpful was when the team couldn't brainstorm **unique** ideas. You may also decide to use it if you feel that the team members are shy and have limited input. **For more information visit :** http://www.creatingminds.org.

Example/Experience

A specific example which highlighted the importance of this tool was when a group member said "I wish the design could be inflatable", as seen in Figure 16. If this statement was said in a normal setting, the student may have feared being criticised, as the statement seems a bit impractical. Although, while using the wishing tool, such statements are wanted, as seen in the image to the left. In fact, this wish was integrated into a design by making some components of the design inflatable. Although, I had experiences where teammates got off track due to very "off topic" ideas while using wishing.

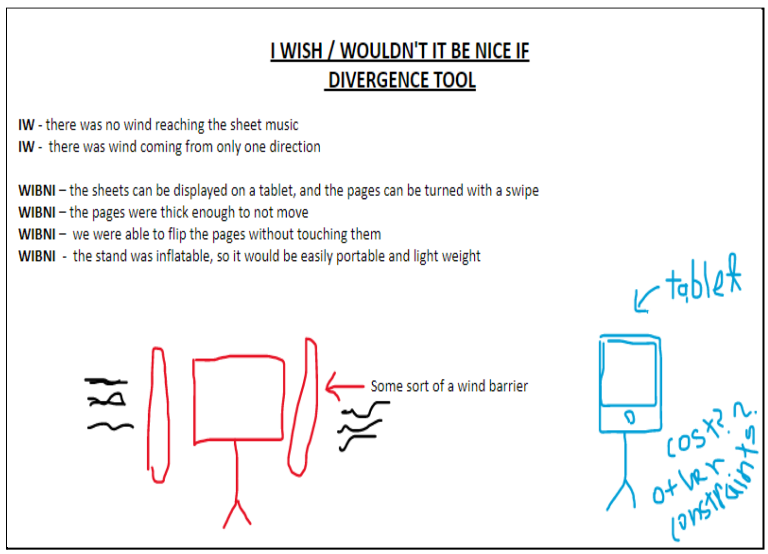


Figure 16: Application of Wishing Tool in Praxis 1 (diverging sprint)

Strengths	**Weaknesses**
Allows to generate unique ideas with a large scope	Can hinder ability to create appropriate engineering ideas
Creates a friendly environment for team	Can easily cause your team to go on a tangent and discuss unrelated ideas
Creates conversations, as you may be able to build upon someone else's wish	Participants need to be willing to stretch their imagination

3.2 Brainwriting 6-3-5

Purpose

This tool is aimed to **influence even participation** and non-verbal participation by encouraging participation from all members, with an emphasis on sketching of ideas.[3] This tool also **limits anchoring,** as you will be working on others' ideas.

How and When to Use It?

The premise of this tool is that each individual starts representing a design, and then exchanges their idea with another team member's idea and builds on their idea. This tool should be used during the **initial divergence process** to generate ideas. You may also decide to use it if you feel that some group members are less spoken. I found it helpful to use it before any group brainstorming took place in order to further limit anchoring. **For more information visit:** https://www.mycoted.com/Brainwriting.

