DESIGN HANDBOOK

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1. Introduction

The purpose of this design handbook is to document the tools, models, and frameworks utilized throughout my Praxis I and II experiences. It is designed to be a practical guide for future engineering tasks by providing a record of your design processes and reflections on their effectiveness. By revisiting these documented experiences, the handbook aims to strengthen my design process and assist in overcoming my biases. Before we start, all credits go to the Praxis I team members Jeffrey Klinck, Aydin Yousaf, Trevor Orlando, and the Praxis II team members Sasha Mee, Mario Arambula, Princess Akinolaore, as well as myself, for the design work.

2. Position & Personal Engineering Design Process

2.1 Positionality

2.1.1 My Value

- Design Implementation: Prioritize phenomenal engineering designs over conceptual ones. Evaluate designs dichotomously—either functioning or not—based on constraints, rather than merely adjusting functionality.
- Clarity and Usability: Ensure designs are straightforward for stakeholders, not through simplicity of operation, but by inherently solving complex issues within the design itself.

2.1.2 My strength

- Prototype Development: comfortable to build physical prototypes using low-fidelity components to demonstrate the most unbelievable part.
- Teamwork: Proactive in expressing opinions within a team to move the process forward. Not distressed by discrepancy in opinion and receptive to constructive feedback.

2.1.3 Bias limited to Praxis I and Praxis II project

- Assessment Criteria: Designs should be evaluated for their phenomenal execution so live demonstration should be possible in our design.

2.2 Overview of Personal Engineering Design Process

My personal engineering design process in practice followed the standard FDCR steps for both Praxis I and Praxis II, but was not confined to using each tool in chronological order at each step. Instead, it involved moving back and forth between steps to arrive at the final design. Typically, in more technical and initially framed design work, such as for the design team (pitch system of a wind turbine), the converging and diverging processes are sometimes substituted by following the reference design and then verifying through calculations.

3. Tools, Models, and Framework

3.1 Engineering argument

Making a engineering claim involves following steps

1. Grounding a claim
2. Making a claim
3. Providing Justification and Evidence
4. Limiting the implications with constraints
5. Addressing possible counterclaims

3.2 Definition of FDCR model

The engineering design process can be classified into four stages: Framing, Diverging, Converging, and Representing (FDCR).

Framing: Forming the direction of the design from opportunities with stakeholders based on requirement strings.

Diverging: Generating many relevant ideas within the initially framed scope and requirement strings to broaden the design space and overcome biases.

Converging: Narrowing down the design using tools, often involving reframing and rescoping.

Representing: Showing or recommending the design to stakeholders with organized and visualized aids.

3.3 Requirement model

The requirement string involves the following components:

- Objective (both high-level and specific)
- Metric: Measurement with units that shows the extent to which the design satisfies the objective
- Constraint: The limits outside of which the design is unacceptable

- Criteria: The qualities that determine greater acceptability

This is the example of using requirement string from Praxis I and Praxis II

Specific Objective	Metrics	Constraints	Criteria
Ensure that all garbage is ending up in the can rather than being littered around it	The ratio of garbage [by weight] inside the can vs. outside the can [within a distance of 2m from the can].	Must exceed existing ratio (undetermined)	A higher ratio is preferred
Maximize the weight of the garbage being collected per can	Weight [kg]	Must **not** exceed <u>39 kg</u> - determined by ergonomic limitations for lifting done by garbage collectors [4]	Greater weight is preferred
Maximize the effectiveness of each can	Density of Garbage/Volume of Can [kg/m^3]	See weight constraint above	Greater density is preferred
Minimize the total footprint of a potential solution	Space Utilization Ratio (Volume of space that can be filled with garbage/Total Volume of garbage disposal area) [no units]	N/A	Greater ratio is preferred
<u>Explanation</u>: The weight and density of garbage, and ratio of liter to garbage in-can are all metrics that can be used to compare the per-unit size effectiveness of potential solutions to previous designs.			

Figure 1 : Part of Praxis I Requirement strings

Objective	**Metrics**	**Constraint**	**Criteria**
7.1 Functionality			
7.1.1 Should be able to adjust the tension in the woven material	Tension Newtons (N)	Must be yes	A larger range is better
<u>Justification</u>: The device should be able to adjust the tension in the woven material because the amount of tension in the material affects the shape of the basket. A higher tension leads to a higher slope on the walls of the basket and vice versa (Extract 11). A larger, adjustable range would allow the stakeholders to make baskets of various shapes. The tension in a string is measured in Newtons (N) and can be measured as shown in Extract 12.			
7.1.2 Should not weaken the weaving material	Tensile Yield Strength MegaPascals (MPa)	Strength must be yield strength shown in Extract 14	Stronger is better
<u>Justification</u>: As per stakeholder requirements, the product should not decrease the quality of the basket, which can be measured by the force it can withstand. Since the basket only experiences tensile force, the product should not lower the tensile yield strength of the material, which must be measured in MegaPascals according to ISO 11566 (Extract 13). Since the yield strength varies with the material, the yield strengths should be maintained as shown in Extract 14.			

