

COBBLE

A beginner bouldering shoe designed
to biodegrade at its end of life

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MSC PDE 2019-2020



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Problem

Problem Definition



The climbing industry is expected to increase by \$1.6 billion between 2019 and 2023 [9]. Currently, there are over 400 climbing gyms open within the UK (Denyer, 2017).

With the growth of the industry as a whole has come the growth of the bouldering segment and an increasing demand for outdoor shared spaces (Technavio, 2019).

This will result in an increase in the negative environmental impacts of the sport with an increased soil erosion, chipping of rocks, manufacturing, and consumption of resources to generate gear.

Current initiatives from gear manufacturers are addressing the environmental impact by increasing the use of recycled material, thereby increasing the lifespan of the resources (Joey, 2019).

Though a worthy initiative, it does nothing to address the eventual end of life for the products and resources. Eventually all gear ends up in a landfill. For a sport like bouldering, where gear is regularly replaced to ensure performance and safety, the amount of goods sent to a landfill can quickly grow.

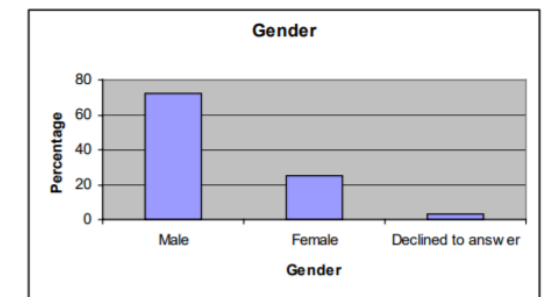
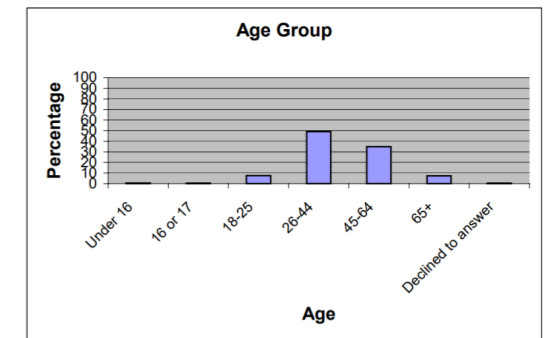
By planning a more environmentally friendly end of life I aim to reduce the overall environmental impact of outdoor bouldering. This will primarily be accomplished through thoughtful material choices and a reduction of environmental manufacturing factors including chemical treatments, dyes, virgin material usage, energy consumption, and water usage.

User Group

The user group selected for this project was based on demographics for the sport as well as the technical requirements associated with varying skill levels.

Overall, the users will primarily fall between the ages of 26 - 44 and will be roughly 75% male (BMC, 2006). The users will have a wide range of shoe sizes. Due to available data, the shoe will be designed for North American and European descent; impacting the dimensions (Jurca et al, 2019). The product, marketed as a sustainable option, will appeal to individuals concerned about their personal impact on the environment.

The bouldering shoe will be geared towards beginner boulderers; whose skill and ability on routes will not be as severely impacted by the alternative material choices. As they are beginners, special attention will need to be placed on ensuring a comfortable fit and extending the coverage of the rubber rand. This will help extend the life expectancy of the shoe by accounting for poor foot technique while slowly acclimating the user to tight shoes.



Stakeholders

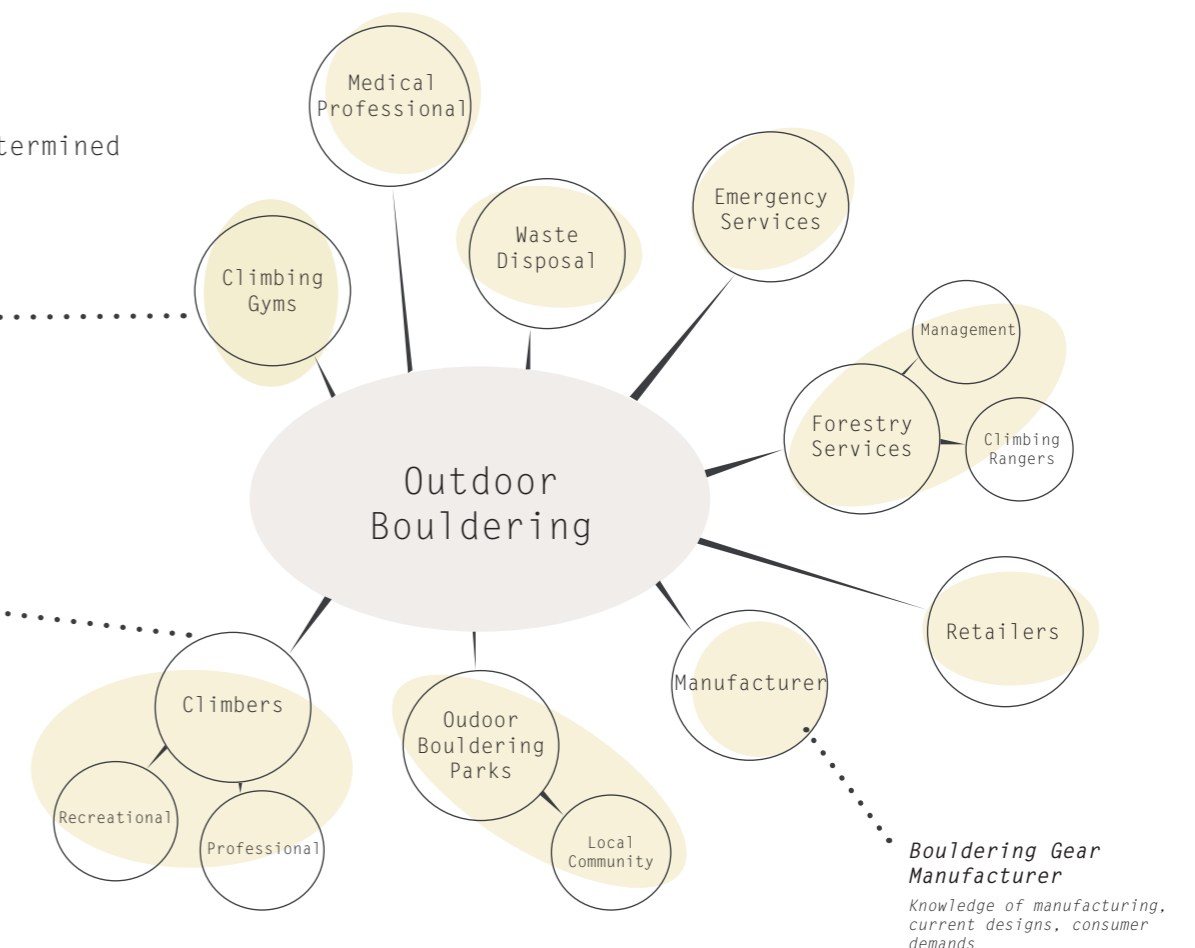
Key stakeholders were determined for user research

