Bamboo Weaving in Rural Northern Thailand
Opportunity Exploration, Design Concept and Prototyping

INTEGRATIVE SUMMARY

(Team 0103A)

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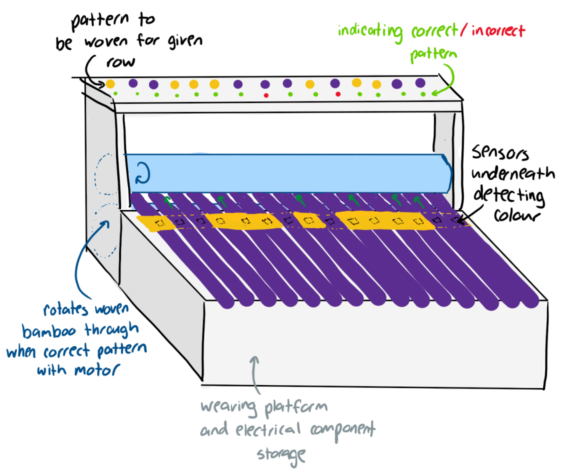
S0: Summary of Revisions (1 page)

Updated Content	Description of Alteration	Justification
Project management tools and timelines	a) Added description about usage of discord to enhance communication b) Added timeline comparing planned vs actual schedule	a) With more tasks being executed individually/small groups, this tool proved to be an effective platform to update and exchange information with group members b) This timeline serves as a resemblance of how our anticipated rate of progression coincided with our actual performance, reflecting the adaptation in our time allocation strategies
Engineering requirements model	a) Objectives ranked in order of importance b) Justification for the objectives are organized in list form	a) Priorities of the design were articulated to reflect the features that were more emphasized in the final prototype b) Upon receiving feedback, a list form description was used to increase readability, clarity, and coherence
Design Context	a) Moved information about initial interpretation about the opportunity from 2.2 to 2.1 b) Added justification for stakeholder identification	a) Upon receiving feedback, made clearer distinction between the initial interpretation of the opportunity and the framing/scoping b) The rationale for the choice of stakeholders ties into the justification of the prioritization of the requirements model

S1: Visual Abstract: Increasing Bamboo Profitability by Teaching New Weaving Patterns (1 page)

In Northern Thailand, bamboo weaving is a traditional practice as well as a primary source of income for many elderly individuals in rural villages [1]. Recently however, this source of income has become unreliable as demand for traditional bamboo products has decreased. Although various challenges are present in the weaving process, the primary message of the Opportunity Champion, whose job is to support rural weavers, was that many of the elderly weavers are only able to weave basic patterns due to the oral tradition of passing down knowledge. These basic patterns sell for very little in comparison to more complex patterns. This led to our pursuit of the opportunity to **improve the profitability of the products created by bamboo weavers in rural Thailand through education of more complex weaving patterns.**

The design concept we pursued is an educational weaving device which teaches new weaving patterns. As bamboo patterns are generally woven row by row, the LEDs first display the pattern for one row of the design. Next, RGB sensors detect if the correct pattern has been woven for that row and provide visual feedback. Finally, if the row is correct, a roller mechanism will feed the bamboo sheet forwards and the pattern for the next row will be displayed. This process is iterated until the entire bamboo product is woven. A notable component of this design is the potential to upload a wide variety of new designs based on customer demand, therefore more closely connecting the bamboo weavers with the marketplace and teaching them *relevant* complex bamboo patterns.



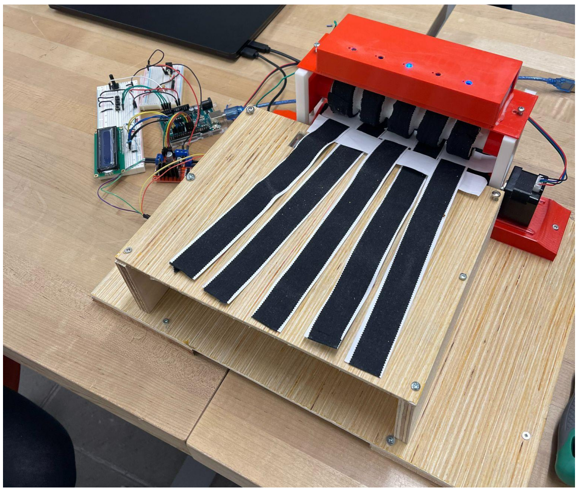


Figure 1: Design Concept Sketch [left] and Final Prototype [right]

The design concept and final prototype are displayed above in Figure 1. The prototype developed included all of the key aspects of the design concept. Some components were designed with increased simplicity or reduced scale, however the purpose of the prototype was to demonstrate that the pattern indicator, colour detector and motor system could effectively interface and convey how to weave a bamboo pattern to the user. Notably, future iterations of the prototype should also integrate in an interfacing system which allows for the uploading of new patterns by an external user.

S2: Summary of Design Activities (15 pages)

S2.1: Design Context: Interpretation of Opportunity and Value Proposition

The opportunity involves helping elderly women living in rural Thailand. After inspecting the challenge statement, we identified multiple challenges faced by the local members: **financial**

instability of the weaving occupation, health hazards experienced during bamboo processing and weaving, disruption of products due to mold, and a threat of extinction of tradition due to all of these factors. Given those issues, we identified the following stakeholders

- The Thailand elderly women who weave for a living (primary)
- Clients and customers (secondary)
- Younger generation of the Thailand Community (secondary)
- Thailand culture of weaving (tertiary)

Elderly Bamboo Weavers in Thailand are the primary stakeholder because they are the ones most directly impacted by the problem. The clients and customers are designated as secondary because they define the value of the bamboo products in the consumer market although maximization of the profit is not the sole purpose of this opportunity. Younger generations are also a secondary stakeholder because their participation in the weaving industry is crucial for the long term preservation of the culture. However, more immediate concern lies in the circumstance of the current bamboo weavers. Lastly, cultural authenticity of the product appeared to be less important to the Thailand community, which will be elaborated later, so it is placed as a tertiary stakeholder.

Figure 2: Photo of Bamboo Weaving (photo credits: getty images)

After reading the document and a round of secondary research (which are documented in the meeting minutes 1, 2 and the annotated bibliography), we have identified four main possible approaches: **a design that addresses the safety of the weavers** [5, 6, 3]**, a device that would ensure a high quality of the bamboo material, a mold prevention container**[8]**, or a tool that facilitates the education of new bamboo weavers.** At this stage, we established our first value proposition concerned with ergonomics design, which would be explained later.

During a meeting with the Opportunity Champion we enhanced our understanding of the problem. Main conclusions that this general research led to was how the core of the opportunity lied on the economical concerns. The value of the Bamboo products was diminishing due to the lack of variety in the woven patterns as well as the inconsistency in dimensions of the final products. Moreover, the Bamboo tradition was in risk of extinction due to the unappealing state of the occupation for the high learning curve yet low profitable nature of the activity. This led us to consider focusing on a design that would help the bamboo weavers increase the value of their products in the market.

Therefore, our final Value Proposition was refined to be **improving the profitability of the products created by bamboo weavers in rural Thailand**. This proposition led to define two potential approaches

1. Standardization of bamboo weaving designs between different weavers.
2. Education of more complex weaving patterns.

S2.2: Approaches to Providing Value: From Design for Ergonomics to Design for Education

Initially, our team was most concerned with the preservation of the traditional authenticity of the weaving products because that was a point of emphasis on the opportunity space document and we assumed it to be a critical element that makes the handwoven bamboo products valuable. With this value in mind, as documented in meeting 3, we tried to avoid a design that would directly interfere with the weaving process. For instance, we disregarded the idea of creating a machine that automates weaving because it takes away the cultural significance of the item. Therefore, we scoped down to either a creation of a bamboo processing device or an assistive device that assists in maintaining a good body posture of the weavers, which are both concerned with the ergonomics of the user. This led to our first value proposition before arriving at the revised value proposition (note that a different value proposition would later be introduced): the alleviation of pain of bamboo weavers while maintaining the cultural authenticity of the weaving process.

After we settled onto our initial value proposition, we had a meeting with the stakeholders, the Professors in Thailand who have ties to local bamboo weavers in the rural area. This correspondence is documented here. The main takeaway were the following:

- There were loss of bamboo products due to the emergence of mold
- The inconsistency in dimension of the Bamboo strips and the lack of flexibility in meeting customer preference led to the decreasing demand of the product

After this interaction, our team decided to rescope our approach, and this design change is briefly documented here.

What was emphasized was the degradation of value for the products due to insufficient adherence to demand. We focused on this aspect the most because

- While emergence of mold and inconsistency in dimensions seemed to be a critical problem, these were likely solvable by altering the material processing procedures using pre-existing techniques and machines.
- Low value in bamboo products is a more fundamental problem without an obvious solution that has been contributing to the decline in the bamboo industry.
- According to the Professors, the Bamboo weavers didn't particularly indicate any problems with their current workspace. This implied that an ergonomic design was unnecessary.