Figure 2 : Part of Praxis II Requirement strings

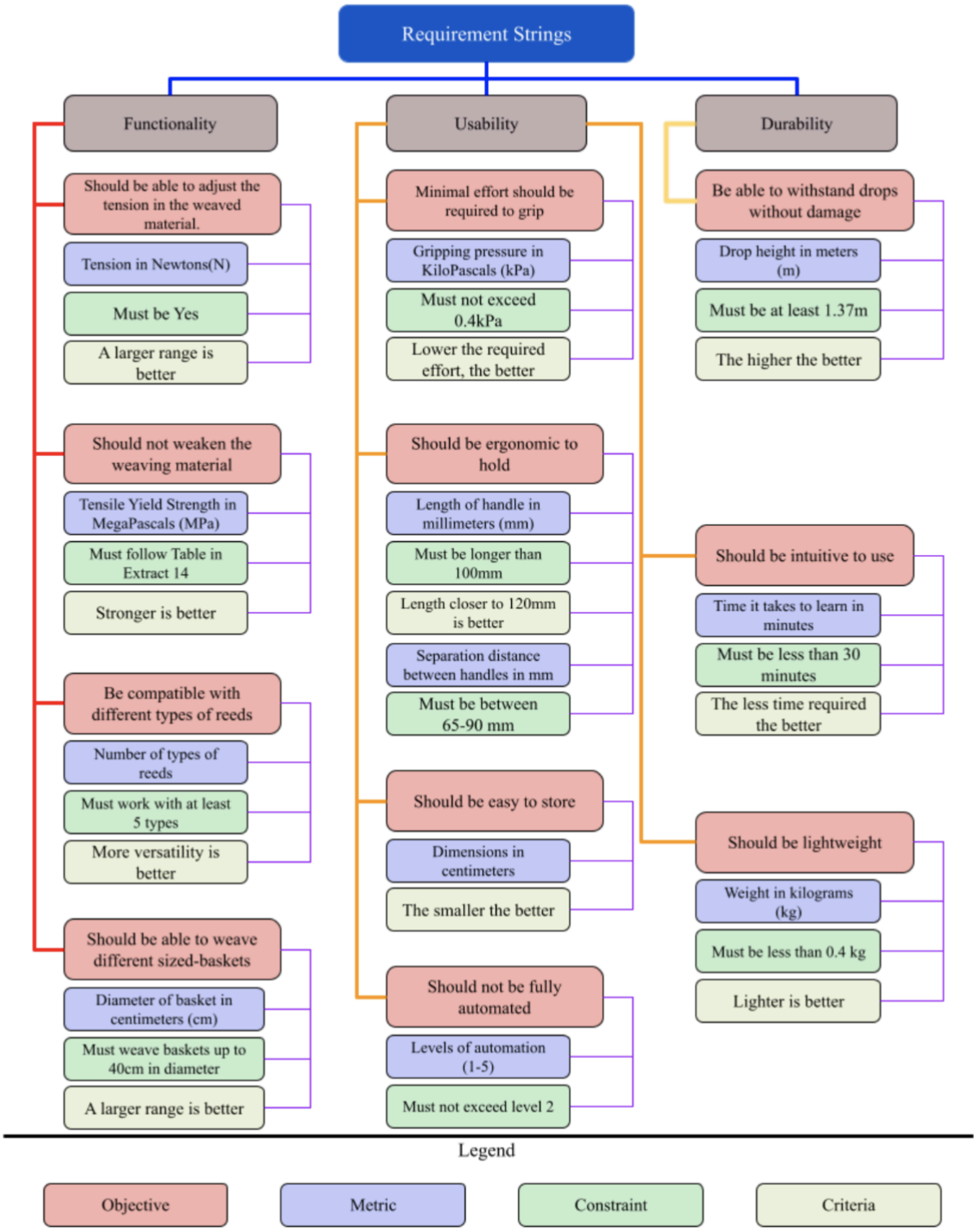


Figure 3 : Simplified version of full Praxis II Requirement strings

3.4 Framing opportunity

Framing involves understanding the situation, and opportunity in Praxis refers to an inconvenience where a potential solution lies.
Below is an example of framing the opportunity.

3.1 Defining the Opportunity

Although there are hundreds of conditions that fall under the category of arthritis, they can be identified by the swelling and stiffness of joints with symptoms of pain, stiffness, and limited movements in those joints (Extract 9). It can affect nearly any joint, but we will focus on arthritis in the hands and the wrists, as basketry mainly involves the use of one's hands. As basket weaving requires nimble fingers and a certain amount of hand strength, people with arthritis may find it difficult to enjoy this craft due to their symptoms. Thus, our opportunity lies in bridging the gap between individuals with arthritis and the process of weaving baskets.

Figure 4 : Praxis II Opportunity

3.5 Diverging Tool

* Note : Instructions and specific steps for tools are in Appendix A. In this section, only examples of usage and brief personal thoughts/assessments on the tools are discussed.

