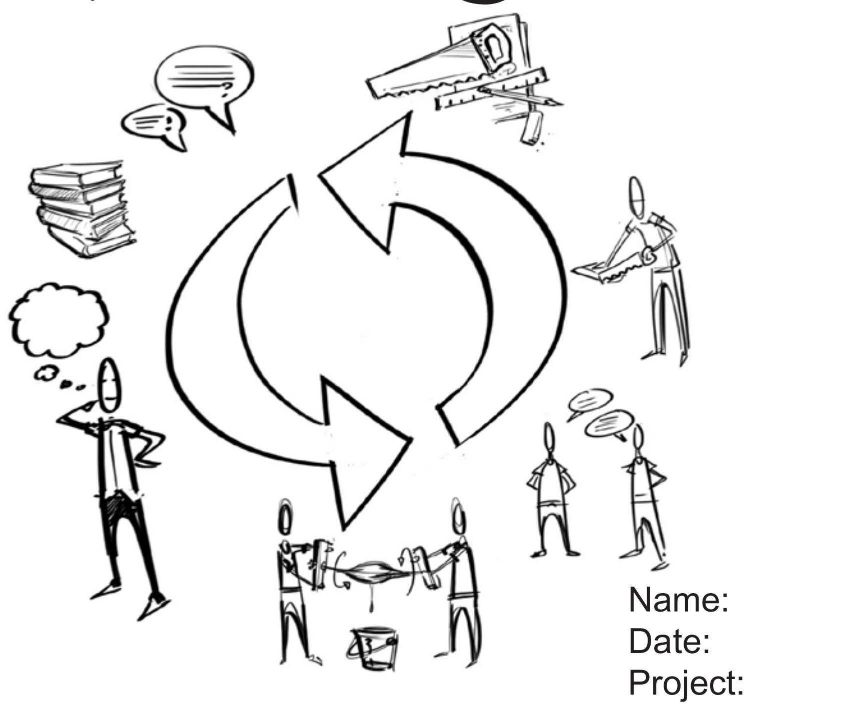
CCB
CREATIVE CAPACITY BUILDING
DESIGN
WORKBOOK



Name:
Date:
Project:

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CCB
Design Packet

Introduction
The design process is both an art and a science, and exists in many different disciplines. A fundamental way to look at engineering design is that you are trying to find a solution to a problem. The following steps may help get you on the road; they can be used as a way to track and document the design process, help you work with teammates on a design project and give you ideas for how to proceed. “Brute force” engineering options, where your resources are basically unlimited, often meet the criteria of solving the problem, but somewhere there is usually a profound solution, which is simple, cheap, and beautiful. It may take a long time to get there, but keep working to find it for it as long as possible.

The design process is generally considered to be a combination of the following stages:

- information gathering
- problem framing
- setting design requirements
- generating ideas
- analysis & experimentation
- concept evaluation
- detail design
- fabrication
- testing & evaluation

The process is not a linear one, however, and can better be thought of as a circle or spiral, as it is often necessary to go through the design cycle many times to get a good solution. Experience has shown that the more time spent on the initial stages of the design, the easier the later stages become. It is also important to go around the cycle often so that you can get feedback on your solution and improve it. Each time you go around the cycle, you learn something new which leads to a better product in the end. Sometimes it takes a long time to go around cycle, but sometimes you can go through the steps quickly, so that you can get feedback and make progress faster. As you become a more experienced designer, you will learn when to go fast, to get feedback quickly, and when to go slower, with more attention to detail.