Different Perspective and interaction with Gear

Largest expense, lifespan of products, trends in wear of products

Primary Consumers of Bouldering Gear

How gear is being used, how it wears down, what is most commonly gear for beginners



Primary Research

Interviews & Observation



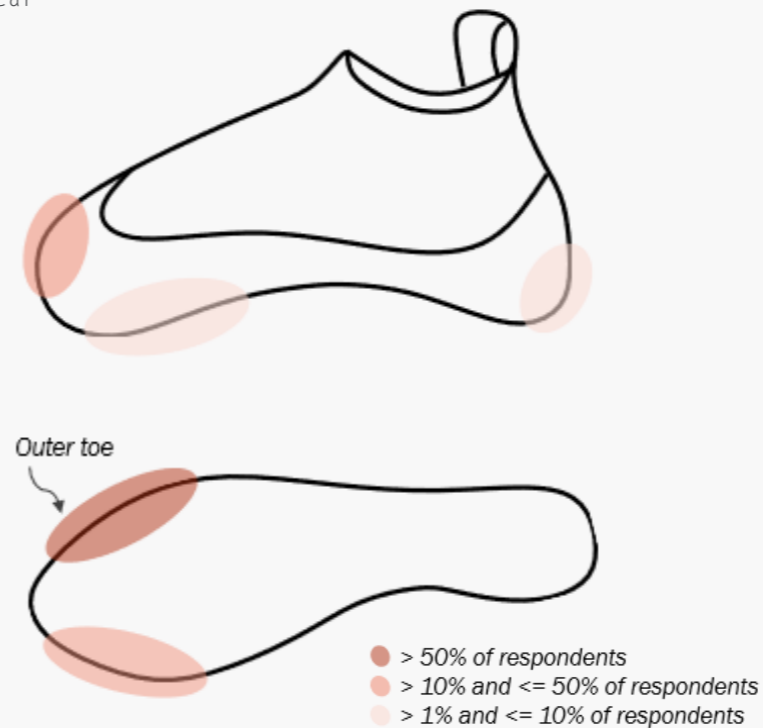
Information gathered through interviews and observation was used to narrow the scope of the project to one specific item of bouldering gear. Interviews and observations of outdoor boulderers indicated the two most common items of gear were bouldering shoes and chalk bags. The only gear that required replacement within the last year was bouldering shoes.

An interview with a local climbing gym manager provided further context about the wear and replacement of various types of gear. From this discussion I learned that bouldering shoes are the largest expense to the gym; often needing replacement and with no sustainable option for their end of life. Additionally, shoes for rent at gyms tend to wear out faster on right feet and in the toe area. To account for this consistent wear, this gym purchased shoes with thicker rubber around the toe.

This information pointed me towards looking at bouldering shoes.

Survey Results

Areas of Wear



A survey was posted to local online climbing groups after the decision was made to move forward with bouldering shoes. The survey targeted the outdoor bouldering subset of the rock climbing community and aimed to provide insight into how bouldering shoes are currently being used, wearing out, and the key considerations when purchasing a new pair.

A total of 17 climbers responded to the survey. Their answers suggested that wet weather is avoided, fit is the most important aspect of a shoe, specific areas wear out fastest, replacement time is typically every 6 or 12 months, and both time and money are considered when purchasing a new pair of shoes. Surprisingly, only 5.88% consider the environmental impact when selecting a climbing shoe (Survey Monkey, 2020).