3.5.1 Brainwriting 6-3-5

Brainwriting diversifies creativity in design by preventing an introverted person's ideas from being overshadowed by others' input. It allows introverted people to contribute ideas stress-free, without the need to speak aloud.

Although brainwriting is primarily a diverging tool, it also serves as the fastest way to check teammates' preferences in design ideas and biases, simply by categorizing similar designs and counting the numbers.

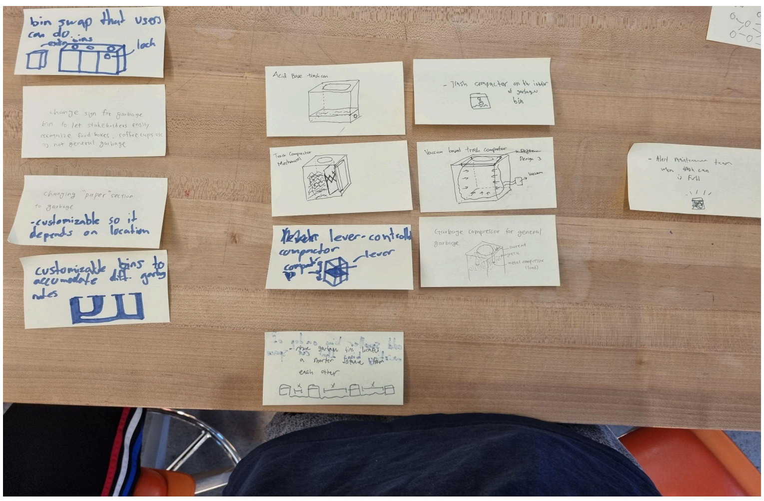


Figure 5 : Praxis I - Categorizing similar ideas using brainwriting

In Praxis II, brainwriting revealed the team's preference for the 'four-way fringe twister.' Many creative ideas, which had not been explicitly discussed orally, were included without overlap, allowing insight into what introverted team members were thinking

Diverging & Converging - Brainwriting

Four Way Fringe Twister	4
Adjustable Length Hook	3
Adjustable Base Mold	3
Arthritis Ergonomic Grip	2
Button Hook	2
Arthritis gloves	1
Regular Fringe Twister	1
Embroidery Aid	1
Cordage Maker	1

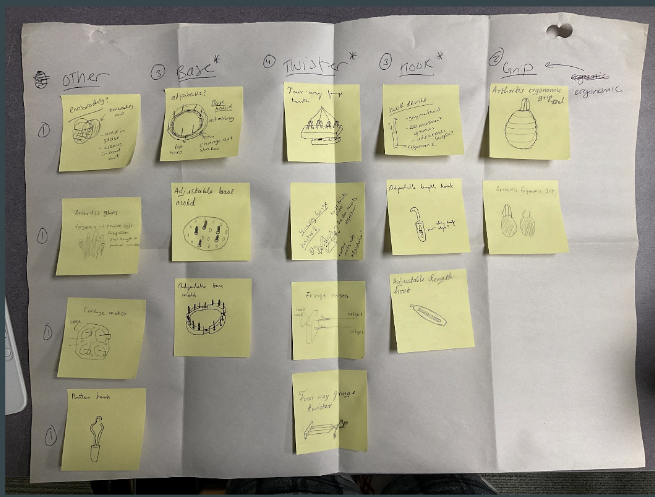


Figure 6 : Praxis II brainwriting

3.5.2 Lotus Blossom

The Lotus Blossom tool, similar to systematic brainstorming, promotes outside-the-box thinking by unfolding themes to trigger new ideas. However, it often results in the repetition of abstract terms, especially when not used early in the process, leading to less effective idea generation. Using this tool earlier could enhance its effectiveness and avoid redundancy.