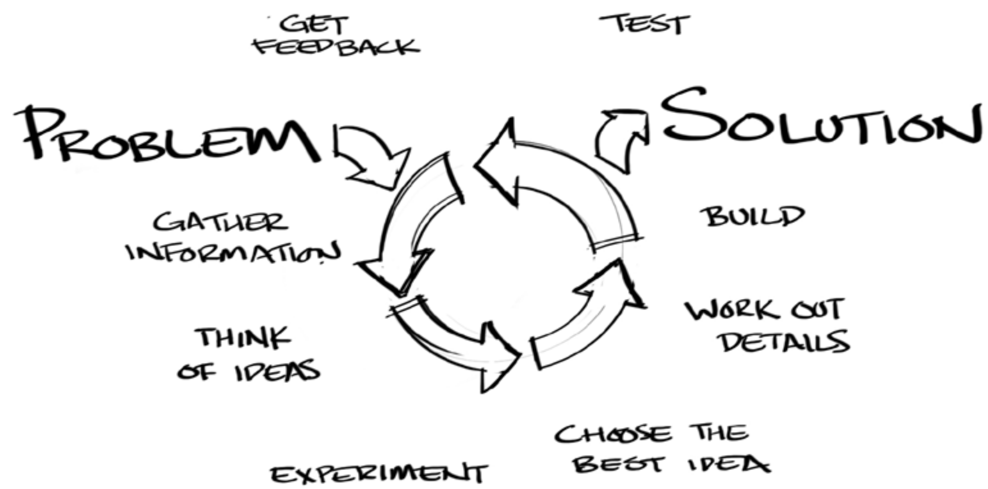


FIGURE 1: THE DESIGN CYCLE

In this course, you will learn the design process by applying it to a real technological challenge. This booklet describes the D-Lab approach and guides you through the steps of the cycle. You should use this booklet as a design notebook, writing directly on the pages provided as you gather information, conduct interviews, think of ideas, perform experiments, analyze your results, work out the details and get feedback from users. There are exercises meant to help you along, but design is a creative process, so there are plenty of blank pages too, to let your imagination run freely. As you move on to other projects, you can use other notebooks, but keep the things that you learned about here in mind as you go through the process. Design is a powerful tool that allows you to create solutions to the problems that affect your life. The techniques in this booklet will help you learn the design process and will lead to better solutions and to better products.

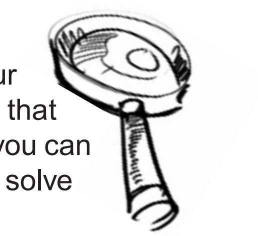
Phase 1: Information

It is important to get as much information as you can about your project before you start designing. You should try to find out as much as you can about

- **the current state of the art:** what else exists that does the same thing that you want to do?
- **the user needs and the requirements for performance of the device:** what size should it be?, how much should it cost? what should the throughput be? will it be motorized or human-powered? ...
- **the context in which the device will be used:** will it be used indoors or outdoors? mostly by women or men? year-round or only in the rainy season? will it be owned by a group or by individuals? …
- **related technologies:** what technologies perform similar tasks? what machines work in a similar way?




There are many ways that you can get this information: interviewing experts and observing users; standard research, using libraries or the internet; and trying things out for yourself. If you have access to computers, the internet is a good source of information. Databases and reference texts such as the World Bank Development Indicators, the Economist Intelligence Unit Country Profiles and others can provide valuable background information; these resources may also be available in libraries. As much as possible, try to consult with the people who will be the users of the product and become as familiar as you can with the context of the device. Here are three ways that you can gather this information:



- **OBSERVE** with all of your senses and record your impressions. Try shadowing a person as they face the problem that your product is intended to solve. Be sure to notice as much as you can about how they interact with existing technologies that aim to solve the same problem.

- **ASK** users what they think about the existing process. Listen carefully to their response to find out what they think the problem is. Have them describe the process to you. Have them describe the environment in which they use the device.

- **TRY** the process out for yourself. Use the existing methods or technologies and note what is good and bad about the process. Try doing time studies where you measure how long the whole process takes and how long each step of the process takes, so that you can see where in the process time is wasted, and you can more easily target improvements in efficiency. Look for technologies that do similar tasks, as well as devices that were designed specifically to address your problem. For example, if you are trying to grind moringa leaves into a powder, is there a mill, that grinds grain into four, that you can look at to understand how it works? Be sure that you record this information and organize it effectively, as it will be useful to refer to it throughout the design process.

observe

(take notes here)

ask

(record questions and answers here)

try

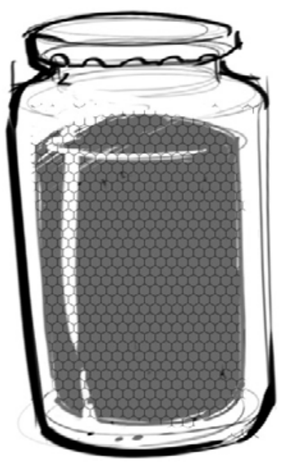
(try things out and write experiences here)

PROBLEM FRAMING

Now that you have a good understanding about the challenge, it's important to frame the problem. What aspect of the problem will you be addressing? Who are your users? Who are your customers? (The user and the customer are not always the same). What do your users and/or customers actually need? It may be different than what they say they want—they may have framed the problem in a way that suggests a solution. It is important to go back to the basic requirements of the problem and to build upon that. Think carefully about the stakeholders who are involved in this project, and those that you are including in your solution. Think of several different problem framings and collect more information about each so that you can be sure that you are solving the right problem.