94% do not climb when it is wet outside

94% consider fit when purchasing a new shoe

From interviews, observations, surveys, and online research I arrived at the following product requirements for beginner bouldering shoes

PRODUCT REQUIREMENTS

- Snug fit with foot
- Usable in multiple locations and weather conditions
- Layout of materials considerate of shoe use
- Low time requirement to obtain shoes
- Comfortable to wear
- Ability to grip onto surfaces
- Design supports common foot technique

End of life not considered when buying gear

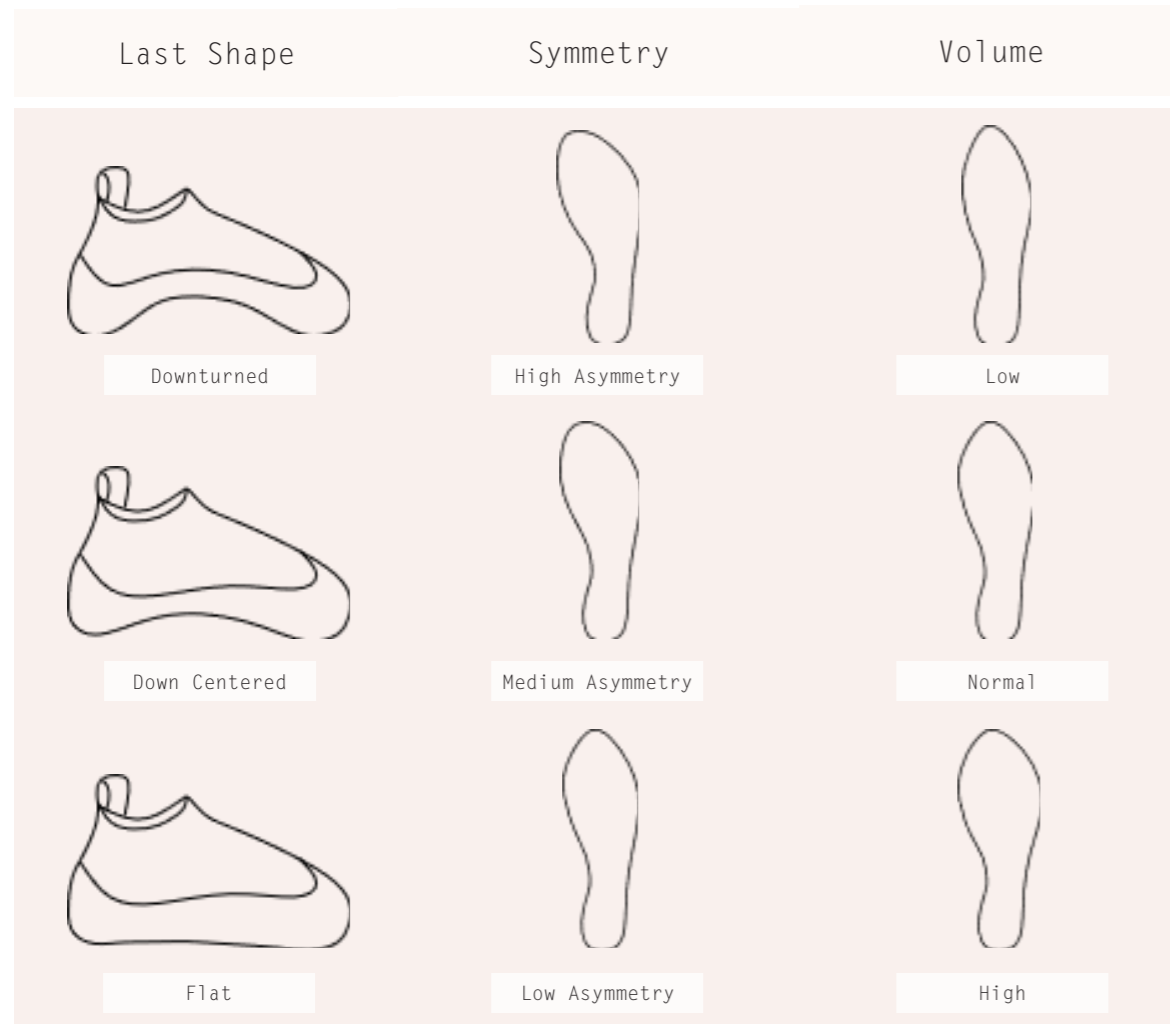
Shoes and chalk bags are the most common equipment

Less experienced climbers wear out shoes more quickly due to bad technique

Shoes wear out the most frequently of all bouldering gear

Secondary Research

Primary Layout Options



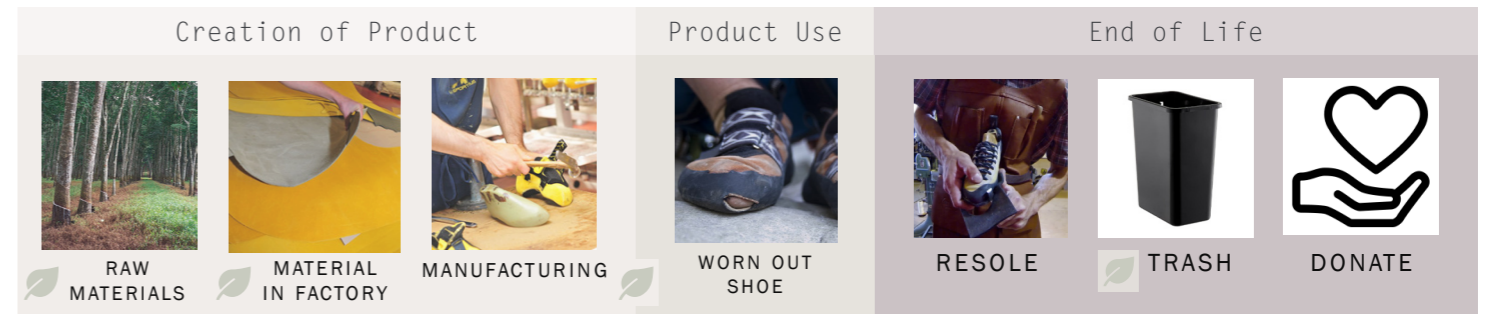
One of the first steps in the process was determining what type of bouldering shoe would be created. This information informs the underlying structure and manufacturing methods used to form the shoe.