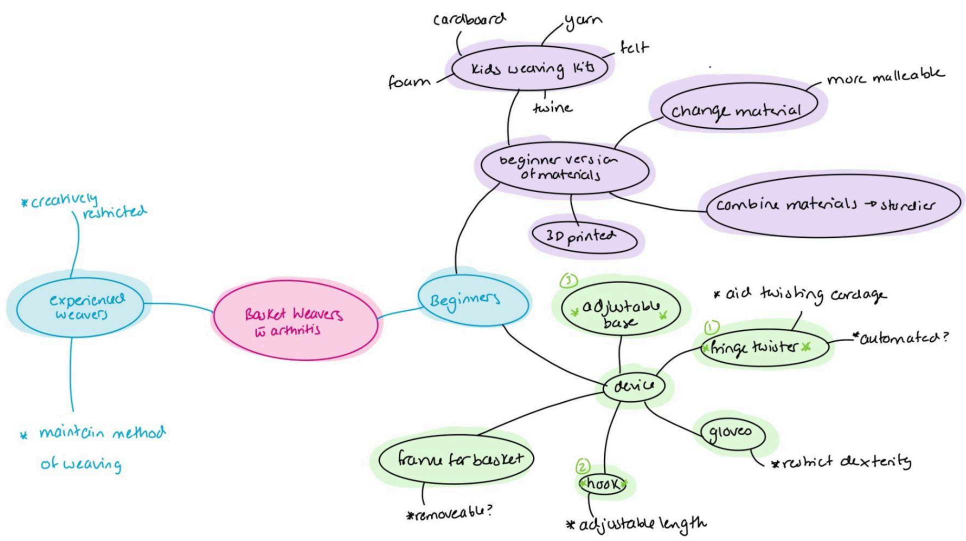


Figure 7 : Praxis II Lotus Blossom at earlier diverging stage

3.5.3 Challenge assumption

Challenge assumption helps avoid assuming correctness by encouraging critical questioning. The usage of this tool to overcome inaccuracies in the RFP by another group allowed the team to better align with the community's stakes. Although this tool was used unintentionally during Q&A sessions, it effectively validated secondary information. However, its intentional use is not recommended as it can overcomplicate the design process and hinder project progress, though knowing the tool exists to systematically validate skepticism is beneficial.

3.6 Converging Tool

*Note : Since the primary purpose of the handbook is to show how to use a converging tool, a simplified example of a converging tool for Praxis I will only be provided for clarity and coherence in understanding the tool itself.

3.6.1 Pairwise Comparison

Pairwise comparison is a converging tool used to evaluate and rank options by comparing them two at a time, assigning a score of 0 for a loss and 1 for a win to determine preferences or priorities.

Converging Process - Pairwise Comparison

	Lead screw with motor	Planetary gear with hand crank	"Rocket" compressor	"Pantograph" lever compressor
Lead screw with motor	-	1	1	1
Planetary gear with hand crank	0	-	1	0
"Rocket" compressor	0	0	-	0
"Pantograph" lever compressor	0	1	1	-

Figure 8 : Praxis I pairwise comparison of four garbage bin designs

3.6.2 Measurement Matrix

A Measurement Matrix quantifies and compares different design options against specific metrics. It objectively evaluates and selects the best option from multiple choices based on measurable criteria such as dimensions, time, force, and security. The process often involves (i) *research*, (ii)*proxy testing, and* (iii)*calculations* ,to gather data for decision-making.

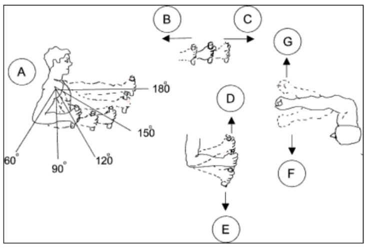
Converging Process - Measurement Matrix

	Lead screw with motor	Planetary gear with hand crank	"Rocket" compressor	"Pantograph" lever compressor
Relative Effort	0	2.75	4.13	1
Volume Compressed	~70%	~70%	~50%	~70%
Time Needed	12	≥4	≥2	≥4
Structural Complexity	3	3	1	3

Figure 9 : Praxis I measurement matrix

(i) Relevant Research

Arm Strength values. (From USA - Adjusted (reduced) values based on tests on young men 80% of (5th percentile group) - Better info in link 4 below



A	B		C		D		E		F		G	
	L(N)	R(N)	L(N)	R(N)	L(N)	R(N)	L(N)	R(N)	L(N)	R(N)	L(N)	R(N)
180^{o}	177.6	184.8	149.6	177,6	32	49,6	46,6	60,8	46,6	71,2	28,8	49,6
150^{o}	149,6	199,2	106,4	149,6	53,6	64	64	71,2	53,6	71,2	28,8	53,6
120^{o}	120,8	149,6	92,8	128	60,8	85,6	74,4	92,8	71,2	78,4	36	53,6
90^{o}	113,6	132	78,4	128	60,8	71,2	74,4	92,8	56,8	64	36	56,8
60^{o}	92,8	85,6	78,4	120,8	53,6	71,2	60,8	71,2	42,4	60,8	L	R

Figure 10 : Praxis I relevant research on arm strength values

(ii) Proxy testing

Proxy testing is using an alternative method to evaluate the performance of a product or system when direct testing is impractical or unavailable.