For example, if we were designing equipment for a beekeepers cooperative and they asked for a honey press, we could start by designing a press, but we could also take a step back and look at why they want a press. It is probably because they want to sell honey.

But what if we talked to the people who want to buy the honey and we found out that they preferred honey that is still in the comb? Perhaps they like to chew on the wax, and use it later for candles or other things. Then we would not want to design a honey press, but we would want to develop a method for cutting the honey cleanly, and packaging it for sale.



Or perhaps after talking to the beekeepers you find out that they would like to be able to re-use the comb, so that the bees do not have to re-build it. Then you would design a honey extractor that does not damage the comb.

Usually, you can come up with four or five ways to frame a problem. Think of several different problems framings and write them up here.

DESIGN REQUIREMENTS

Now that you have an idea of the scope of your project, it is necessary to determine the user's needs and convert them into specific design requirements. Start by generating a list of customer/user needs. When possible, try to get information directly from the people who will be using your product. If this is not possible, then identify several people who are knowledgeable about the topic and get their input. Group together similar concepts and make a list of the customer needs.

Once you have the list of customer needs, decide upon the metrics (measurement methods) that you will use to determine whether you have met these needs. Assign acceptable and ideal values to these metrics and use this to create the design requirements for your project. An example of a list of design requirements for the honey press is shown in Figure 2.

Customer Need	Attribute	Metric	Acceptable Value	Ideal Value
Convenient	Time to set up	minutes	< 15 min	< 5 min
	Time to clean	minutes	< 30 min	< 15 min
Affordable	Cost of device	kwacha	< K250,000	< K100,000
	operating expenses	kwacha/kg of honey	< K15,000/kg	< K5,000/kg
Produces good quality honey	Debris in honey	number of particles >0.5 mm /100 ml	< 5	< 1
	Water content	% water	< 20%	< 10%
	Low rate of sugar breakdown	time exposed to temp > 35° C	< 30 min	0
Human powered	power required	watts	< 100W	< 50W
Safe	exposed sharp edges	number	0	0
	speed of exposed moving parts	m/sec	< .2 m/sec	< .1 m/sec

FIGURE 2: DESIGN REQUIREMENTS FOR A HONEY PRESS

Design Requirements chart

Customer Need	What are you going to measure	How to measure it (units)	Good Value	Better Value

Design Requirements chart

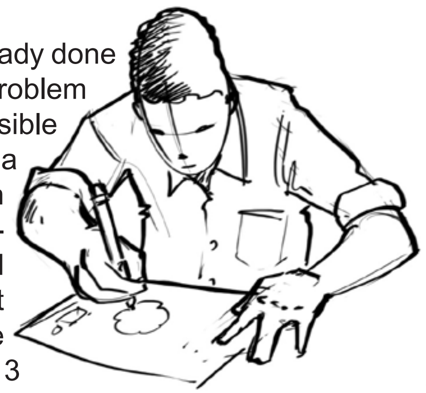
Customer Need	What are you going to measure	How to measure it (units)	Good Value	Better Value

Analysis and Experimentation

It is often useful to show your data in a graph.

Phase 2: Ideas

Now that your design problem has been clearly defined and the requirements have been set out, it is time to concentrate on thinking of ideas for solutions. When there is an existing solution to your problem or a similar one there are three basic types of design ideas that you may generate: scaled designs, evolutionary designs or revolutionary designs. A scaled design comes from an existing design that does the job well, and just needs to be scaled for your application. An evolutionary design can be created when an existing design is pretty good, but fundamental improvements are made. A revolutionary design is a totally new approach used to achieve the same function as an existing design, but with better performance. All three approaches can have successful results. In fact, your final design will probably be a combination of all of them.