Therefore, we decided to focus on increasing the value of the products so that their market value is elevated, which led to our revised value proposition: improving the profitability of the products created by bamboo weavers in rural Thailand.

Within this value proposition, we considered two approaches.

1. Standardization of the dimensions of the bamboo strips to increase consistency in the products
2. Education of weaving to enable production of more complex weaving patterns and alleviation of the teaching process

We chose the latter approach due to the anticipation of a greater yield of value through fostering the economy and cultural preservation of the bamboo community (details of the rationale are found in meeting minutes and design requirements). Furthermore, the requirements model was made to reflect the value proposition. This required meeting both the consumer (client) and user demand, so our requirements promoted a consumer and user centric design.

The main functionality of the design is its ability to teach a variety of bamboo patterns with the flexibility for the clients to request special weaving orders to increase consumer demand of the products, which will be guided by the following objectives. They are ranked in the order of importance as justified in the requirements worksheet.

1. *Design with flexibility to teach weaving designs with different patterns, sizes, and shapes* (Objective 1): To allow bamboo weavers to learn different kinds of weaving patterns
2. *Accommodate designs imported by external sources* (ex: a design that could import weaving pattern images and convert it to signals that could educate the weavers how to weave) (Objective 2): Lack of adherence to customer needs, or the limited variety in the bamboo design, was one of the main factors for its low market demand. Design importability from the clients would increase the value of the products.

The DFX requirements focused on increasing convenience and the assuring operability of the design in the local space. The objectives are summarized below in order of importance followed by the rationale of incorporating those objectives.

1. *A design that only requires a power amount that could be sourced from the current working environment in Thailand* (Objective 7): The design must be compatible with the working space to ensure proper operation
2. *A design that is maintainable with the tools and skills available in the community* (Objective 6): Design must be maintainable using the tools accessible in the local space, or else, long term installment would not be possible.
3. *A design that is easy to us*e (Objective 3): Learning that the bamboo weavers generally exhibit low willingness to acquire new skills, the design must be easily understandable and usable in order to minimize the learning curve of the operation of the design.
4. *A design with minimal maintenance, installation, and manufacturing fee* (Objective 8): If a design cost interferes significantly with the profit of the bamboo weavers, the design would be better off not being installed
5. *Design that does not interfere with the existing weaving process while guaranteeing a design of equal quality if not better* (Objective 9 and 10): One concern we had is the potential for the design to disrupt the current working style of the weavers and the quality of the bamboo designs. As much as possible, the traditional authenticity of the design should be preserved, so the design style of the weavers should not be altered significantly.
6. *A portable design* (Objective 4): Informed that Weavers weave at different locations, both indoors and outdoors, the design must be carryable to different places.
7. *A design that can be easily and readily installed at different location*s (Objective 5): Design should be operable under different settings, even outdoors without an immediate access to various supplies (e.g. high voltage power port)

Further detailed justifications are found in the requirements document.

S2.3: Conceptual Design: One Row LED pattern indicator

After several meetings of diverging and converging, our team decided to settle on a design that contains two main parts. The first part (A) contains LED lights that provide a weaving pattern for the user to follow (top portion of Figure 3 below). The second part (B) contains sensors that can tell if the woven pattern is done correctly (drawn at the very bottom of Figure 3). Another key aspect of our design is the ability for customers to import custom weaving patterns/designs. Ideally, the two parts will work in harmony to provide a prototype that allows for full functionality and the most value to the stakeholder. Sketches of the design can be seen below in Figure 3.

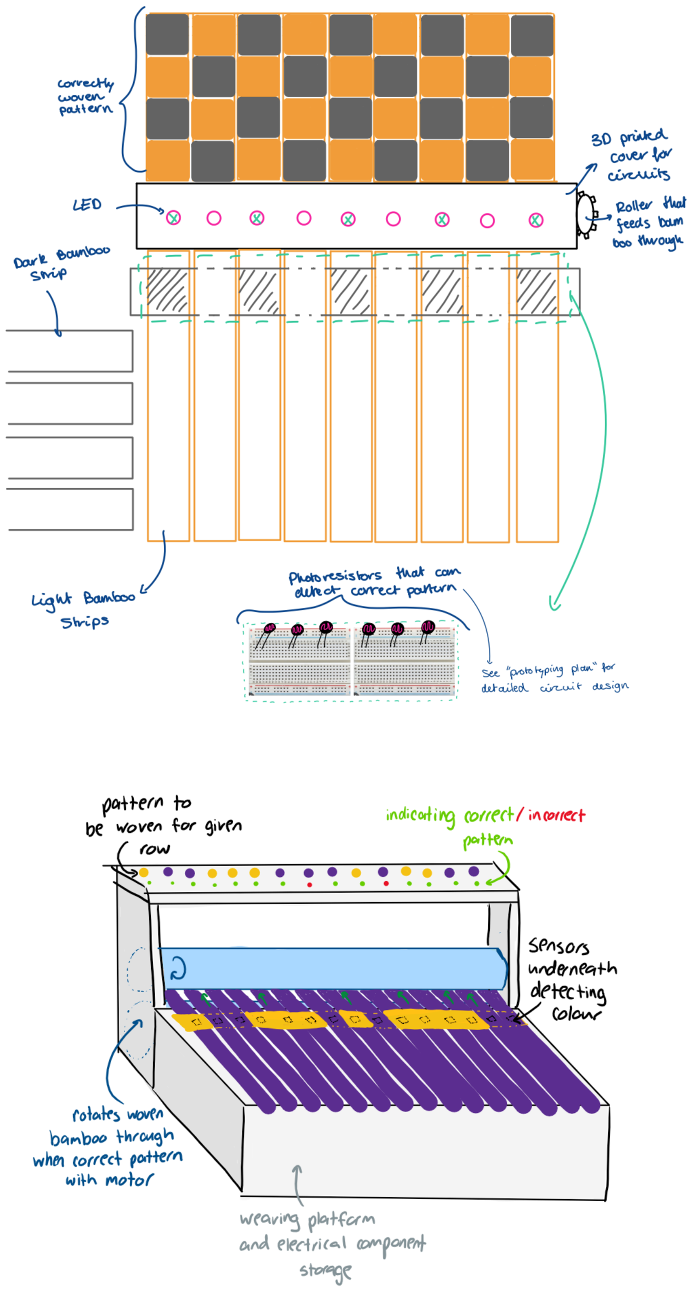


Figure 3: Sketchs of Design Concept

Part A:

Part A of the design features several LED lights in a row connected in line to a circuit and covered by a 3-D printed CAD design. The vertical bamboo strips can be fed through a slot in the 3-D printed cover and as such be held in place, while the horizontal bamboo strips will be woven over and under the attached vertical bamboo strips by the user. The weaver will weave according to the pattern visible by the LED's. The pattern provided by the LED's will change once the weaving of that pattern has been completed for the specific row in use. Part A of the design was first inspired by several of the reference designs. Specifically, the concept of learning a pattern from arranged colors was taken from the game "Mastermind", while the implementation of the LED's was inspired by "Lite Brite". Lastly, the concept of learning patterns from visuals was inspired from friendship bracelet patterns. We delve further into reference designs in the "Reference Designs" document in the dossier. Another element of the design concept is a roller system that will allow the bamboo user to move the completed woven pattern out of the way, and make space for new rows.

Part B:
Part B of the design includes RGB colour sensors that will be able to detect different colors. Therefore, the sensors will be used to detect whether the colored pattern of the bamboo is correct. A sensor will be dedicated to each vertical bamboo strip. The "Design Artifacts" folder contains a detailed sketch of where these sensors will be placed. A further extension to this part would be to connect the LED lights switching colors to the sensors. Hopefully this would allow the LED's to switch colors, given the sensors observe the correct colors. This would save the user effort.

Design Process

The design process was performed in two main stages, the diverging and converging stage. Specifically, during the diverging stage, we used several brainstorming techniques to accumulate as many ideas as we could. For example, we learned the very useful 6-3-5 technique in Praxis 1. The technique consists of 5 members, who write three ideas down on a paper each in 5 minutes. Then the papers are swapped and annotated by the others to comment on the design, suggest new ideas, extensions, improvements, etc… The "Diverging Evidence" folder in the dossier contains pictures of each paper. Another brainstorming technique used was the morph chart, which contains all the main functions we want the design to be able to perform, and then a list of ideas that perform each function. By the end of diverging, we had five solid ideas. The converging stage of our conceptual design process was slightly less formal, and occurred in a more discussion-like format. The five ideas were listed on a board (photo included in "Converging" folder), and we had a very good talk about each design, discussing the benefits and downfalls, and annotating each idea on the board. Furthermore, we made a Pugh chart which compared the designs against our requirements. One of the five designs was chosen as a reference design and the other four designs were either same, better, or worse, and were given a score of 1, 0, -1, respectively. The one row LED design had an outstanding score of 8, relative to the other designs that had scores of -11, -2, -5, -2. It is important to note that while a pugh chart is helpful too, it cannot be fully relied on for design decisions. For example, one of our designs which had the second highest score, did not have a mechatronic element and therefore did not fulfill the course requirements.