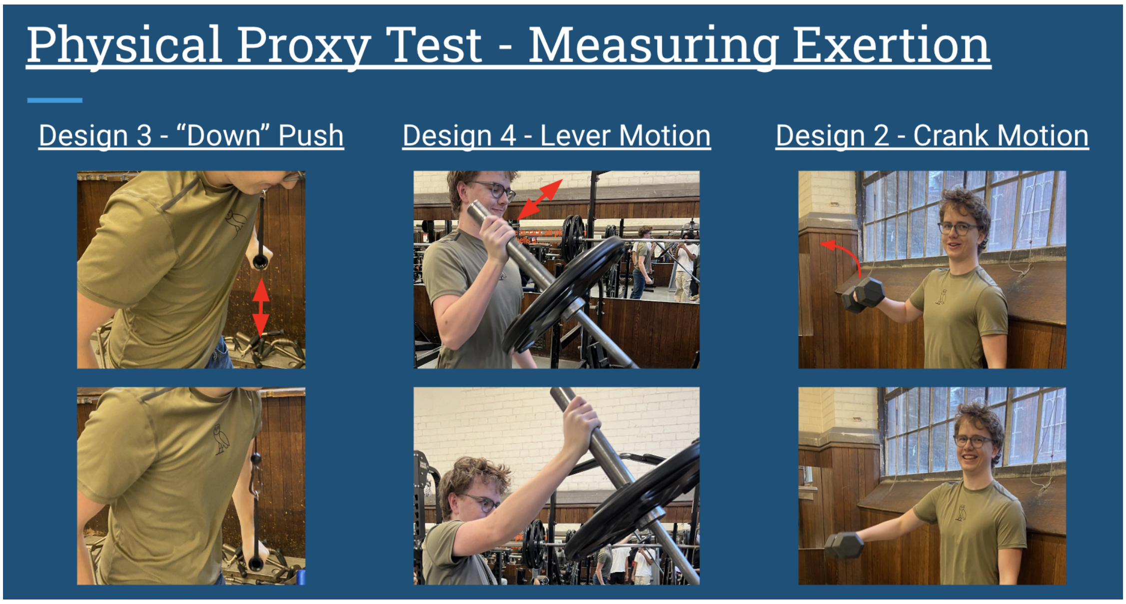


Figure 11 : Praxis I Proxy test on amount of force - used for measurement matrix (credit: Jeffery, EngSci 2T7)

Result of Proxy Test - Measuring Exertion

Type of Exertion	**Max Weight (lbs)**	**Max Weight (N)**	**Qualitative ‘Difficulty’ Score (1-10)**	**Mechanical Advantage**	**Relative Effort Score:** min(max*M.A.)/force
Down Push	**40**	177.9	6	1 - No Advantage	**4.13**
Lever Motion	**55**	244.7	4.5	3 - Length of input arm/ Length of output arm	**1**
Crank Motion	**20**	89.0	8	2 - Radius of Gear/ Radius of Crank	**2.75**
Button*	~2	~8.9	1	Essentially ∞	**0**

Figure 12 : Result of proxy test - used for measurement matrix

(iii) Calculation

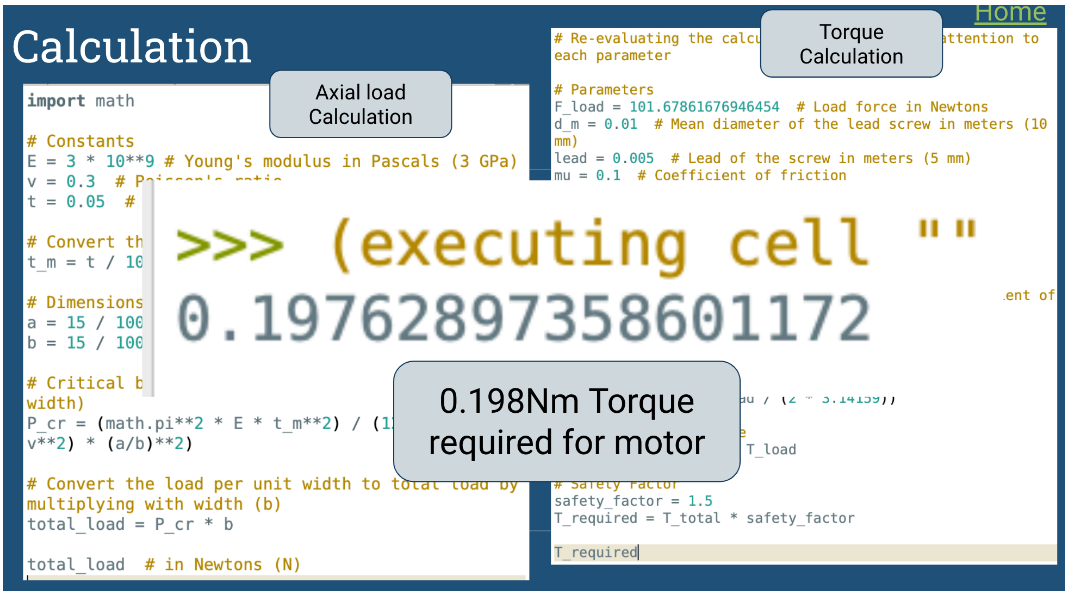


Figure 13 : Calculation in required torque - used for measurement matrix

3.6.3 Pugh Chart

A Pugh Chart compares multiple design options using a set of criteria to evaluate and score each option. Holistic weight(priority) is given for each criteria.

Converging Process - Pugh Chart

	Priority	Lead screw with motor (reference)	Planetary gear with hand crank	"Rocket" compressor	"Pantograph" lever compressor
Relative Effort	1	0	–	–	–
Volume Compressed	2	0	0	–	0
Time Needed	3	0	+	+	+
Structural Complexity	4	0	0	+	0

Figure 14 : Praxis I Pugh Chart

3.7 Representing

Representing includes prototyping(CAD, physical prototype) and presentation(poster, one pager, showcase)

3.7.1 Prototyping

1.CAD: Onshape software was used to represent our initial design ideas from design sketches. At this stage, the desired functionality, including the locking mechanism (the pole in the middle) and the inner gear mechanism, was assumed to be operational.