Begin by generating ideas on your own (you may have already done a little of this while you were doing research into the problem definition). Try to think of as many different ways as possible to solve the problem. Be sure that you do not focus on a single approach. Use sketches and notes in your design notebook to record your ideas. Be sure to use large, well-labeled sketches so that others will be able to understand them. Some ideas will be at the system level and others at a more detailed level. Keep track of them all and make sure that you capture all your ideas in your this booklet. Figure 3 shows some examples of ideas for the honey press.

Put your ideas here...

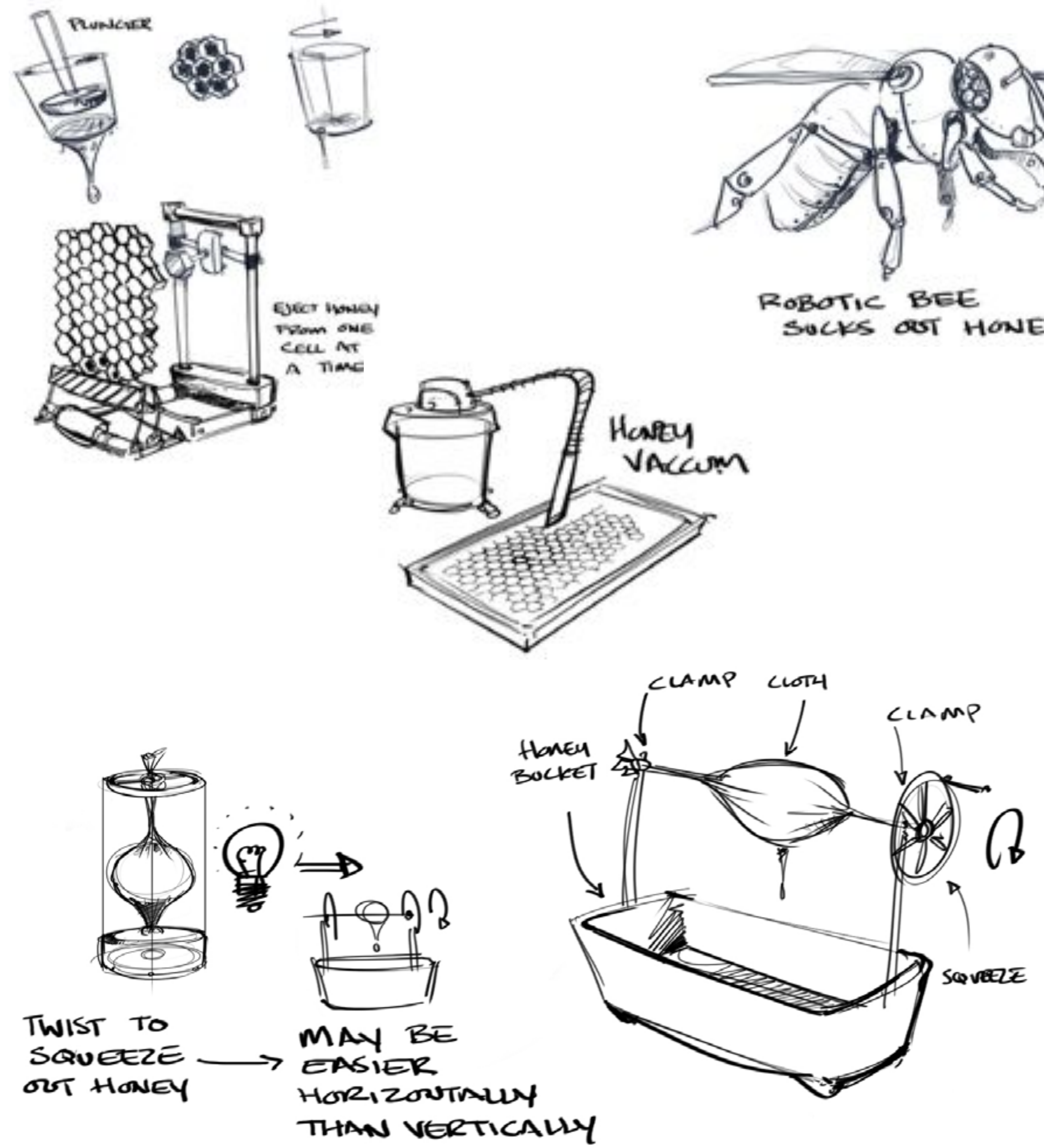


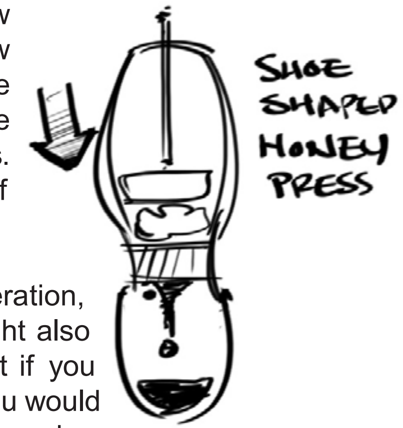
FIGURE 3: EXAMPLES OF IDEAS FOR A HONEY PRESS

GROUP BRAINSTORMING

Next, meet as a team to have a group brainstorming session, chose one or two people to record information. Before you start, be sure that you agree on the problem, and state it clearly. Each person should have paper and a pen or pencil, and as you come up with new ideas, write them down and add them to the work surface (wall, table, floor, or whatever is comfortable for you). This allows you to capture your ideas as they come in without interrupting others. You should start by giving each team member the opportunity to share an idea from their individual list. Build off each idea as it is presented, and see where it goes. New ideas will emerge, don't pass judgment at this point, and encourage all new ideas. You will evaluate and critique ideas at a later stage. In order to ensure a productive brainstorming session, keep it under one hour, and follow the Rules of Brainstorming:

- Defer judgment: don't dismiss or criticize any ideas
- Build on the ideas of others: no "buts", only "ands"
- Encourage wild ideas: think naively, keeping all engineering knowledge of what is feasible to the side. embrace the most out-of-the-box notions because they can be key to innovative solutions