Justification of Design

Our design focused on easing the burden and inefficiency in the educational sector of weaving because we learned that education is a huge factor that affects the bamboo industry in Thailand. It takes a significant amount of effort for bamboo weavers to teach new designs to others in the current educational system. They rely on experienced weavers teaching others one by one using a paper instructional booklet, which is highly inefficient. Our design aims to fulfill all requirements, which will in turn benefit the stakeholder by easing the burden and inefficiency of the current education system. The first requirement **(1)** is accounted for by the design's ability to import any weaving patterns and display it on the LED lights. The second requirement (**2)** is also fulfilled by this aspect of the design as customers can send in custom designs. The third requirement (**3)** is fulfilled due to the design's simplicity and basic logic (light a certain color means weave a certain way). The design falls slightly short in the portability requirement (**4**), but portability is a low priority among all. Our design fulfills requirement **(5)** as it does not need many extra materials other than what is already in the design, and will require only a plug in to a computer as installation. The simplicity over other designs fulfills the requirement concerned with maintenance (**6**). Again, minimal connection is needed, and therefore the **(7)th** requirement is fulfilled with relative ease. The design also includes accessible and cheap electrical components and is cheaper than a lot of the alternative designs, so account well for the **(8)th** requirement. The **(9)th** requirement is yet to be determined, as we cannot predict how the Thai women will react to it. However, when we talked to the opportunity champion, they said the Thai people were not very receptive to new ideas. The **(10)th requirement** is also accounted for by having the weavers still weave the designs by hand. The only aspect that may potentially influence the aesthetics of the bamboo is the fastening of the bamboo in the CAD model, but the prototype is rather an educational tool, so the final appearance of the woven item has a lesser importance.

S2.4: High-Fidelity Prototype: Design for One Row LED Pattern Indicator

S2.4.1 – Q1.4: The Prototype and Its Evolution

Selecting our Design

Our design concept meets the objectives and requirements set out in the Objectives section. Our main objective was to produce a portable, easy to use, and can teach a large variety of patterns and designs to our users. It will be affordable, make learning a new pattern easy for users with minimal knowledge in technology.

To demonstrate these aspects of our design in our high fidelity prototype, we've decided to prototype two main components of our design: the basic LED lights lighting the weaving pattern and detection feedback of the actual weaved patterns, and the color sensor component that will crosscheck the woven pattern with the imported pattern and will light up an LED if the correct pattern is woven. Our team brainstormed four different designs for the color-sensor-feedback component of our design, and five different designs for the basic unit which displays weaving patterns and allows the user to follow this learning process. We converged after lab 5 when we gained a better understanding of sensors, arduino, and microcontrollers. We converged as a team to finalize our prototype to color-sensors and LED lights blinking the patterns that the user wishes to learn. We realized that we could achieve the same result using simpler materials. For example, we all agreed that displaying the patterns using a hologram and projection was very unrealistic and did not meet our 'cheap and affordable' objective as well.

Main Components

Part A: LED Pattern

Part A of our prototype demonstrates how we use LED lights to display a particular pattern that should be woven. When the correct colour for each segment is woven, a green indicator light will turn ON. The Raspberry Pi PICO is used for the array of 5 pattern-indicating LEDs. The color sensors will detect the colour woven by the user and compare it to the correct pattern. If the woven pattern is correct, then the LED lights will change to the next horizontal line of pattern, and the process repeats.

We will create the protective case for the basic unit and attach it to a platform which provides the user with a portable working space. Integrating a portable working space into our design will allow them to weave comfortably at any location.

Part B: Color detecting sensors feedback component

The color detecting component of the design will be placed directly below the bamboo being woven and attached to the weaving platform upside down with velcro. We will connect the Arduino Nano RP2040 for the color sensor. The design will include a colour sensor for every column of the pattern, however one colour sensor may be used to simplify the prototype if needed.

Various ranges of the colour sensor must be investigated to determine proper threshold values to detect the colour of the material being woven. The design concept will be able to detect any RBG value, however simplification to contrasting colours or shades (such as red, blue and yellow or black and white) may be used in the prototype if more intricate threshold values are unreasonable to achieve in the timeline.

Prototyping Plan for Week 7 to Week 10:

We are planning to devote at least 3 weeks to build a working prototype containing part A and part B components. More details of our prototyping plan can be seen on our team Notion (Design Dossier 1 Notion, Design Dossier 2 Notion) calendar as well as summarized here.

Evolution of Prototype:

Below, primary prototype changes are discussed and categorized by sub-system.

Motor

1. Modification of Lab 6 stepper motor system, with one button

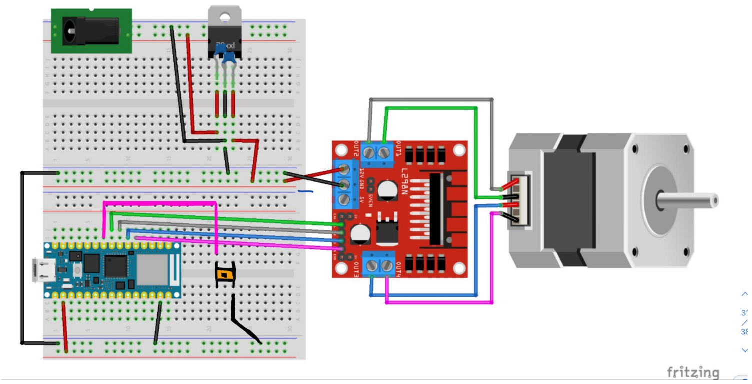


Figure 4: Schematic Diagram of version 1 of the Motor System (click on image for enlargement)

We initially wanted to design a simple motor system that could rotate a two-cylinder dispenser system that allows the bamboo strips to be fed forward toward the user. When the button is pressed, the motor rotates, when the button is not pressed, the motor stops rotating. The speed of the motor rotation is fixed in the circuit python code.

Problems:

It does not consider boundary conditions such as: 1. a possible jam where the motor needs to rotate backward, 2. The user pressed the button for too long by accident, causing bamboo strips to be over-pushed, 3. Lack of precision in pushing forward the bamboo strips, for example, one speed for the motor cannot account for the needs of the user to control how much of the bamboo strips they want to be pushed forward to the working area, 4. There was a wiring mistake in the schematic diagram provided in lab 6 on how to rotate the motor, 5. Code issues, we had to do trial and error on changing the pin in the code to match it with the circuit schematic provided. It was a very painful and time-consuming process. 6. The Arduino nano is very expensive, our sensor/LED system also uses this particular nano microcontroller, therefore we could not risk burning it during debugging the wrong circuit schematic diagram in lab 6.

2. Three buttons system

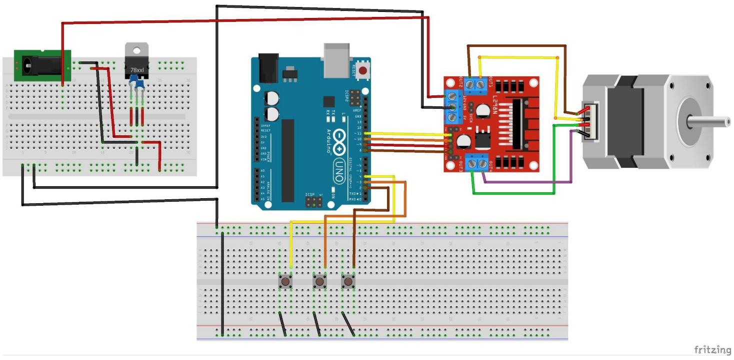


Figure 5: Schematic Diagram of version 2 of the Motor System (click on image for enlargement)

In order to satisfy all the boundary conditions outlined in the previous process and allow more control over the motor rotation. Three buttons were implemented, each button can rotate the motor forward (counterclockwise), backward (anticlockwise), and stop the rotation entirely. We used the less expensive Arduino Uno R3 for the motor system to account for possible mistakes we might make during debugging. In addition, the Uno's on-board regulator can handle up to 20V, tested to be able to handle 17.8V, it is safe to test our 12V powered motor on it and it costs much less than the Nano.

Problems:
The user cannot control the conveying bamboo process with great precision, because the speed is fixed by the code. If the user wants to feed the bamboo strips forward to their workspace only a small amount, they must react very fast to control the forward and backward buttons, which isn't very user-friendly.