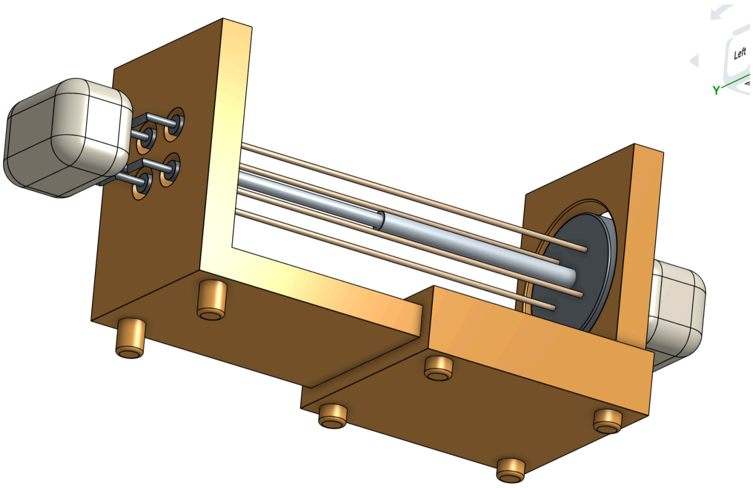


Figure 15 : Praxis II cordage maker CAD by Onshape

Physical Prototype : Inner planetary gear mechanism that twists all four cordage clips before combining them was added in a low fidelity prototype to demonstrate the most unbelievable part.

Figure 16 : Praxis II physical prototype of cordage maker with gear system adopted

3.7.2 Presentation

1. Poster : A poster was prepared for the showcase to visually display our engineering design. The CAD model was updated when it was added to the poster.

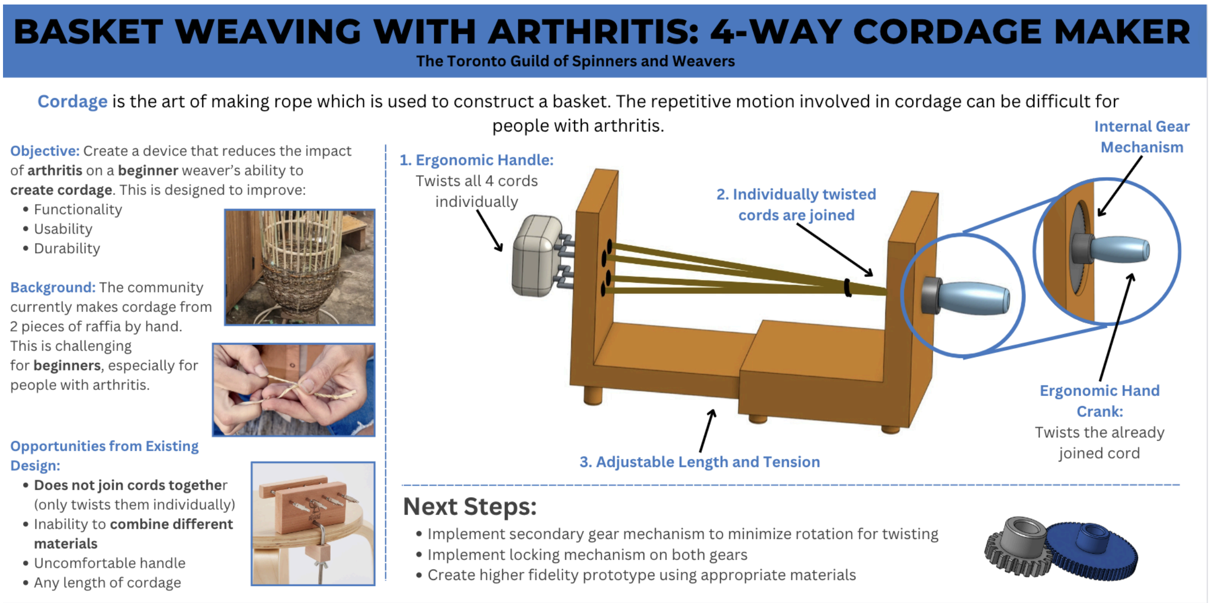


Figure 17 : Praxis II poster for the showcase

2. One pager :A one-page printed document, containing content similar to the poster, was prepared to distribute to attendees