- Go for quantity: aim for as many ideas as possible: in a good session, up to 100 ideas are generated in 60 minutes
- Be visual: use sketches or models to convey your ideas
- Stay focused on the topic
- One conversation at a time: no interrupting, no dismissing, no disrespect, no rudeness
- Be optimistic

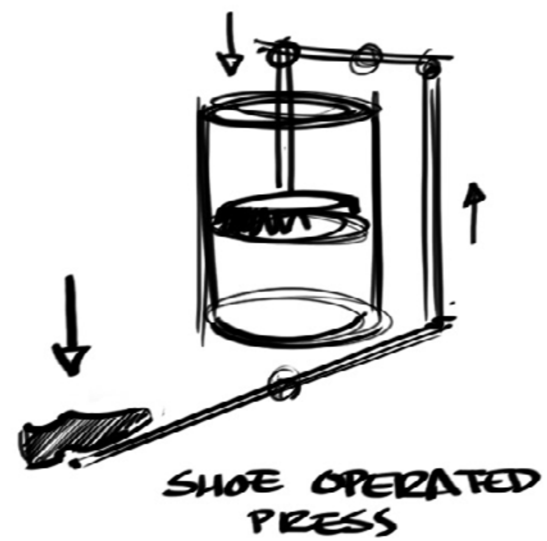
Once you feel like have exhausted your ideas, try to generate more. One way to do this is through a process called bisociation. In this approach, you choose a topic that may seem unrelated to your topic, and then think of ideas that bring these two ideas together. For example, if you are generating ideas for the honey press, you could choose the



bisociation topic of shoes. Then you might think of how you could use shoes as a material to make the press, how a shoe could operate the press, how the shape of the shoe could be incorporated into the press design, how shoe manufacturing methods could be adapted for the press. You may choose to do bisociation with additional topics if you don't get fruitful results from the first.

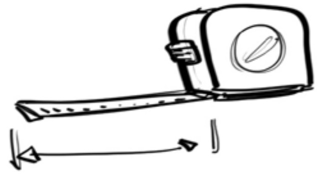
There are many strategies for creative idea generation, brainstorming and bisociation are just a couple. You might also want to try changing your constraints: for example, what if you wanted to make the honey pressing process really fast, you would think of ideas for how to extract the honey in less than a second; or you might want to make the press very inexpensive, and you would think of how you could make it for less that K10,000. Another method for generating more ideas includes changing your perspective: look at things backwards or upside down, or from the perspective of the honey, rather than the user. Pages 24-59 give you some suggestions for different ways to look at the problem. Try to come up with at least two or three ideas for each suggestion.