By setting the user group to be beginner outdoor boulderers, I directed myself towards a flat last with low asymmetry. This in turn suggested that a slip last be attached to the upper material using a strobel stitch during the manufacture of the shoe and that the midsole be relatively flexible while still offering support for the foot.

For this project, I aimed for a normal volume as it will accomodate the majority of the targeted user group.

Life Cycle Analysis

Through looking at a bouldering shoe's current life cycle, I was able to find opportunities to reduce its environmental impact. (indicated with 🌱)



End of Life Facts

70% of bouldering shoe resoling fails

(Gear Use within a Gym, 2020)

< 5% of shoes are recycled

(Better Shoes Foundation, n.d.)

In the UK, 85% of shoes are thrown out

(Better Shoes Foundation, n.d.)

Manufacturing Waste Facts

"65 to 85 percent of the environmental impact of a product happens at the materials stage"

(Dennis, 2017)

"...often 80 to 90 percent of the chemicals used to make a product are not detectable in the final product"

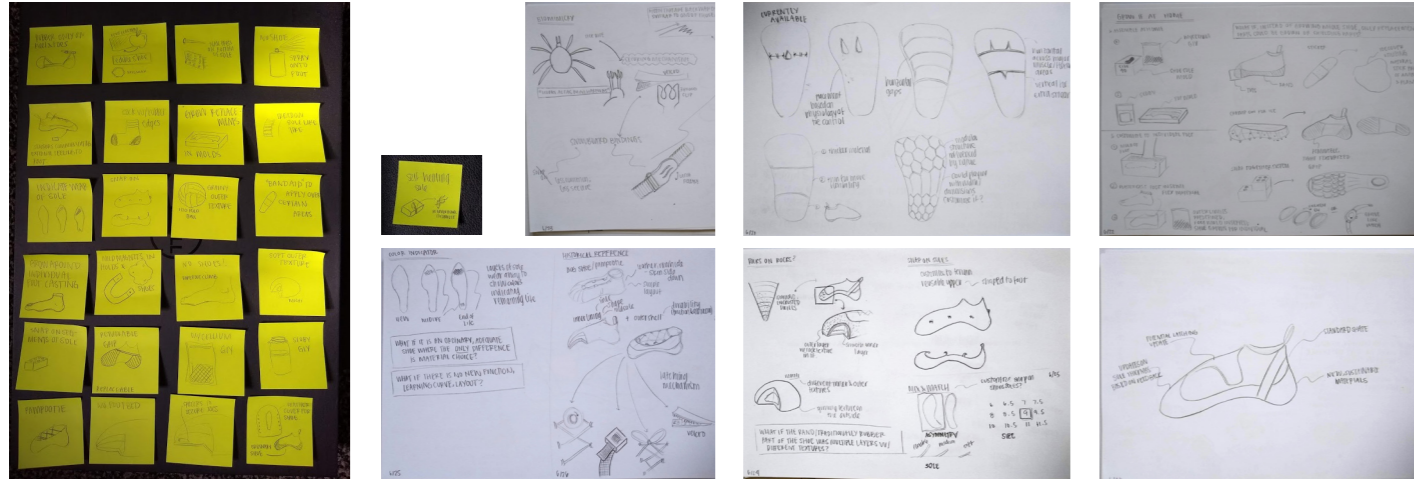
(Dennis, 2017)

"The clothing industry is the second largest polluter in the world, second only to oil"

(Dennis, 2017)