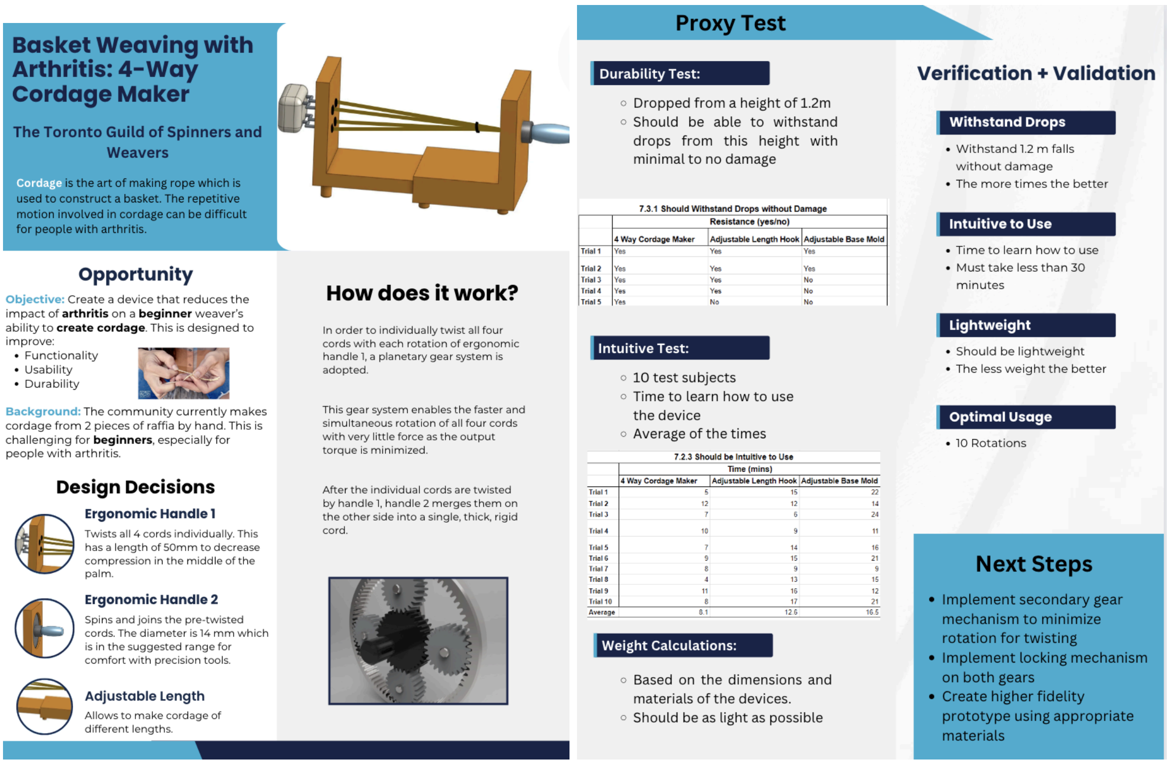


Figure 18 : Praxis II one pager for the showcase

3. Showcase : At the showcase, the team exhibited engineering design projects (4-way cordage maker) to attendees, aiming to validate and recommend their design concepts through prepared 15-minute presentations, demonstrations with a physical prototype, and a 15-minute Q&A section

Figure 19 : Praxis II Showcase

4. Assessment

This assessment section reflects on my application of tools, models, and frameworks, assessing their value in the context of my design activities, skills, teamwork, and values. Given that the utility of diverging tools has been covered, this part focuses on my overall contribution, particularly in design implementation and clarity/usability—values emphasized in the "my value" section.

In both Praxis I and II, my efforts were centered on prototyping,especially in making the physical prototype operational and functional for demonstration at the showcase. The development of our team's final prototype was significantly influenced by my value on a working vs. non-working dichotomy. For example, my team realized that achieving the desired functionality was not as simple as replicating an existing design's appearance. Specifically, when our prototype could not independently twist four cordages before combining them,we had a critical discrepancy. I was the sole team member pushing to refine the inner mechanism to ensure a functional prototype for the showcase.

Based on my value of “proactive approach to expressing opinions and advancing team discussions”, I proposed using an inner planetary gear mechanism for the cordage maker. This suggestion was well-received, leading to a last-minute CAD modification that was enthusiastically adopted by my teammates.

However, the final prototype slightly deviated from my second value of inherently solving complex design issues internally. The gear mechanism, which ideally should have been concealed within the design, was deliberately externalized. I was biased towards this arrangement, believing it would be advantageous to explicitly showcase our internal workings to the Praxis team during evaluation. Nonetheless, aligning with my values, the team planned future revisions to integrate the gear system internally, further justifying this decision in subsequent steps of the design process.

5. Appendix

Appendix A : How to use diverging tools

Divergence

BRAINWRITING 6-3-5

How to use: individual / **group** | **open** / closed problems | **products / services**

Description:

A creativity tool aimed to address the potential deficiencies of brainstorming (uneven participation and verbally led) by encouraging participation from all, with an emphasis on sketching of ideas.

Steps:

1. Establish team & Define scope and purpose

A good size team for brainwriting is between 3 to 8 people - 6 is about right, hence the '6' in the name of the tool. As with brainstorming, the process will be more effective with a clear focus.