3. Three buttons and adjustable speed

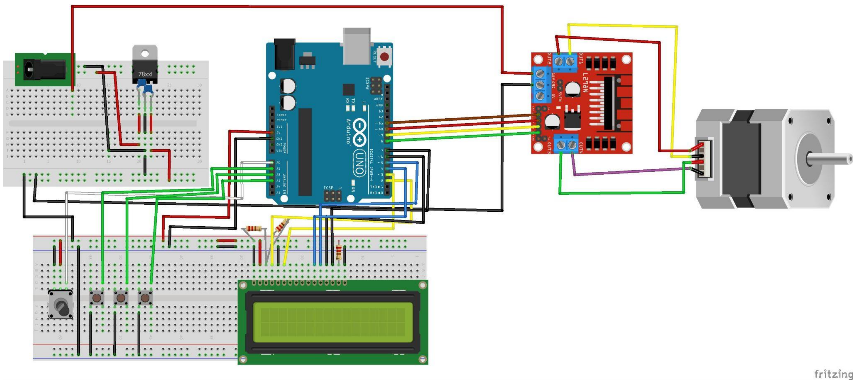


Figure 6: Schematic Diagram of version 3 of the Motor System (click on image for enlargement)

In the final version of the design for the motor component. We added a potentiometer to control the speed of the stepper motor, and an LCD display that shows the speed in percentage. The three push buttons control the motor by moving forward, backward and stopping entirely. This design allows the user to have more precise and personalized control over the feeding mechanism of the bamboo strips, satisfying our requirements of being easily maneuvered and requiring minimal technical skills to operate it.

Structural

1. *Connect CAD parts 1 and 2 (as described in the System Architecture) using a screw*

Justification: When making sketches for the structure as a whole, we were discussing how to connect the protective case with the adjustable support system. We figured that since we needed to have a screw on top of both sides of the adjustable support system in order to move the cylinder, we would just use that same screw to also connect the protective case which would go on top of everything. That also allowed the parts to be easily disassembled as needed.

2. *3D print a cylinder that perfectly fits the motor*

Initially, when designing the structural component, we anticipated that we would be using two PVC pipes. But after we started working on the CAD, specifically the component that has the hole in which the motor would go in (in part 1), we realized that if we wanted the lower cylinder to properly spin according to the movement of the motor, it had to perfectly fit. Since the extension of the motor that rotates isn't perfectly circular (as seen in the CAD drawing), we decided to 3D print our own cylinder with the same type of hole. This as well gave us the flexibility to make the cylinder as big as we wanted, which was essential since we recognized when doing the CAD, that the cylinders had to be relatively big to be able to reach each other.

3. *Dividing the adjustable support system in multiple pieces*

To facilitate the CAD of the adjustable support system and its 3D printing process, the adjustable support system which was initially designed to be two big identical pieces, was broken down into more components as it will be explained in the iterative process section for this system.

Sensor/LED

1. *Use only 1 colour sensor*

Justification: Given the budget constraint of the project and the relatively high price of colour sensors, we decided to only include 1 colour sensor in the prototype. Therefore, the pattern detection is only based on the first column of the pattern being correct.

2. *Black and white detection instead of multiple colours*

Justification: After setting up the colour sensor and writing preliminary colour detection code, we decided that in order to achieve more reliable results we would only use black vs white detection in the prototype. This allowed for factors such as lighting and shadows to have less of an impact on the sensor results. Furthermore, the use of a single threshold value allowed for easy adjustments in the integration process.

3. *Adjustment of threshold value while integrating*

Justiciation: Initial testing (see Colour Sensor Meeting Minutes/Notes) involved placing a finger directly over the sensor to represent "black" and the light of the room to represent "white". However, once integrated with the structural system and using pieces of black and white paper to represent bamboo, we realized that different threshold values were needed. Our easily modifiable threshold value allowed us to adjust this value based on the readings we were receiving with our full prototype system, resulting in a value that reliably read black vs white in our final prototype.

Rationale for the final prototype system architecture:

Our prototype is intended to convey the possibility that a certain weaving pattern can be taught to be woven out of instructions displayed on a physical autonomous system. This articulates the potential to teach weaving patterns without having anyone physically teach you the steps in person. Therefore, our design must be able to instruct the weaver, detect incorrect weavings, and maximize convenience in operating the design.

Having said that, our system architecture includes the following components:

1. **A row of LED**: Allows to instruct the desired weaving pattern by indicating the arrangement of the Bamboo strips
2. **A color sensor**: Enables correction of the weaving by detecting when the weaver places the wrong colored strip on the top. Note that the “Bamboo strips” will be resembled by a white and black strip of paper
3. **A Motor with a cylindrical extension**: Many bamboo weaving patterns are created by the overlap of horizontal and vertical strips. Long bamboo strips often remain dangling from the edges in front of the weaver, interfering with the workflow. A motor system enables the strips to move forward between the space between two cylinders. This maximizes the working space of the weavers to weave the unwoven parts thus increasing the convenience.
4. **A structural system**: Adjustable pillars with springs allow for the adjustment of the cylinders to be tight enough to shift the bamboo through. A 3D printed casing surrounds the LED circuit and a wooden platform holds the colour sensor and also acts as a weaving platform.

Some compromises were made on the scale and features of the design, which is noted in the *Evolution of Prototype* section. Notable adjustments include

1. **Weaving on a 2D platform (and the limited shape to a 2D weaving product)**: Our prototype serves as an educational device that fosters the early stage for bamboo weavers to learn new design patterns. The emphasis is to help bamboo weavers understand the basic structure of the bamboo design and be able to apply the knowledge in order to eventually weave without the facilitation of the prototype. Therefore, it does not necessarily have to allow the production of a complete bamboo good that is readily saleable on the market.
2. **Usage of proxy bamboo strips (colored paper strips) instead of real bamboo:** Similar to the earlier argument, because the motivation of the design is to help weavers learn a new design, the physical outcome is not the focus in this instance. Therefore, those colored strips are a valid material to be used as an educational tool to support learning.
3. **Usage of three microcontrollers**: A Raspberry Pi Pico, Arduino Nano, and Arduino Uno were used to execute the tasks. Since each part was physically distanced from each other, it was more convenient to use different microcontrollers instead of having multiple long wires extended to different parts of the prototype. This way, the number of visible wires was reduced although the complexity of the design may have increased by adding the need to interface the arduino and the pico board for the LED and color sensor feedback mechanism.

S2.4.2 – Q1.5: Detailed Design, Debugging and Prototype Communication Purpose

Detailed Description of Design:

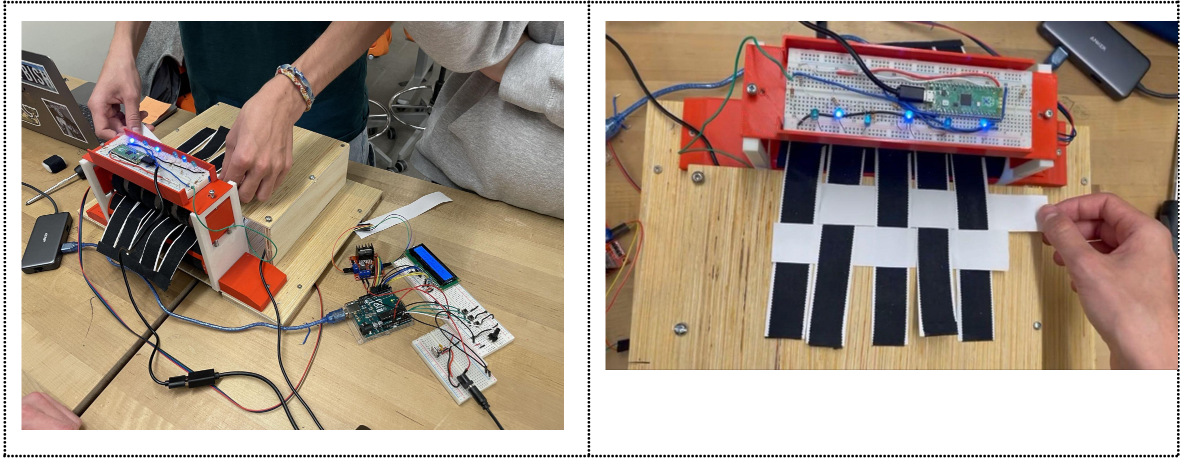


Figure 7: Fully functioning high-fidelity prototype (click on each image for enlargement)

Bamboo strips are represented by black and white bendable strips. The structural component is composed of two cylinders, the rigid cylinder with a larger diameter is placed on the bottom, and attached to the motor and a soft compressible cylinder is on top of it. Its rotational motion is controlled by the stepper motor that allows the cylinder to spin in both clockwise and counterclockwise directions with adjustable speed. There are three buttons in the motor system, a button that turns the motor clockwise (feeding the bamboo strips forward toward the user), a button that turns the motor counterclockwise (backing up the bamboo strips, moving them away from the user), and a stop button that stops the motor. The knob, located next to the buttons, will control the motor's speed, and the motor's current speed will be displayed on the LCD screen.