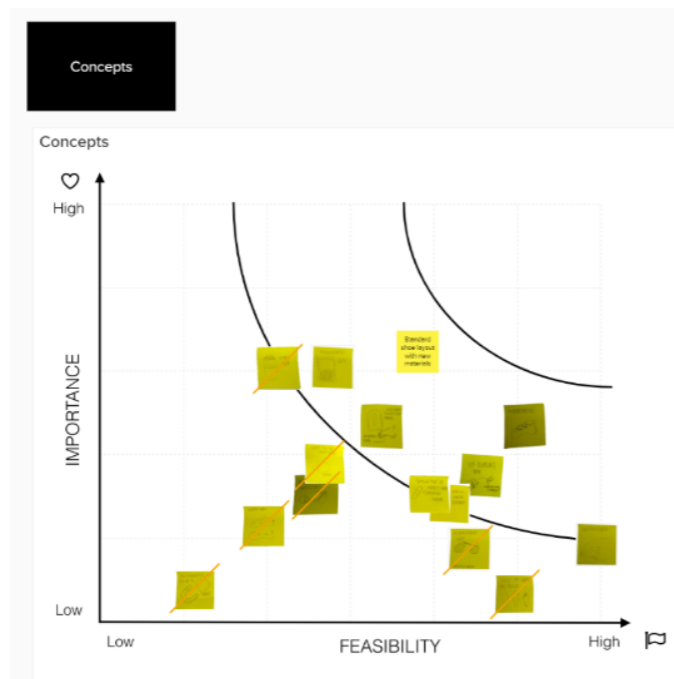
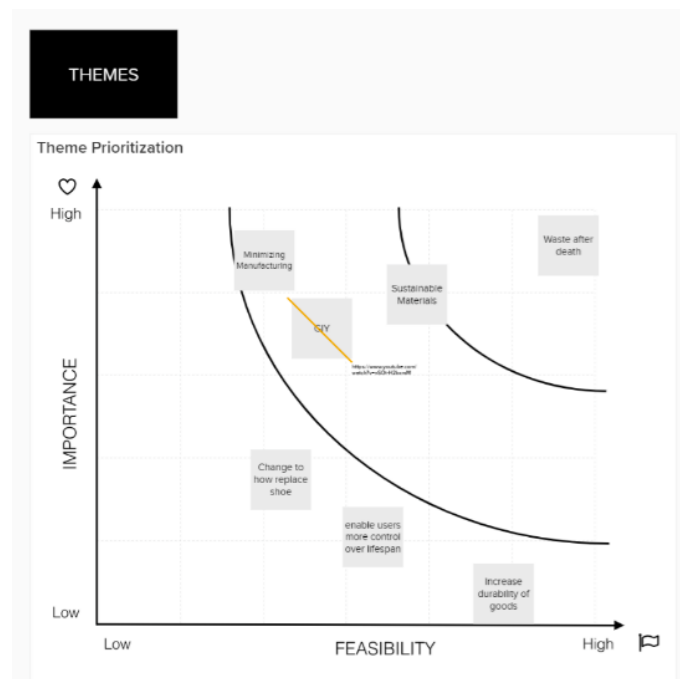
Concepts

Brainstorming



Once a direction was decided on and a bit of background research had been conducted, I began brainstorming ways a bouldering shoe could be altered to make it more environmentally friendly. Concepts included the themes of reducing manufacturing, allowing for easier replacement of parts, increasing the durability of parts that wear out fastest, and eliminating transportation.

Once concepts were created, I plotted both the concepts and the themes to pull out the ideas that were most relevant to the project topic - improving the environmental impact of bouldering shoes through end of life planning.



Top Ideas

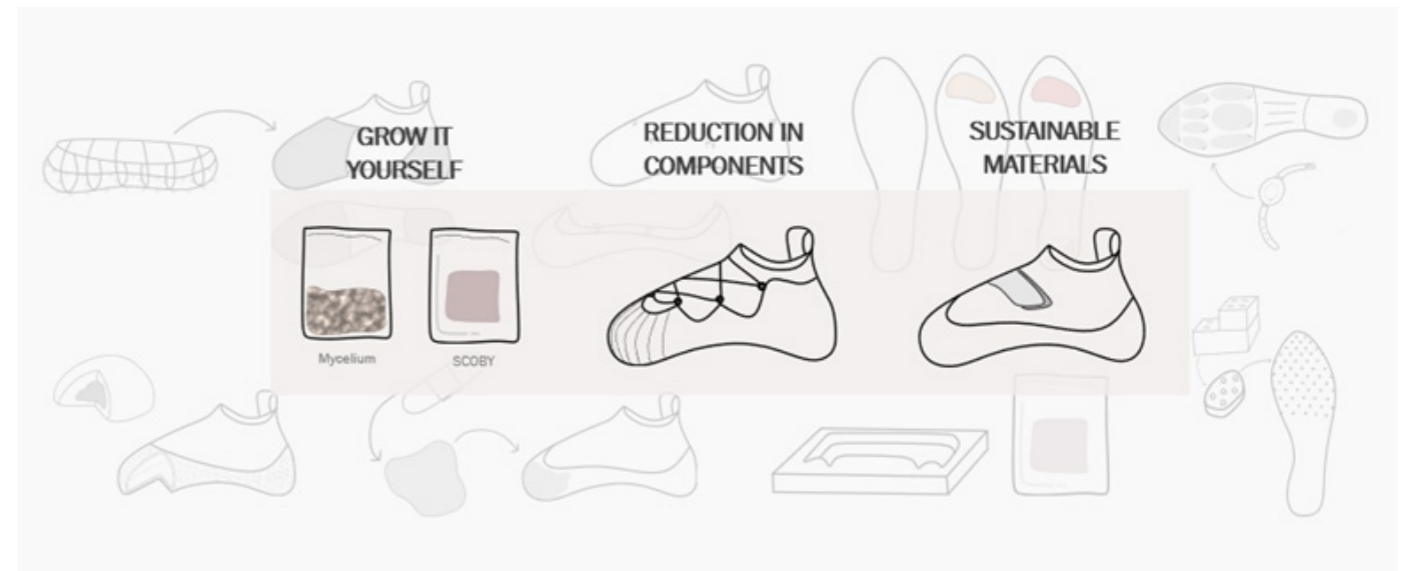


The above eight concepts were the highest evaluated ideas. Main themes were drawn out of them for further evaluation.

3 Main Themes

The three most prevalent themes within the top concepts were selected for further development.

The ideas of grow-it-yourself, reduction of components, and using environmentally sustainable materials all had the potential to reduce manufacturing waste, minimize material needs, and allow for a planned end of life.