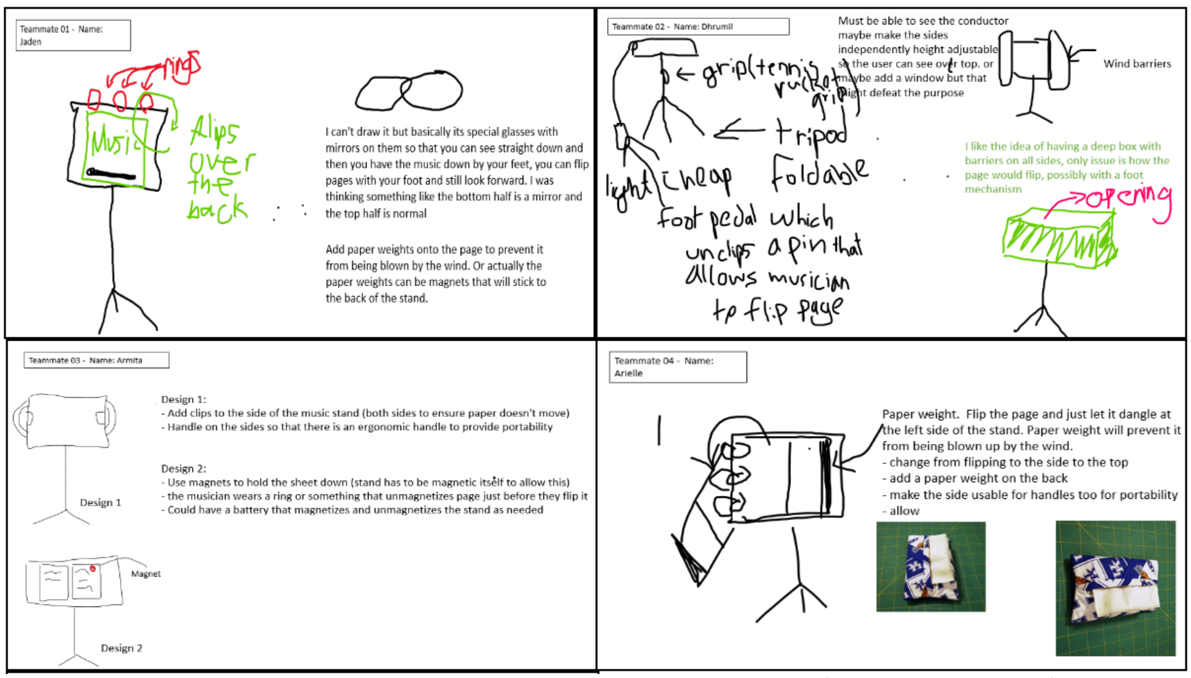


Figure 17: Brainstorming Tool used in Praxis 1 (diverging process)

Strengths	Weaknesses
Generates very unique ideas, as each person builds a part of the design	May be tedious to use in large groups of people
Limits anchoring, as ideas are explored from different perspectives	Can cause very flawed designs, if new member doesn't understand previous idea
Gives each member an equal opportunity to present their idea	Will not be as effective if group brainstorming has already taken place, since ideas will be repeated

3.3 Challenging Assumptions

Purpose

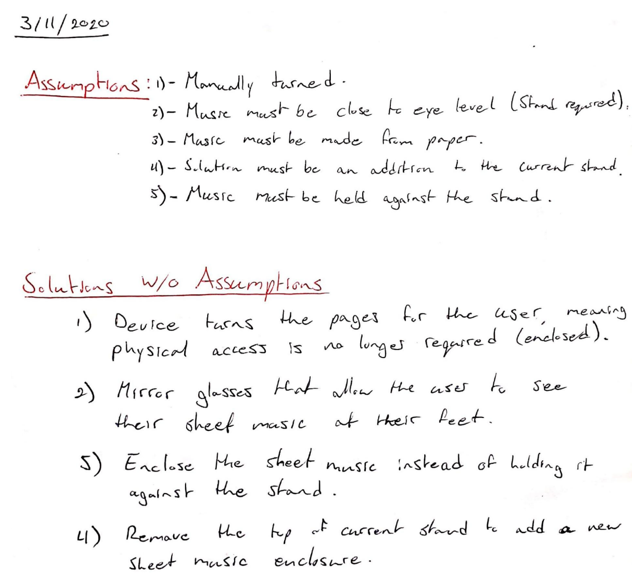
The premise of this tool is to **forcefully overcome** your thinking habits in order to look at the opportunity from a **different angle** [4]. This tool comes in handy to mainly challenge assumptions you made unconsciously based on your past experiences while reading the opportunity. By overcoming these assumptions, you enable yourself to create a less "restricted" design.

How and When to Use It?

Take an important topic from the opportunity and list assumptions you have regarding the topic and challenge them by asking yourself "what would happen if this was not true?" This tool should be used at the **beginning of the divergence process**, so you can effectively remove any assumptions for the rest of the process and explore more ideas. **For more information visit:** [http://members.optusnet.com.au/ ~char les57/ Creative/Techniques /assump. htm](http://members.optusnet.com.au/~charles57/Creative/Techniques/assump.htm).