The wooden box provides a working area for the user to weave the patterns at a comfortable height. The LED lights system is placed on top of the two cylinders and display various patterns to guide the user on what pattern to weave next in a sequential manner. Expand the number of LED lights and increasing the complexity of the patterns can be achieved easily in future design iterations.

A colour sensor system is attached to the wooden box, through the small square opening on the wooden surface. As the motor/structural subsystem pushes bamboo strips toward the weaving area, LED lights are blinking in designated patterns for the user to weave. Once this section of pattern has been woven, the colour sensors will check the correctness of the pattern from the bottom up. Once the checking is completed, the user can control the motor/structural system again to push the bamboo strips further toward the wooden workspace. More photos of the final prototype and final sub-systems can be seen here.

Iterative Process of Building and Debugging

Motor

Most of the debugging problems we have encountered in designing a fully functioning motor system came from correctly wiring the 12V power supply to the stepper motor.

Version 1: *Modification of Lab 6 with one push button*

Initially, we only wanted one push button to control two states of the motor, rotating and not rotating. We added a button to D6 of the Nano and kept the entire circuit the same as lab 6. However, we noticed that the red LED on the L298N motor driver that was shining very brightly in lab 6 was not on, indicating there was an error in wiring.

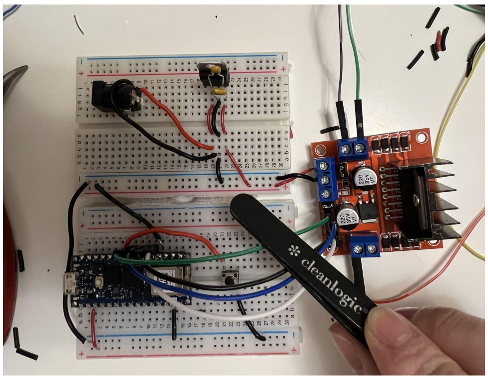


Figure 8: Motor System

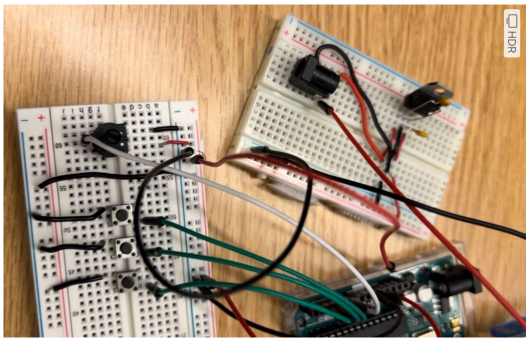


Figure 9: Button System

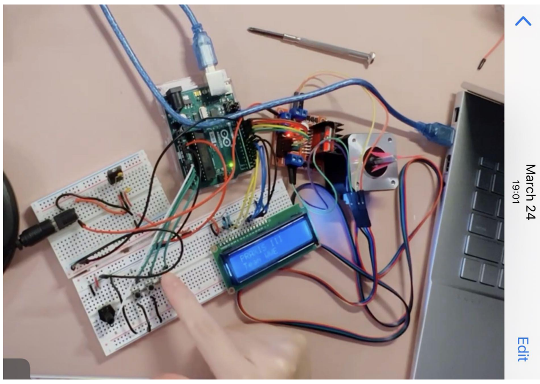


Figure 10: Complete system

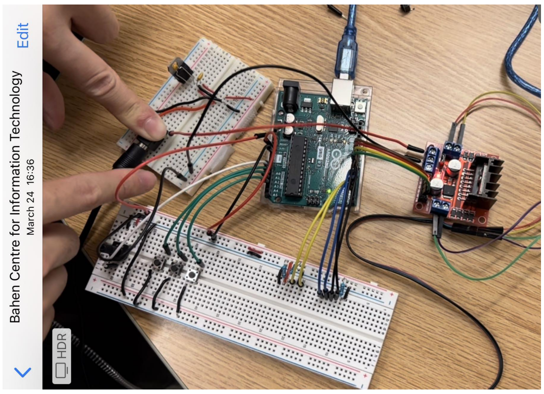


Figure 11: Complete System 2

More detailed iterative debugging documentation for version 1 and version 2 of the motor system is found in this document.

Final Design: *Using Arduino Uno, three push buttons, Potentiometer and LCD display*
Changes made:

- Modification: adding a potentiometer to control speed of motor, an LCD displaying speed

Debugging:

- Testing only the buttons, potentiometer and LCD display. Only motor part is not functioning
- Connected the ground of the power supply breadboard to the button-potentiometer-controller board, connected this ground to the GND of the motor driver, and connected the red wire (power) from the barrel-to-breadboard connector directly to the 12V port on the motor driver. This was the correct connection, the motor driver's LED started to shine brightly and the motor was rotating.

Structural
The structural component was key, and it was heavily emphasized by TA's to have it completed early and correctly, as the structure is crucial in order to hold everything together and integrate the electrical systems properly. The structure was split into two parts (both 3-D printed and designed using Fusion 360). The first is an adjustable side (Figure 13) with the purpose of being able to regulate the height of a cylinder, and the second being a protective case and cylinder (Figure 14 & 15).

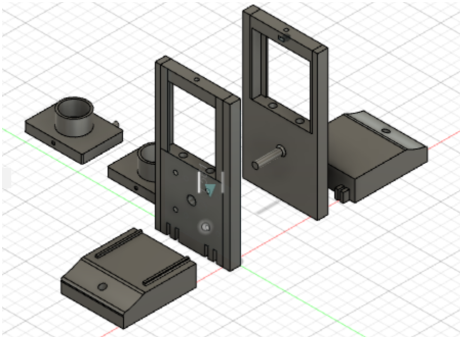
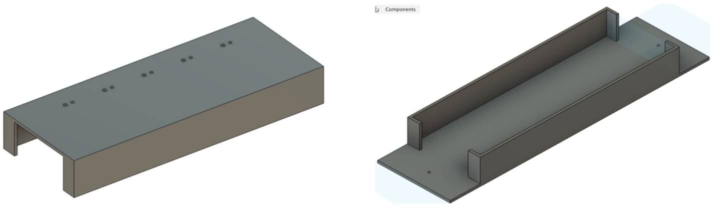


Figure 13: CAD model that was 3-D printed



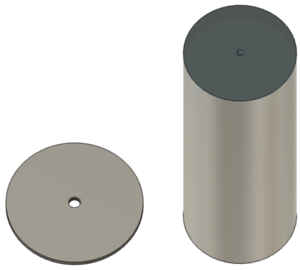


Figure 14/15: CAD of the cylinder and box

For part 1, the following steps were taken in the iterative process, and are elaborated in much more detail in the "Iterative process for structural sub-system":

1. Reference designs and inspiration from external sources, **2.** Make an initial design and sketches., **3.** Design on Fusion 360. **4.** Print the CAD from fusion 360. **5.** Troubleshoot the printed design

For part 2, the steps taken in the iterative process are enumerated below. Note that they are described and justified in detail in the "Iterative process for structural sub-system":

1. List the set of components we want the protective case to have based on what we need it to do, **2.** State the main goals of the cylinder, **3**. Correspondingly make sketches/come up with a design, **4**. Perform any needed measurements/calculations, **5.** Create a CAD of both the protective case and the cylinder using Fusion 360, **6.** 3D print the CAD, **7**. Troubleshoot the printed design

For the protective case, there were four essential components that had to be implemented/designed for:

1) Holes for the LED light pattern to be visible
2) A space from which the wires of the board connected to outer components can come out of
3) A base that can be connected to the other part of the structure through screws
4) A case that can be disassembled to easily place or remove the circuit

Sensor/LED

Details of the building and debugging will be found here, which will be summarized below.

Material Selection

We began by selecting the materials that would be incorporated into the design: rows of LED, color sensor, Arduino Nano, and Raspberry Pi Pico. The initial plan was to have two different colors of LED that would resemble the position of the horizontal and vertical strips. But we decided to use a blue LED and have the ON and OFF signal to indicate the position of white and black strip respectively. Other design changes/evolutions are as noted in the *Evolution of Prototype* section.

Color Sensor Debugging

We ran into some issues with the operation of the color sensor. We used both the Raspberry Pi Pico and Arduino to run the sensor. Some notable errors include:

1. Pico detecting a microphone instead of a sensor.
2. Error outputting "does not have module attribute I2C". → imported library

After consulting the Myfab staff, we were informed that they were encountering the same issue. We were told that Arduino was more promising, so we transitioned to the Arduino board.