Sustainable Materials

Mycelium



Experiments were conducted using 3 types of mycelium - grain, wood chips & liquid suspension.

Mycelium, the fungal vegetative structure of mushrooms, is becoming more prevalent within design due to its versatility, strength, and sustainable properties. With a yield strength and young's modulus falling within the standard range for foams (Islam et al, 2017), the wide variety of structures it can produce, its ease of use, and its biodegradable nature - mycelium quick-

ly became a material considered for the insole, midsole, and sole of the bouldering shoe.

Experimentation and research proved that though unsuitable for grow-it-yourself concepts, the insole, and the sole; mycelium has potential to be a part of a high performance midsole (Ecovative Design, n.d.).

SCOBY



Often considered the waste product of the kombucha making process, SCOBY is easy to acquire, easy to grow into any shape, and has been applied to many textile based projects in recent years - including the creation of shoes (Ted, 2011). SCOBY was considered as a replacement for components traditionally constructed using leather - the upper, lining, and heel loop of the bouldering shoe.

Through experimentation I found that the material thickness is inconsistent. This, along with its brittle structure that couldn't be corrected through post drying treatments, eliminated SCOBY as a potential material within the the bouldering shoe and eliminated the possibility of Grow-it-Yourself Concepts.

Additional Materials



1. BlackMorph: a biodegradable, mouldable rubber that can be reformed by applying heat. Though biodegradable, there is no mention into specific conditions needed to break down product (Thermoworx, n.d).
2. Natural Rubber: biodegradation is possible but takes a long time (Rose et al, 2005) (Clark, 2013). Process of harvesting does not kill the tree. Possibility in the future to use dandelions as source of rubber (Sustainable Footprint, n.d.).
3. Chamois: extremely soft and grippy biodegradable material that is sustainably produced using fish oil tanned sheepskin and without chemical processing (Hutchings & Harding, n.d.).
4. Canvas: typically a cotton - linen blend, but it can be made using hemp. Hemp uses 1/2 the land per ton of fabric (Greene, 2019) (Palmer, 2011).
5. Cork: a sustainable and biodegradable material that, among other properties, is antimicrobial water resistant, making it a good option for the interior of the shoe (Pereira, 2007).
6. Leather: Vegetable tanned leather uses no harsh chemicals, is biodegradable, and can be sourced from local tanneries to create a sustainable supply. (Common Objective, 2018)
7. Fish Leather: a biodegradable bi-product of the fishing industry with a superior strength to traditional leather due to the layout of fish skin (Leather Dictionary, 2020).
8. Cotton: biodegradable, natural, and soft; cotton is a common material within sustainable design. Unfortunately the production of cotton has large environmental impacts due to water usage, land usage, pesticides, and insecticides (How Stuff Compares, n.d.).

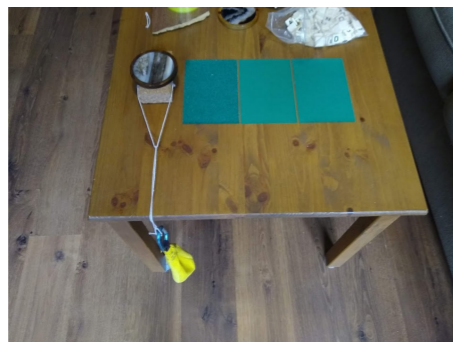
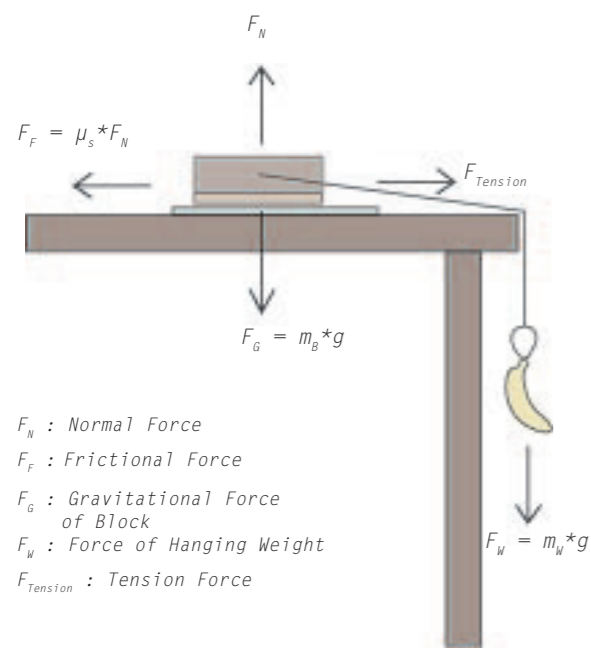
Grow-it-Yourself concepts are not feasible due to material limitations and inconsistencies

A balance of pros and cons must be found within materials as no biodegradable option is perfect

Applications of mycelium could be appropriate for future work, but not feasible for current prototypes

Technical Testing

Friction



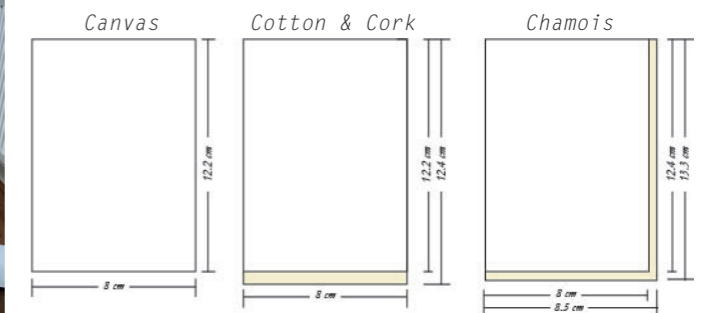
The coefficient of static friction was calculated for all material options being considered for either the inner lining or the sole of the bouldering shoe.