Example/Experience

In this particular case, Challenging Assumptions was used after my team's initial brainstorm, where our first five designs were conceptualized, to help us come up with more outlandish or abstract solutions to the opportunity. **I wish my team used this tool at the beginning of the diverging process to maximize our ability to brainstorm new ideas.** Nonetheless, it enabled us to break away from constraints and preconceptions, as well as cast away from the "ideal" solution and think of more out of the box solutions. At the end, it gave my group creative designs equally capable of solving the opportunity as the "ideal" solutions we initially thought of.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Assumptions: 1) - Manually turned.
2) - Music must be close to eye level (Stand required).
3) - Music must be made from paper.
4) - Solution must be an addition to the current stand.
5) - Music must be held against the stand.

Solutions w/o Assumptions
1) Device turns the pages for the user, meaning physical access is no longer required (enclosed).
2) Mirror glasses that allow the user to see their sheet music at their feet.
3) Enclose the sheet music instead of holding it against the stand.
4) Remove the top of current stand to add a new sheet music enclosure.

Figure 18: Challenging Assumptions Used In Praxis 1 (diverging sprint)

<u>Strengths</u>	<u>Weaknesses</u>
Aids in casting away from similar solutions and think beyond preconceptions (reduces bias in idea generation).	Relatively difficult to come up with assumptions, as most assumptions are unconscious.
Allows you to clarify any critical assumptions with the primary stakeholder, incase they had the same or different assumption	Requires each participant to intentionally self-doubt themselves and admit their preconceptions.

3.4 Random Input

Purpose

The main goal of this tool is to help you come up with **fresh ideas** and **new perspectives** to the problem.[5]

How and When to use It?

This tool can be used at any time during the **divergence process**, especially if the design team is stuck and can't find ideas. The premise of the tool is to generate a random noun from a dictionary and use it as a basis for brainstorming solutions to the problem. **For more information visit:** http://www.sociology.org.uk/as4i3ri.pdf.

Example/Experience

From my experience, this tool has had a great **impact** on the diverging process. In the image to the right, this tool was used and the word "feed" led to an actual candidate design which we initially never thought of. Most of the nouns didn't lead to anything, which was a waste of time, but I realized if you are persistent, you will find at least one relatable noun. Overall, I found that the tool was useful for developing surface-level ideas quickly. **Tip: To gain a better insight, choose words from fields you have some expertise in.**

Random Input	Design Ideas
Bongo	Nothing
Avalanche	Nothing
Screw	Screw the paper to the stand so it doesn't fly away
Cartridge	Nothing
Lollipop	Make the paper stickey so that the sheets stay together
Snowflake	Nothing
Spandex	Nothing
Cinnamon	Nothing
Feed	Have each sheet "fed" to the musician

Figure 19: Random Input used in Praxis 1 (diverging sprint)

Strengths	Weaknesses
Opens up new ideas your team would have never tried to connect with the opportunity	Can lead to a waste of time if nouns continuously are not relatable to the topic
Helps expand the scope of the opportunity	Sometimes forcefully connecting two unrelated ideas can cause a flawed design/idea

3.5 Comparison Matrix

Purpose

This is a great tool to visualize how each design **compares** with other candidates regarding the requirements. It also enables you to identify various features that make a design stand out and potentially combine multiple designs based on these features.

How and When to Use It?

This tool should be used during the **converging process** in order to narrow down the number of candidate designs. There are various ways to set up the matrix, but a common way is creating an n by m matrix (n= # of designs, m = #of requirements), where each design is compared against a reference design, to ensure if it is “better” or “worse” for a certain requirement(i.e 1 for better, and -1 for worse). In the example, below the matrix was altered to better suit the designs. **DO NOT sum the entries to decide the best design(s).**

Example/Experience

The matrices in Figure 21 were used to compare designs based on how well the designs met the two primary functions of the opportunity. This enabled my team to narrow down designs that were the best in the two categories (pulling/allgining) and then combine ideas from the two matrices to create a proper functioning final design. In this matrix, every design is compared with each other design. The matrices could have been created to compare with a reference design, but that would have hindered our ability to find the “best” designs for each primary function.