1. Arduino Error: "can't open device "\\.\COM4": Access is denied.".
2. Response: conducted a factory reset and it properly outputted the detected color values

Now a connection between the color sensor and the microcontroller was established.

Color Detection Code Debugging

Our "bamboo strips" were proxied by white and black strips, so the color sensor needed to distinguish between black and white color. This was done by taking the average of all the detected color values. We also defined a "black threshold" that corresponded to the maximum color value that would be outputted as detecting a black object. Any value higher than the threshold was considered as white. Also, we realized that there needed to be sufficient light passing through the gap above the sensor, which is a notable edge case to consider under dark environments. For our prototype, we addressed this by inserting a light source right beside the color sensor.

Interfacing between Pico and Nano

The pico board controlled the display of the LED while the Nano controlled the color detection. Now, we want it so that when the right color is detected, the LED pattern is changed to the next sequence of LEDs. We accomplished this by sending a HIGH voltage signal from the Nano when the color sensor detected the expected color. This signal would be received by defining the pin on Pico as an input, changing the LED pattern when a voltage signal is detected. The communication was established by binary signals, in which a HIGH value signified that a correct pattern was woven. Some errors and debugging measures included

- False detection of the signal by Pico as HIGH when the output was a LOW.

It turned out that our expectation of a HIGH on the pico side was different from what was defined as a HIGH in the Pico.

How will the design concept perform against our requirements?

Given how similar our high fidelity prototype is to our design concept (apart from minor simplifications), it is relatively fair to assume that however the prototype performed would be representative of how our design concept would perform against our requirements. We came up with the following functionalities to test based on the three subsystems of our design concept: The prototype should feed strips forward, should detect and distinguish between white and black strips, and the indicator LED should light up when the detected color is the same as the desired color displayed by the LED patterns (correct interfacing between two microcontrollers). The functionality of the three subsystems was a crucial step in finalizing our prototype. If the three functionalities worked in harmony, the prototype was considered complete and working. The results of the testing, procedure, and outcomes can be found in the final prototype testing document in the testing folder, along with a video of the final prototype function. After the testing was complete, the model could be evaluated with our requirements model found on the requirements worksheet. The two primary functional requirements, with respective sub-requirements are:

1. A design that teaches a wide variety of weaving patterns and designs (Accommodate wide variety of patterns. Accommodate a wide variety of bamboo design sizes. Accommodate wide variety of design shape)
2. Adheres to customer demand (Import different designs. Adjustable by different sources)

Analysis of prototype against requirements

With the prototype functioning, it accomplished nearly all of the primary functional requirements. While it was limited to one weaving pattern (a simple under over pattern), the point of the design is to allow for users to import their own code for specific demands. Therefore, the fact that the prototype only has one pattern is more of a dummy example of what the pattern "could" be, rather than a limiting factor. This effectively means the prototype fulfills objectives **1a** and **1b**. Where the prototype falls slightly short is its accommodation for different design shapes. As of now, the prototype only accommodates a rectangular shape where strips are woven horizontally through vertical strips. Circular or three dimensional designs would not be manageable for the prototype and the design concept as of now, meaning the design would not meet requirement **1c** very well. However, the requirement is a motivating factor to create a better design that can indeed handle intricate shapes, and potentially multiple dimensions. In terms of the second objective, assuming the stakeholders that are in demand of bamboo patterns provide code for different patterns, the design certainly allows for objective **2a** and as such would be able to change the pattern according to the stakeholders desired, meeting objective **2b**. The main lesson we have learned from our testing is that our prototype, besides the simplifications, functions almost exactly how the design concept was intended, but lacks in the specific area of accommodating intricate shapes. However, this was a good sign to us, as it implied the design is relatively easy to create, as we were able to create a fully functioning prototype in a matter of weeks. While testing, we also learned that many of the DFX's (also listed in the requirements worksheet) were met. For example, moving the design around from room to room for testing/storage was not too much of a hassle as the design breaks down entirely into its individual subsystems– the structural subsystem breaking down further into each individual 3-D printed object. As a result, objectives 4 (**A design that is portable**) and 5 (**A design that is easily installable**) were met.

Future Work & Improvements

Although we did end up having a working prototype that integrated all the different components, there is room for some improvements to be made. **1.** For the electrical part, implementing more LEDs and color sensors that could detect several colors could allow weaving more complex patterns. Moreover, since the open air is currently considered as "white", our next step would be to define an intermediate value between black and white so that the detection only occurs when the right strips are on top. Another future step for electronics would be to use serial communication instead of binary signals to be able to deliver different kinds of signals to interface microcontrollers. **2**. For the structural part, the iterations made manually (such as filing/carving etc.) could be instead changed on the CAD and 3D printed again, for more accuracy. That being said, if upgrades were to be made to the design in the future, the structure would have to be redesigned correspondingly. **3**. Lastly, the motor driver being used right now tends to get very hot with time and shouldn't be used for prolonged periods. Therefore, in the future we plan on using an alternative motor driver that can be used to limit the amount of current supplied and prevent overheating.

S3: Statement of Collaboration (3 pages)

Team Strategy and Values Statement: We are a team that values diligence, respect and having fun while working hard (see Team Charter for additional values). Our general strategy as a team is to divide work into sub-teams with individuals working on things that excite them, while also keeping the whole team updated with individual work and seeking out advice from others. Additionally, through our project management tools such as Notion, we hold each other accountable for the work one another is doing. Further details of our team's organization and communication are discussed below. See compilation of team meeting evidence here.

Q#2.1 How did you organize yourself as a team, and why?

Our team is structured with all individuals on the same "level". During in person meetings, we assign roles evenly to all team members based on their interests. We recognized that all individuals on the team want to gain technical skills as a primary goal (see Team Charter motivations table), therefore it would seem unfair to make one team member take on a greater amount of team management skills. As we moved forward into the second stage of the project and began prototyping, we assigned roles of individuals to different subsystems as seen in our System Architecture. These roles were assigned based on the *motivations* and areas of desired growth each of us had as much as possible (see Team Charter). Our team goals were discussed at the beginning of our team formation and are discussed in greater detail in our Team Charter.

Q#2.2 How did your team communicate and interact? Was this successful? Why or why not?

Our team interaction consisted primarily of in person meetings which we found highly effective, in particular for brainstorming meetings. We had attempted an online meeting, however found the team had low energy and decided we were more easily distracted. During these in-person meetings we have identified a few strategies that have led to the most progress as a team.

The first is having a space to **visually represent our** ideas. We realized this by accident when we met in a tutorial room with a blackboard- it was during this meeting (see Meeting Minutes 03-02-23) that we were able to brainstorm a new value proposition idea based on discussions with the design champions which we have now decided to pursue. The blackboard aspect of our discussion was critical in explaining and adding onto each other's ideas. Since then, we have actively pursued meeting locations where a drawing space is available and have found similar success (see 635 video with whiteboard and paper drawings for diverging). Additionally, our team ***actively*** **seeks each other's opinions**, especially when making a final decision. For example, if one team member has not had much input on a decision we are making, a team member will ask them for their thoughts before a final decision is made. A recent example of a contribution of this nature resulted in our team more carefully considering the scope of the course and what was realistically prototype-able. When working on our prototype, we communicated updates between subsystems via discord. This allowed the team to stay updated with other subsystems, encourage one another while also not wasting valuable in person time.

Q#2.3 How did your team use Project Management structures to move your design process forward?

We first established the Team Charter to explore an effective workstyle of the team which enabled us to realize our strengths and weaknesses as a team. For instance, we were good at integrating and building up on each other's ideas, so a group meeting was suited for initiation of new creative ideas. However, we also realized that we occasionally got sidetracked during conversions, which suggested that we were more productive at executing non-collaborative work on our individual times. Therefore, we established a working structure with a mixture of team and independent work. To manage the responsibilities to fulfill, we utilized the responsibility tracker and notion. In particular, we found notion to be very helpful. This ensured that there were no duplications on the assigned tasks and enabled team members to know who to consult when we had queries about that task.

We also created meeting minutes which facilitated the process review work. This helped us to review, revise, and refine our work by having a platform to refer back to and cross reference current ideas with previous discussions. Detailed description of the functionality of this artifact and the outcome is noted in the teamwork process review.

Discord was increasingly useful for project management in the prototyping stage. While we still used notion to assign roles and dates, Discord was used to communicate between subsystem teams by creating separate chat channels. This allowed team members to talk to individuals in their subteam, while also keeping the rest of the team up to date. While we acknowledged that we are working in sub-teams, we also knew that these subsystems must be eventually integrated. Discord additionally allowed us to share photos and videos easily with the rest of the team. This is a significant accomplishment to our team as after Assessment Point #1 we recognized that we could improve upon updating team members on individual work (see teamwork process review for more details). We are proud that this is something we achieved in the second half of the project. Not only did this update team members, but also provide an opportunity to celebrate each others' successes.