To do this, the materials were adhered to a block and placed on 4 different surfaces, mimicking conditions one may find while bouldering. Weight was added through a pulley system and measurements were taken when the material started to move.

The materials being considered for the sole were compared against the determined coefficient of friction for an existing bouldering shoe.

The materials being considered for the inner lining were compared against each other. The surfaces did not replicate the material's interaction with skin, but the tests did provide a useful method for comparing the materials.

Stretch



Materials being considered for the slip portion of the bouldering shoe were tested for their stretch by measuring displacement in the X and Y directions when 250 g of weight is applied.

An ideal slip will not stretch as it is responsible for providing structure to the shoe. Results of this experiment indicated that Canvas is the best material choice for the slip.

Abrasion

The friction tests narrowed down the sole material choice to one - natural rubber. To ensure natural rubber is durable enough for outdoor bouldering, abrasion tests were conducted.

Six rocks, accounting for roughly 89% of the total outdoor bouldering routes in Scotland, were rubbed against pieces of natural rubber 400* times. At the end, samples were examined - none of them having had significant wear.

*Based on average wall height, route times, shoe lifespan, and recommended rest periods - an estimate for the number of foot placements per shoe during its lifetime was reached. This value, ~17k, did not account for the distribution of abrasion over the surface of the shoe. With 5-6 common foot placements, the expected use of each area is roughly 3400 - making 400 around 11.8% of its life. Future tests would increase this value to ensure the material will last the full lifespan.



Material Elimination

As a result of the three indicated tests, materials were eliminated from the list of potential options.

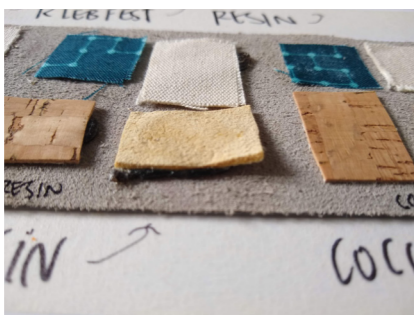
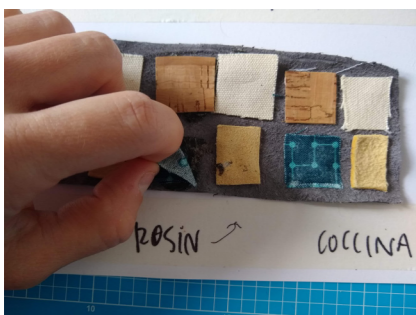
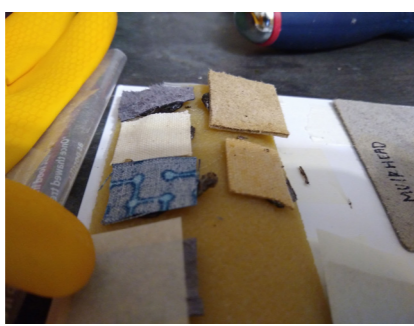
After friction testing, only natural rubber remained and chamois was first choice for the lining. Stretch testing eliminated cotton and chamois as options for the slip.

	Material					
Upper	Canvas	Leather	Fish Leather	SCOBY	Cork	Mycelium
Lining	Canvas	Cork	Chamois	Cotton	Hemp	Cotton Grass
Slip Last	Canvas	Cork	Chamois	Cotton		
Midsole	SCOBY	Cork	Mycelium	Bamboo		
Sole	Mycelium	Natural Rubber	Mouldable Rubber			
		Dandelion Rubber	Sugar Cane Rubber			
						Failed during testing
						Unable to acquire

Manufacturing

Glues

Pine Resin

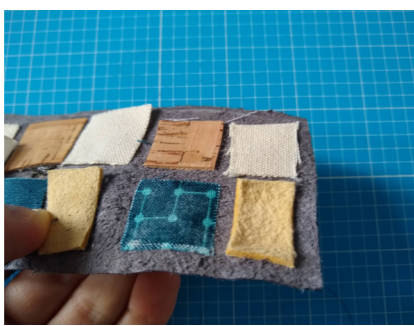
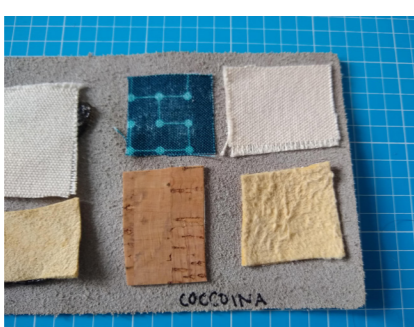


Pine resin, a natural substance that can be sustainably harvested was historically used in combination with charcoal as a glue. Research indicates that pine resin based glues are comparable in mechanical properties to some options found in stores (Le Boudier et al, 2019).

Testing indicated that though this glue can be strong, it is also extremely brittle - reacting poorly to the bending and compression of the materials it is applied to.

Ultimately, this version of pine resin glue was deemed insufficient for all applications within the bouldering shoe. Further tests could be conducted, replacing charcoal with beeswax.