Pulling Mechanism

	3	4	5	6	8	9	10	13
3	-	0	0	1	-1	1	-1	1
4	-	-	-1	1	-1	1	-1	0
5	-	-	-	1	0	1	0	1
6	-	-	-	-	-1	1	-1	1
8	-	-	-	-	-	1	-1	1
9	-	-	-	-	-	-	-1	-1
10	-	-	-	-	-	-	-	1
13	-	-	-	-	-	-	-	-

Alignment Mechanism

	1	2	7	9	10	11	12	14
1	-	1	-1	1	-1	-1	1	1
2	-	-	-1	1	-1	-1	1	-1
7	-	-	-	1	-1	-1	1	1
9	-	-	-	-	-1	-1	-1	-1
10	-	-	-	-	-	0	1	1
11	-	-	-	-	-	-	1	1
12	-	-	-	-	-	-	-	-1
14	-	-	-	-	-	-	-	-

Figure 20: Using a Comparison Matrix for Praxis 2 Based on Primary Functions (Phase 2)

Evaluation of Tool

Strengths	Weaknesses
Easily able to visualize how a design compares	In some cases, you can only compare relative to the reference design and not know how designs compare within
Quickly able to determine the best designs	Can lead to removing designs which could have in the future been integrated into another design

3.6 Testing

Purpose

By testing designs, you are able to **compare** different designs with data and converge down to a final design. Testing also enables you to better **understand** your designs and also make proper adjustments based on test results. A successful test will also enable you to **validate** a design.

How and When to Use It?

Testing should be done primarily in the **convergence process**, but the test results may help with finding new ideas. You should only test ideas that meet the constraints. In order to implement a reliable test, you must have **research** to back it up. Also, you DO NOT need to always follow industry grade tests. You can make a **proxy test**, based on scientific testing methods for your requirement.

Example/Experience

Figure 22: Time Test on the Showcase Design in Praxis 2 Done by Team Member(John Wolf)

While doing the time test above, we **certified** that the design met the constraint time noted in the requirement and performed better than other candidates. We also decided to add finger grips to further **improve** the time criteria. One **improvement** we could have made to the testing process was to take more data to increase the accuracy and reliability of the results.

Testing Checklist

- [ ] Designs tested under similar conditions
- [ ] Tests are based on requirements
- [ ] Tests are backed up with research
- [ ] Results are reproducible
- [ ] Test is able to be done on most designs(with minor adjustments if needed)
- [ ] Ensure test is ethical (e.i do not mock a disability)

The checklist is based on this online source [6] and my experiences/values.

4. Models/Frameworks

4.1 Requirements Model

Purpose

The requirements model allows a visual representation of the relationship between the project's objectives, criteria, constraint and metrics. It also helps exclude products that you do not want to create. Personally, it helps me to organize the **linear process** of how a stakeholder affects the metrics for the project (stakeholder -> higher level objectives -> detailed objectives-> criteria/constraints ->metrics). Essentially, it helps me connect everything to the **bigger picture -the needs of the stakeholders**. If there is a metric that doesn't connect with any objectives, I can easily figure out that it doesn't belong in the project.

How and When to Use It?

The model should be used during the **framing process** of the project. It is important to do research while/before building the model, so you can add appropriate detailed objectives and metrics. Depending on the type of project, the requirements model can be organized into a neat table, or any suitable form which effectively relates the objectives, criteria and metrics.

Example/Experience

DO1 - Improving Recyclability		
Metrics: 1. Percentage by weight of DHBCE-related contamination in the Toronto Zoo's blue bin waste stream.	**Criteria:** A lower percentage of DHBCE-related contamination is preferable.	**Constraints:** Contamination due to DHBCE's must not exceed 80% overall, ensuring improvement over the current process.

Figure 21: One Row of the Requirements Model from Praxis 2 RFP

While using the requirements model, I found out that it made the framing process more efficient, since I was easily able to organize the multiple objectives and metrics in a linear manner which made the process logical and easy to follow for my peers. Figure 23 shows an example of one of the detailed objectives, and how it affects the metrics, criteria and constraints. This detailed objective was a need of our primary stakeholder. Overall, assessors were pleased with various projects when the engineering requirements were structured in a linear process, connecting the stakeholders' needs to the metrics. I would definitely use this model, and idea of how each part of the framing process links to each other for future projects.

4.2 Toulmin's Argument Model

Purpose

The main purpose of this model is to help you support a claim, or even better, you can find out if your claim is credible and strong. The distinct elements in the model allow you to frame your argument in a manner which will **convince the audience to believe in your claim** [7].

How and When to Use It?