2. Each team member captures 3 ideas each

Each team members writes, describes or sketches 3 ideas each on a piece of paper. It is highly recommended that at this stage, the participants should be encouraged to sketch their ideas, an annotate the sketches with writing where appropriate. It may help the team members to focus on the top 5 elements of product functionality, as viewed as important by customers. This stage should last around 30 minutes (longer if people are still going strong, shorter if ideas have dried up) and in that time, a team of 6 people should have produced between 15 to 30 unique concepts.

3. *Pass the concepts around the table - 1 round*

Following the initial session, the concepts are passed to the right, to the next person around the table. Allow 10-15 minutes for each person to add to, modify and extend each of the ideas passed to them. Once they have done this, the sheets are passed on until all ideas have been seen and modified by all team members. This can take in total about 60 minutes. The focus of any modifications to ideas should be on advancing the idea, not criticising.

4. *Repeat 5 times*

It is recommended that they are passed around the table in total 5 times, to encourage combination of ideas, refinement and development of concepts. This can be laborious, and the rounds should be spaced out in time to prevent the team becoming stale. After a few rounds, it can be beneficial to use traditional brainstorming rules, to encourage some debate and discussion about the ideas, with a view to advancing the concepts more quickly and potentially eliminating the weakest ones.

More information:

http://www.mycoted.com/Brainwriting

Divergence

LOTUS BLOSSOM TECHNIQUE

How to use: **individual** / group | **open** / closed problems | **products / services**

Description:

This technique involves starting with a central theme or problem and working outward, using ever-widening circles or "petals." Central themes lead to ideas that themselves become central themes, and so forth. The unfolding themes trigger new ideas and new themes.

Steps:

1. Copy the diagram

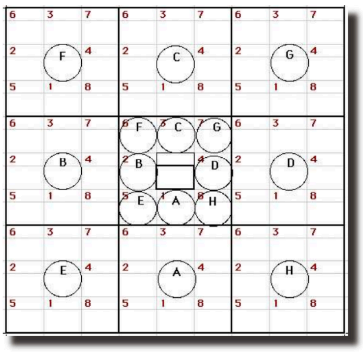
2. Write your central theme or problem in the diagram's center. Think of related ideas or applications and write them in the surrounding circles (those labelled A through H). For instance, one company's central theme was "establishing a creative climate." They surrounded this statement in the central box with: "offer idea contests," "create a stimulating environment," "have creative-thinking meetings," "generate ways to 'get out of your box'," "create a positive attitude," "establish a creative-idea committee," "make work fun," and "expand the meaning of work."

4. Use the ideas written in circles ADH as central themes for the surrounding boxes. So, if you had written "create a stimulating environment" in circle A, you would copy it into the circle labeled A directly below, where it would become the central theme for a new box, and so on.

5. Try to think of eight new ideas involving the new central theme, and write them in the squares surrounding it. Use the idea stimulators to help you generate ideas. Fill out as many boxes as you can.

6. Continue the process until you've completed as much of the diagram as you can.

7. Evaluate your ideas.



Example:

An unemployed marketing executive used the lotus exercise to generate ideas he needed to land a job. His central theme was "job". One of the ideas surrounding this central box was "create a resume." "Resume" then became a new central theme and, using the idea stimulators, he came up with a number of variations on the idea of a resume. For example, he took out ads in several papers with the bold headline, "$50,000 Reward." The fine print underneath explained that an employer could save $50,000 by not paying a headhunter to find a person with his marketing talents. When interested employers called the number listed in the ad, they heard a recording of his resume. He received forty-five job offers.

More information:

http://members.optusnet.com.au/~charles57/Creative/Techniques/lotus.htm

Divergence

CHALLENGE ASSUMPTIONS

How to use: individual / group | open / closed problems | products / services

Description:
The ‘assumptions’ technique aims at overcoming your thinking habits in order to create new perspectives on a given topic. This technique is also called ‘presuppositions’.

Steps:
1. Take a crucial term from your problem or topic formulation.

2. List the assumptions you have on the topic and fundamentally challenge them by asking "What if ….. was not true?

3. Answer this question and from this new perspective you will come up with a bunch of new ideas.

Example:
How can we decrease the weight of a car, while still preserving its security and stability?
1. Car assumptions:
   wheel driven - means of transport - has a certain volume
2. What if a car is not wheel driven?
3. The car would float in the air! Or, the car would stand still! Or, the car would jump!
4. New ideas from floating:
   - a car with surrounding plastic bumper around full of compressed air that can take heavy shocks and makes the car float in water.
   - an airbag around the car as soon as the car runs out of the road.
   - ...

More information:
http://members.optusnet.com.au/~charles57/Creative/Techniques/assump.htm

6. Work Cited

[1] R. Irish, *Writing in Engineering: A Brief Guide*. Oxford, U.K.: Oxford University Press, 2015.

[2] “ESC 101 Lecture 11[slides]”. ESC 101H F LEC0101 20239: Praxis I (October 3, 2023)

[3]”27 Creativity Tools for Divergent and Convergent Thinking”

[4]”Lotus Blossom Instructions”

[5] “ESC 101 Lecture 27[slides]”. ESC 101H F LEC0101 20239: Praxis I (week 9)