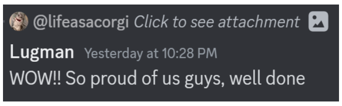


Figure 16: Celebrating integrating prototype successes on Discord

Q#2.4 How did you document your teamwork process throughout the course?

Our teamwork documentation started with our first meeting and the development of our Team Charter. This document outlines our team identity, communication and interaction plans. Some of the most significant discussions, however, revolved around explaining our individual strengths, areas for improvement and motivation. It was important that this was clearly outlined from the beginning of our team formation as it allowed us to take advantage of our existing skills (for example in the prototyping skills assignment we knew how to effectively assign roles), as well as support one another in pursuing things they want to improve upon. We plan to reference the team charter and further discuss our interests when breaking down additional prototyping plan details. Additionally, a few weeks after our team formation, we adopted Notion for team planning which contributed to useful outlining of team and individual tasks. More details can be seen in our Teamwork Process Review.

Planned vs Realized Timeline

When making the planned timeline (summarized here as well as Notion), the main goal of our team was to organize it in a reasonable, yet optimistic way, which is mainly the reason why some main events occurred later in time than what we had anticipated. Although we finalized the prototype and had a working design by the week of April 3-April 7 as predicted, a few things did not go as planned.

For the electronics related tasks, the main end objective was to be able to interface the LED pattern and the sensor. This task was scheduled to be done by March 25, but it was actually done on March 31. This is partially because the sensor wasn't ordered right away, due to a delay in deciding which sensor was needed and how many were needed. From that point on, we decided that we should avoid delaying ordering materials. Moreover, setting up the arduino and sensor took longer than expected which also slowed down the timeline.

For the structural related tasks, we started the CAD earlier than we had scheduled because we thought that starting it earlier would give us more time for iterations (March 15 instead of March 21), which was a crucial move. In fact, working on the CAD was a long process, specifically because of changes during the design process. We had to reiterate our initial idea to optimize the efficiency and precision of the model, to ensure both CAD parts integrate well together. Because of the time iterations took, 3D printing the design occurred later in the timeline. Nevertheless, with setbacks from other sections, the timing of when all main components were done was aligned well.

Finally, for the motor system related tasks, due to the complexity of making the power supply connect to the system, the debugging of the motor system took a while. However, having completed Labs 5&6 in previous practicals, we knew that making the motor work would be a difficult task and hence scheduled to have it done as late as March 26. But, as a result of constantly working on it, it was fully functioning by March 24.

Individual Contributions

Specific individual contributions are clearly laid out with due dates and prioritization of tasks at the time they were assigned. Additionally, the "Board View" of our Notion board under "Tasks" is actively used by the team to keep track of tasks throughout the project. This feature allows the team to see all tasks in calendar form, as well sort for their individual tasks in board view. The prototype foci of each individual are outlined below in Figure 17. As previously discussed, our team split up into subcomponent teams. While we still discussed things as a group and major changes were decided as a team, each sub-team was responsible for the more technical aspects of the subsystem. Details on specific contributions to deliverables and prototypes are listed in the Responsibility Tracker.

Team Member	Sub-System	Primary Prototype Contributions
Alice	Motor	Motor subsystem
Emily	Structure	LED Casing, Turning cylinder
Hikaru	Sensor/LED, Motor	RGB sensor detection, Pattern indication and changing
Alex	Structure	Adjustable side support system
Grace	Sensor/LED	RGB sensor detection, Pattern indication and changing

Figure 17: High-Level Outline of Prototype Contributions

Areas for Team Improvement

After completing prototyping, we realized that an area that our team could have improved upon is more carefully planning out the less critical aspects of our prototype. When setting a timeline initially, we carefully planned time to design, prototype, iterate and test the primary components including the motor, sensor/LED and structural systems. We also knew that we needed a base to secure the various components, however as this component was not as complex, we left it until the end with a "we'll just quickly get it done at the end" mentality. This resulted in us not realizing we needed additional materials until the last minute and rushing to get it done. Similarly, for our Design Dossier I, we left the Annotated Bibliography until the end with no clear assigning of who was responsible for it. In future projects, we should remember to prioritize what is important (as we have already done), while *also* taking the time to plan simpler aspects of the project so that these do not cause stress and rushed work before a deadline. Even basic parts of a project require planning. Additional areas of improvements are elaborated upon in Teamwork Process Review.

S4: Annotated List of Supporting Artifacts (6 pages)

1. Annotated Bibliography: Preliminary Research for Scoping In and Out

This artifact is the compilation of the annotated bibliography we have done as a group to familiarize ourselves with the context of this opportunity. Most of the research that is documented here was done during our individual time before coming up with our first value proposition as a team. These research served as our basis to identify challenges the stakeholders are facing and as a resource to justify our reasons to focus on a particular approach. This process later functioned as a resource to cross reference with the ideas mentioned in the meeting with the local stakeholders to identify areas of overlap to determine issues that are actually worth addressing. Different resources served different purposes. Some resources were more informative about the context in Northern Thailand; others were about case studies in which researchers explored ways to improve the bamboo industry in Thailand; another source offered inspiration for reference designs for the current tools that were used in processing bamboo. Overall, this artifact formed a good foundation to be able to accurately frame the opportunity to create a meaningful solution.

Path: ESC204 Team → Research → Annotated Bibliography Compilation

2. Team Charter: Exploration of Team Structure

This artifact was initially created in the first studio but has been updated constantly throughout the design process as we gained greater understanding of our team dynamics. This activity served to explore and establish the team structure we were going to operate in by discussing our preferences, goals, and values. It was a way for us to seek the optimal method to communicate and function as a team. On top of that, we
created some interaction protocols to lay out the expectations we have as a team when we engage with each other. In these ways, team charter was a tool that facilitated a smooth team engagement experience throughout the first Praxis III phase.

Path: ESC204 Team → Teamwork → Team Charter

3. Requirements Worksheet: A Guidance to a Feasible Design

This artifact was created during our team meetings as we changed our value proposition. It documented the reframing and rescoping we have done after the meeting with the local stakeholders that led to a shift in our value proposition and approaches. We also established a requirements model that lays out the DO (functional requirements) and BE (DFX) of our design. This process was useful in ensuring our team had a justification for every step of our design decisions. It also organized our ideas as a team and made sure all the members were on the same page with the types of design we wanted to create. Most importantly, this document served as a guidance during our subsequent diverging phase and helped converge down to a feasible design with sound arguments.

Path: ESC204 Team → Design & Prototyping Plan → Requirements Worksheet

4. Lab 5 and 6 Documentation: Inspiration for a Viable Prototype Design

This artifact is a documentation of the lab 5 and 6 activities that includes answers to the discussion questions as well as discussion of potential uses of the sensors/actuators in our actual prototype. It was created during studio hours as well as outside of class to do some research on the functionality of sensors and actuators. This lab was useful in offering an inspiration for how we could attain the functionalities we have specified in the requirements document and the concept designs. For instance, we wanted a feature that could detect if the bamboo weavers were properly following the steps indicated by the design. To do this, we envisioned using LEDs to create weaving patterns to guide the weavers and photoresistors to detect the amount of LED light transmitted through the bamboo strips to indicate whether a strip was correctly placed on the right place or not. We found this activity useful in ensuring the feasibility of our concept designs.

Path: ESC204 Team → lab 5&6 → sensors and actuators

5. Meeting Minutes: Collection of Team Conversations

This artifact was created during every team meeting to document our discussions. We included goals to accomplish for each meeting, details of the discussions, and questions/next steps to take before the next meeting. This made sure our team was on track and was aware of the tasks to be completed during and after the meeting.

Path: ESC204 Team → Meeting Minutes

6. Video recording of a team discussion: Footage of Team Design Process

Our team meeting video captures one of our diverging meetings where we used the 635 brainstorming tool. In this video we brainstorm design ideas individually first, each with our own drawing space and pen. We also played fun music to motivate ourselves and encourage creativity. At the end of each song we switched spaces and added onto each others' design ideas. After we iterated through this process, we came together as a team and discussed all of the ideas that resulted. Finally, we summarized the key design concepts on the white board. This video highlights our teams' intentional use of drawing space, inclusion of our value of "fun" as outlined in the team charter, and balance of individual and group work. The video illustrates how our team functions by building on top of each other's ideas while inviting critiques into the discussions as well. A clear record of our previous discussion helped us to later develop the Morph chart and Pugh chart to compare different designs.