Coccoina



Coccoina is a natural, biodegradable glue developed in the 1920s (The Green Stationary Company, n.d.). Primarily used for fabric and paper, this glue has potential to adhere the upper with the lining as well as the inner sole and midsole. Though it is not developed with rubber in mind, tests were conducted to evaluate the adhesive limits of the almond scented paste.

Results indicated coccoina was sufficient for bonding together two fabric based materials. In regards to rubber, the coccoina only succeeded in adhering the cotton and this bond was easy to pull apart - indicating it would not be sufficient for the needs of a bouldering shoe.

Sewing



Material options for the components that would be sewn together were tested - validating the the combinations could be reasonably manufactured.

Of all tested materials, the combination of chamois with chamois was the only one that failed. This option was being considered as a liner - slip option. This furthered chamois's elimination from the options for a slip.

Material Selection

At this point, all planned testing had been conducted, material options had been reduced based on material limitations, and options were selected for the components of the shoe. For components not discussed in the above tests, selections were made based on information available online.

	Material					
Upper	Canvas	Leather	Fish Leather	SCOBX	Cork	Mycelium
Lining	Canvas	Cork	Chamois	Cotton	Hemp	Cotton-Grass
Slip Last	Canvas	Cork	Chamois	Cotton		
Midsole	SCOBX	Cork	Mycelium	Bamboo		
Sole	Mycelium	Natural Rubber	Mouldable Rubber			
Adhesive	Pine Resin	Coccoina	Klebfest	Sewing		

Failed during testing
Unable to acquire

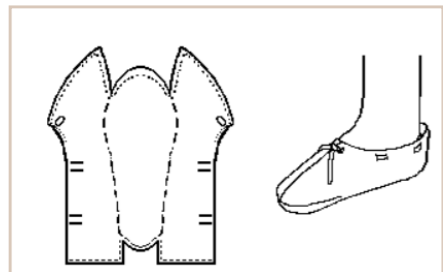
Upper	Lining	Eyelets
Fish Leather	Chamois	Embroidery
Slip Last	Midsole	Laces
Canvas	Cork	Hemp
Sole	Adhesive	
Natural Rubber	Coccoina, Sewing, Klebfest	

Layout Testing



Process of creating a pattern. This process was used to test out historical designs as well as design and iterate the final pattern

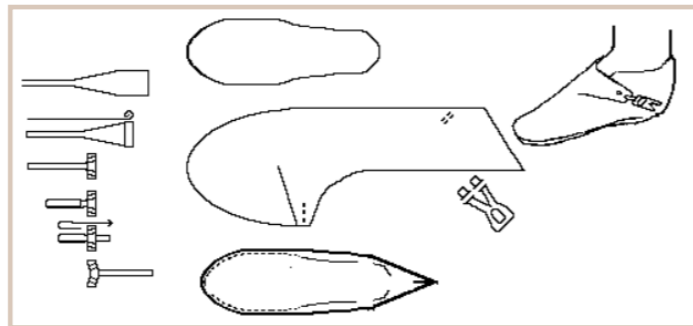
Historical Layouts



Historical layouts were researched and evaluated as they provided insight into how to minimize material usage and manufacturing demands.

Patterns found online were replicated using spare material and were assembled to test the possibility of using the patterns in the final design (University of Tulsa, n.d.) (Traditional Living Project, 2015).

Aspects of these patterns made their way into the final product. For example, minimizing upper components was utilized within the final product.



Shoe Deconstruction



A simple shoe was deconstructed to better understand shoe patterns and shoe construction.

Though different in function from a bouldering shoe, this experience provided valuable insight into the construction of an upper.

It also highlighted the possibility of finding ways to reduce the amount of adhesives used - an area of particular interest since no natural adhesive has been found to adhere the sole.

Iteration and physical prototyping of the patterns

Is reducing the amount of adhesives possible?

Minimizing material usage through smart pattern development

Final Design Overview

CAD



CAD was used to render the final design based on anthropometric measurements and using the developed pattern.

Product Requirements

Snug fit with foot

Anthropometric data to determine dimensions; High friction lining to promote close bond with foot

Usable in multiple locations and weather conditions

Tested against rocks representative of most bouldering routes. Materials supportive of different weathers

Layout of materials considerate of shoe use

Rubber rand placed in areas of high wear

Low time requirement

Use of standard shoe manufacturing methods

Comfortable to wear

Soft Chamois lining, springy cork midsole, and dimensions based on foot dimensions of proposed user group.

Ability to grip onto surfaces

Frictional capabilities of natural rubber used for shoe comparable to existing bouldering shoe

Design supports common foot technique

Sole and rand providing support for all common foot techniques

Product Overview



Cobble

A biodegradable beginner bouldering shoe whose natural rubber sole is capable of providing a secure grip; comparable to traditional bouldering shoe options.

Comprised of chamois, cork, natural rubber, fish leather, and hemp - this is a shoe that is as friendly to the environment as it is comfortable and functional on your feet.

Designed to be destroyed, this is the first bouldering shoe one does not need to feel bad about discarding at the end of its life. Simply put it in the compost and let nature handle the rest.

Alternatively, if compost is not available where you live, simply mail the shoes back to us. We have your back.

Updated Life Cycle



The final design takes into account and improves the projected life cycle through its updates to the creation and end of life of the bouldering shoe.

Final Design Details

Component Details



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