This tool should primarily be used for **communicating the design** effectively. You may use it to convince your boss, peer, investor or any audience for any claim that you want them to believe in. The implementation of the tool follows the steps shown in Figure 24. **For more information on each specific step, visit:** https://courses.lumenlearning.com/englishcomp2kscopexmaster/chapter/toulmins-argument-model/.

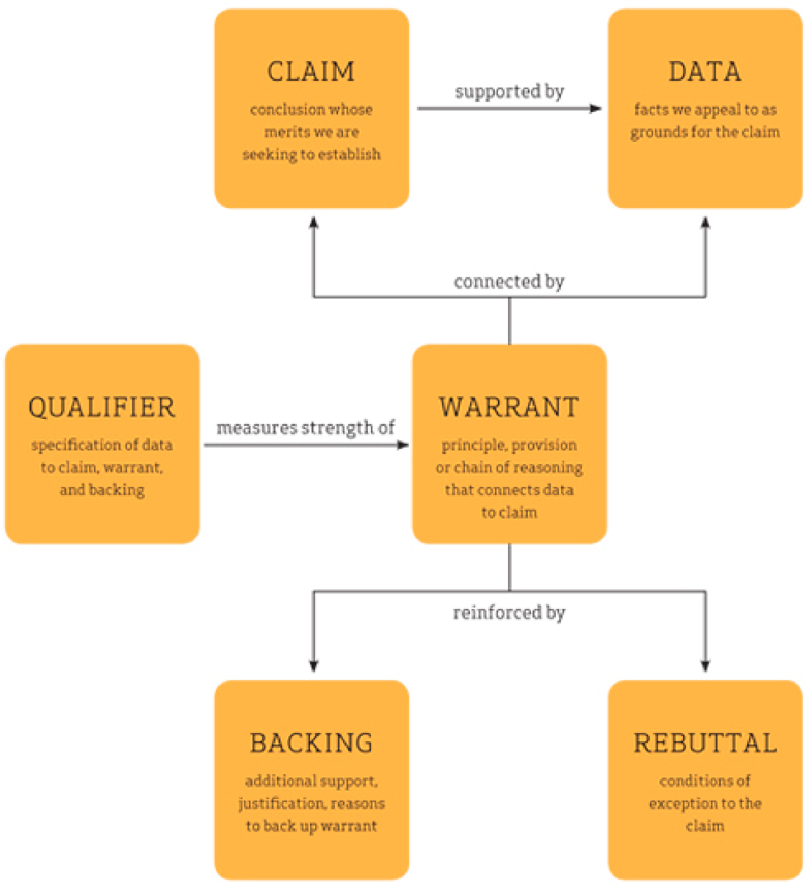

Figure 22: Visual Representation of the Toulmin Model [7]

Example/Experience

For presenting the Zipper Assist Tool design(Praxis 2 Showcase Design), my team and I applied this model in order to convince the assessors that the design meets the requirements of the opportunity. I will show you examples of some of the steps and how it affected our claim.

Rebuttal

My team and I decided to **pre-empt counter arguments** by showing flaws in our design during the initial presentation, as seen in Figure 25. This showed that we had carefully considered all aspects of the design. During the Q/A this allowed my team to build upon the flaws and talk about potential improvements/ tests that we have considered to minimize the flaw.

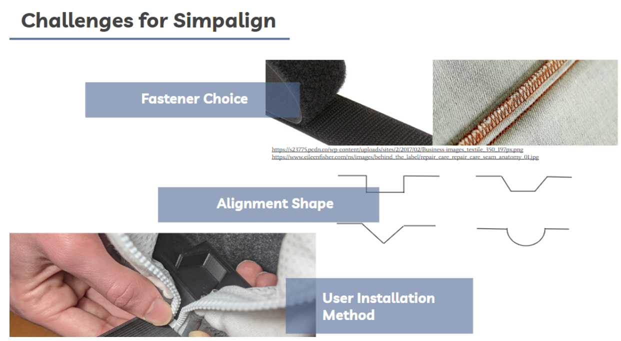

Figure 25: Laying out the Flaws of the Design

Data

The results of multiple tests that we did on the design proved to be a great source of a supporting argument. Figure 26 shows one of the tests that my team performed on the design and the associated result. This result was used to back a supporting argument relating to successfully achieving the time constraint.