Path: ESC204 Team → Diverging Evidence → 635_Team_Meeting
Path: ESC204 Team → Diverging Evidence → 635_Discussion

7. Responsibility tracker artifact

This artifact was created on a spreadsheet during studio 5 alongside the task tracker on notion to manage the responsibility of each member. We documented the responsibilities with the due date and indication of urgency by assigning a number between 1~3 with 1 being the task with the greatest priority. It served as a "todolist" that reminded ourselves of the duties we had to complete. This was distinct from the task tracker on notion because the primary function was to visually organize the responsibilities and ensure that each task was done. In contrast, notion offered a broader view of the entire design process and how each responsibility fitted within the bigger picture.

Path: ESC204 Team → Team Planning → Responsibility Tracker

8. Project management artifacts

This artifact was created on notion towards the beginning of the design process to organize our individual roles and overall design schedule. This platform enabled us to assign individual tasks to team members with the capacity to notify people via email as a reminder. We documented our meeting times, due dates for different assignments, and future prototyping plans. This allowed us to pace ourselves according to the deadlines and successfully navigate ourselves through the FCDR (frame, converge, diverge, represent) process. Aside from the notion, we used the teamwork process review document, prototyping plan, and prototyping materials budget list to evaluate our current workflow and make plans for . Overall, notion was used as a framework to organize the different components of the design process while the other PM artifacts were used to facilitate each phase in the design process.

Path: Notion (Design Dossier 2)
Path: Notion (Design Dossier 1)
Path: ESC204 Team → Prototyping plan → Procurement and Budget Tracker and Prototyping Plan
Path: ESC204 Team → TeamWork → Teamwork Process Review

9. Opportunity Champion Meeting Notes: Cross Referencing with Secondary Research

This artifact was created during the online meeting with the opportunity champions, who were University Professors that had connections with the rural Thailand communities. We were able to ask questions to gain more information about the opportunity beyond what was available through secondary research. It was a precious opportunity to hear about the lived experience of the Thailand Bamboo Weavers. In fact, this meeting was the reason why we chose to shift our focus for our value proposition and approaches because their main concern seemed to be the profitability of the product more so than the ergonomic issues such as the tools they use for cutting bamboo. This document served as a source to cross reference with our secondary research to identify areas of overlaps to ensure an appropriate framing of this opportunity.

Path: ESC204 Team → Opportunity Champion Meeting - 02/02/23

10. Design Process Artifacts: Diverging and Converging

These artifacts were created during the diverging and converging phase of our design process. It includes photos and writings from our 635 activity as well as the morph chart and pugh chart that were used to compare and narrow down to the most favorable design. We initially only had the idea of creating a holographic teaching device that would cast out holograms to show the weaving patterns to create. But this diverging phase helped us widen our possibilities by seeking other ways to accomplish the same functionalities defined by our requirements model. As a result, we were able to come up with the idea of using rows of LEDs instead of a hologram to guide the weavers, which drastically improved our feasibility in our design. In fact, the pugh chart helped us to abandon the hologram idea since it failed to meet most of the requirements.

Path: ESC204 Team → Converging
Path: ESC204 Team → Diverging Evidence

11. Reference Designs and Design Artifact

This artifact was created to document the reference designs that served as our source of inspiration for coming up with the LED teaching device. The first idea was proposed by Grace right after we changed our value proposition but was still stuck on the holographic device idea. She mentioned how she used to play with a toy called “Lite-Brite” where you could create designs using pegs that would illuminate. This revealed the potential of using different LED colors to indicate individual bamboo strips and guide the weavers to form different weaving patterns. By referring to an existing design, it allowed all the team members to envision what kind of design we were aiming to create, which helped the team to get onto the same page.

Path: ESC204 Team → Design Artifacts → Reference Designs and Detailed Design Sketch

12. Design Changes: Documentation of Key Changes to Design

This high level document outlines key changes in our design and opportunity space we are working with. For example, it outlines when we changed value propositions. The purpose of this document is not to go into detailed reasoning behind decisions made (these are discussed in other documents such as meeting minutes), but rather keep track of high level changes being made.

Path: ESC204 Team → Design & Prototyping Plan → Design Changes

13. System Architecture

This document outlines the key aspects of the design concept, allowing the team to effectively divide roles. Furthermore, it establishes the extent to which each part of the design are independent of one another.

Path: ESC204 Team → System Architecture → System Architecture

14. Prototype Final Testing Videos

Folder contains videos from our final prototype testing with our fully integrated system. Various tests were performed as discussed in the Integrative Summary and Final Prototype Testing document.

Path: ESC204 Team → Final Testing → Integration of Sub-Systems

15. Photos of Structural Components

Folder contains photos and videos of structural components.

Path: ESC204 Team → Prototyping & Sub-System Testing → Structural → Photos

16. Structural CAD files and drawings

Folder contains CAD files and drawings for the structural components designed in CAD and 3-D printed.

Path: ESC204 Team → Prototyping & Sub-System Testing → Structural → CAD files/drawings

17. Motor Photos

Folder contains videos of the motor sub-system.

Path: ESC204 Team → Prototyping & Sub-System Testing →Motor

18. Sensor/LED Subsystem Meeting Minutes

This document outlines the meeting minutes, testing and notes during the sensor/led prototyping process. Using one document that was continuously updated allowed us to easily reference previous work done, to-do lists and pick up from where we left off. Furthermore, we documented fixes to debugging here which we referenced when encountering a error for the second time.

Path: ESC204 Team → Prototyping & Sub-System Testing → Colour Sensor/LED → Colour Sensor Meeting Minutes/Notes

19. Colour Sensor/LED Photos and Testing

Folder contains photos of evolution of sensor/led prototyping and initial testing videos.

Path: ESC204 Team → Prototyping & Sub-SystemTesting → Colour Sensor/LED → Photos

20. Black vs White Colour Detection Code

This code for the RBG sensor detected if the colour was black or white based on an average RGB value and threshold value on an Arduino Nano RP2040. It then determined if the correct colour was woven and adjusted the pattern accordingly. Furthermore, a 0/1 signal was sent out of a pin to the Raspberry Pi which connected to the LED array and updated the display of the LED pattern. An indicator light was also turned on when the correct colour was woven.

Path: ESC204 Team → Prototyping & Sub-System Testing → Colour Sensor/LED → Code → black_white_detection_txt

21. Sensor and LED Interfacing Testing Code

This code sent an always high signal to the Raspberry Pi from the Ardunio Nano RP2040 to determine if the high value was being correctly received by the Raspberry Pi. This was part of the debugging process to ensure that the interfacing between the Pico and Arduino was correct.

Path: ESC204 Team → Prototyping & Sub-SystemTesting → Colour Sensor/LED → Code → always_high_txt

22. LED Pattern Code

This code controlled the LED patterns array on a Raspberry Pi Pico. It received a high/low signal from the colour sensor circuit which indicated if the pattern should be changed or not and made the change accordingly.

Path: ESC204 Team → Prototyping & Sub-SystemTesting → Colour Sensor/LED → Code

23. Initial Testing Sensor/LED Code

This folder contains code from Arduino used to test basic colour sensor functioning, as well as the prototyping assessment LED code which was referenced in the making of the LED array.

Path: ESC204 Team → Prototyping & Sub-SystemTesting → Colour Sensor/LED → Initial Testing Code

24. Final Prototype Testing Results and Procedure

This document records the testing of our final prototype. It includes various tests, the procedure followed, functionality of interest and the results. Notably, multiple iterations were performed and the design iterations which occurred after failed tests were recorded. Edge cases and unexpected inputs/outputs are also discussed.

Path: ESC204 Team → Final Testing → Final Prototype Testing

25. Colour Sensor/LED Debugging

This document outlines the debugging and testing process of the sensor and LED sub-system. The justifications of various design decisions are discussed in the various different sub-components of the system.

Path: ESC204 Team → Prototyping & Sub-SystemTesting → Colour Sensor/LED → Sensor/LED Building and Debugging

26. Timeline

This document summarizes our planned time line as well as our actual timeline achieved. While notion was used in practice for planning purposes, the purpose of this document is to investigate our our planned timeline different from out actualized one.

Path: ESC204 Team → Timeline → Planned vs Actual Timeline

27. Design Dossier 1 Integrative Summary

This Integrative Summary was submitted for our Design Dossier 1 Assessment and is here for reference.

Path: ESC204 Team → OLD Integrative Summary → OLD Integrative Summary Design Dossier 1

28. Photos of Final Prototype and Sub-Systems

This folder includes final photos of the integrated prototype and the final sub-systems before integration. The purpose of this folder is to allow the prototype to be quickly seen in a visual format, however additional photos including interaction of the prototype are in Prototyping & Sub-System Testing

Path: ESC204 Team → Photos and Videos of Final Prototype

29. Team Meeting Video

This folder contains the video that captures our team process.

Path: ESC204 Team → Meeting Minutes and Team Videos

S5: Works Cited (1 page)

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