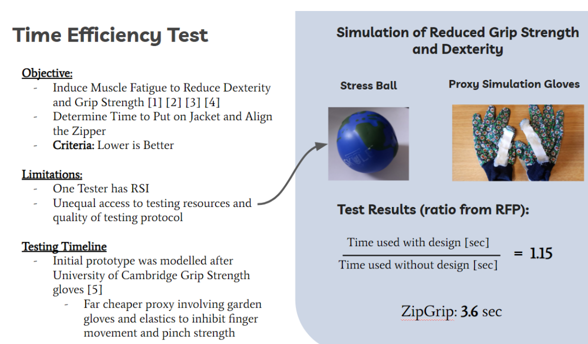

Figure 23: Time Efficiency Test Results

Warrant

The warrant connects the data and claim, by answering the question **"Why does that data mean your claim is true?"** [7]. Regarding the test discussed above, my group verbally explained how the test was done, showed supporting research and explained a logical connection between the data and the engineering requirements. It was done in an implicit manner by applying parts of logos and ethos.

Overall, I would definitely use this tool to prepare for presentations or any argument in general. This tool was not only helpful for effectively presenting designs, but also helpful for casual conversations within my design team. It also gave me a pathway to dissect other people's arguments by questioning missing elements from the Toulmin model in their argument.

4.3 Theory vs Reality

Purpose

As an engineer, you will always be looking to apply the theory you have learned in class to solve real word problems. There will be a constant, let's say "change of basis" between the theoretical and real world while you try to solve problems. Through a series of steps, this framework will allow you to gain information from the real world, apply theory and output a curated solution back into the real world. Moreover, I see this framework as an opportunity to constantly seek opportunities where you can help others by applying your knowledge.

How and When to Use It?

This framework is an overarching theme of any design work you will do and you should try to internalize it. The premise of this framework is to seek the needs of your stakeholders(reality) and create a requirements model(theory). Then, using the requirements model you will create a recommended solution(theory). Lastly, you will gain stakeholder validation and create a usable solution(reality). Most of the time you will be using this framework implicitly, but the focus should be to apply the ideas intentionally.

Example/Experience

Figure 27 shows the framework of ideas (requirements, validation,verification, recommendation) come together for my team's project and turn a set of stakeholder needs into a product. What I learned from this experience was that sometimes an idea may have great conceptual attributes, but it just can't be built in real life due to lack of resources, cost and other factors. Therefore, it is always important to recommend a solution which is practical and feasible in the real world.

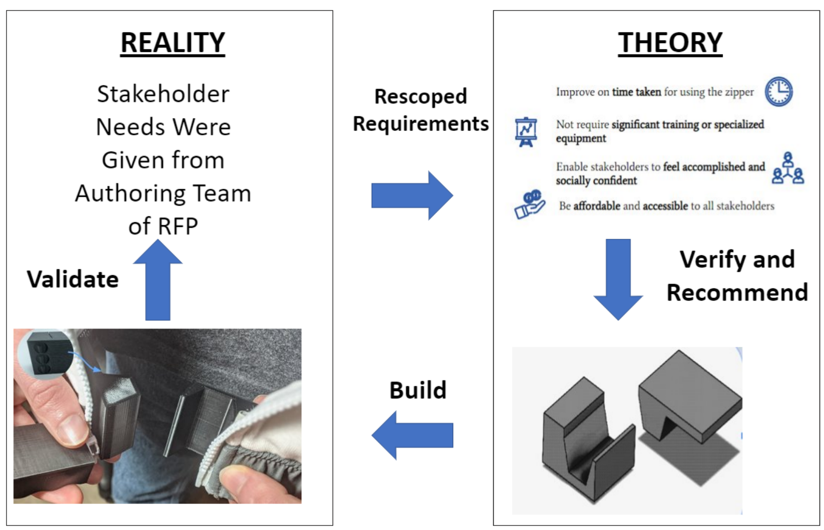

Figure 24: Theory vs Reality Representation of Assisted Zipper Tool (Inspired from Praxis 2 Teaching Team's Model)

4.4 Prototyping

Purpose

The purpose of prototyping is to explain your idea in a **tangible/visual** form which enables others and you to understand the idea. Depending on the fidelity, a prototype enables you to **validate/verify** the design through testing. While prototyping, it is important to express the most **“unbelievable”** part of the design. Low-fidelity prototypes can be used during **diverging** and high-fidelity prototypes for **converging**. Any level of a prototype can serve as a great visual representation of key features, and help you **effectively communicate your design**.

Prototyping Journey for Showcase Design by Stages

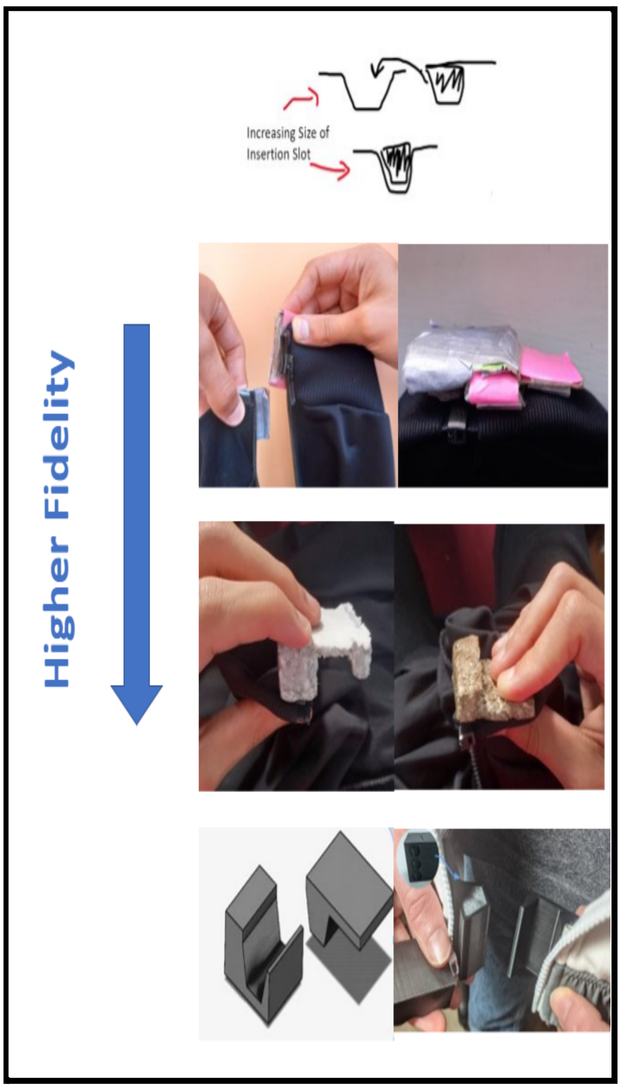

Figure 25: Prototyping Process for Assisted Zipper Tool Showcase Design (3D printed design created by John Wolf)

Sketch (Diverging)

I used a sketch to outline the **fundamental idea** of the design. Through this sketch I was able to gain approval from my teammates of the design not having any major flaws, and meets the opportunity requirements. **Don’t waste time trying to make it perfect.**

First Tangible Prototype (Diverging)

This prototype took **< 10** minutes and I used it to demonstrate the most **unbelievable part** of my idea to my teammates and gain their trust. Although, this prototype was not sturdy enough to test/evaluate since the shape is not correct and it is made out of cardboard.

Testable Prototype (Converging)

With this styrofoam prototype, I was able to do preliminary **tests** and essentially enabled the design to be a final candidate. You can see this prototype has a more appropriate shape to the final design, and is much more sturdy.

Final Prototype(Converging)

The final prototype was 3D printed, with exact measurements,a very durable/sturdy material and we were able to do more accurate tests with this prototype ensuring **validation/verification**. In showcase, we presented this prototype, and we were effectively able to communicate the design, and gain the **trust of assessors** that this design would work in reality. The quality and preciseness of the final prototype convinced the assessors that this product could actually be made and sold.

Important Tips

1. **Do not waste time on details if it is a preliminary prototype. You want your idea to be shared with others, so you can quickly find out if there are any major flaws which may hinder the development of the design.**

2. **Sketching is a great starting point for any visualization, although it may not yield meaningful engineering judgments.**

3. **You should primarily try to prototype the most unbelievable part of your design.**

4. **Slowly build your way to a higher fidelity prototype after gaining validation/verification from your team, tests and stakeholders. Remember that in a real engineering environment, your company may not have enough time and resources to make high quality prototypes from the get-go.**

5. **To perform a specific test, it may not be necessary to have a full functioning prototype.**

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