At the end of your session, group your ideas together into similar approaches and write up a brief summary of each approach. Some of your ideas will be for a full system, while some will be just parts of a system. Make sure that you develop them all into complete systems before comparing them. You may also want to have another idea generating session to see if you have more ideas after some time has passed. As a team, choose five to ten approaches that you think are worth following up on.

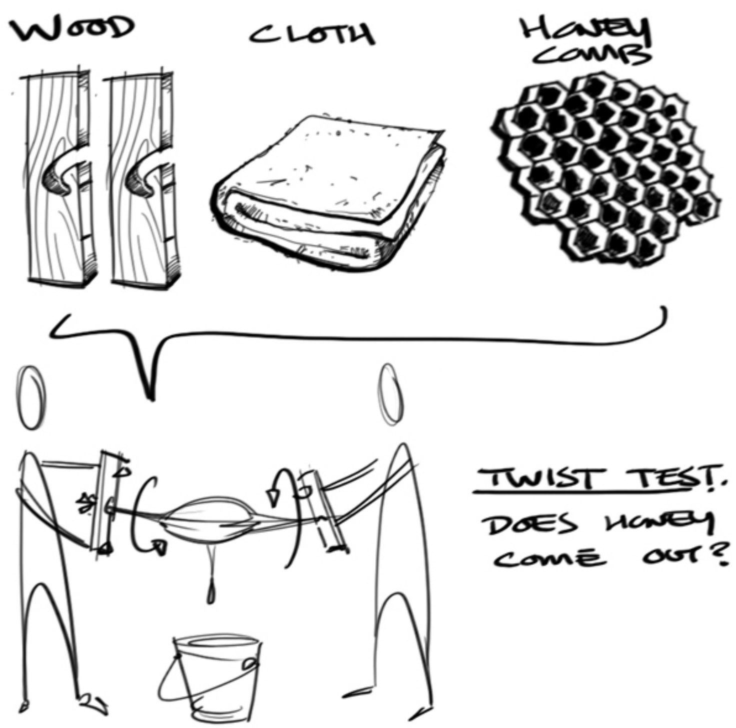


ANALYSIS & EXPERIMENTATION

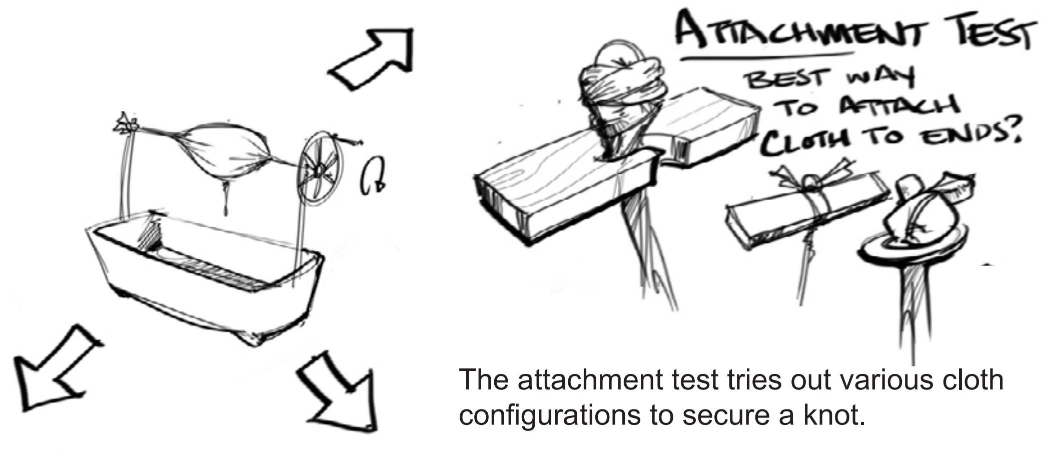
Now that you have sorted through your ideas, you will need to start the process of choosing the best approach. It is often necessary to learn more about each option in order to make that decision. Go through each approach and think of the key things that you would need to know in order to effectively evaluate the approach. Think of simple experiments that you could do to find out this information if it is not possible to get the information through additional research or through analysis. Devise an experimental procedure, and perform the tests to get the information you need. At this stage, you need to go fast, build mock-ups quickly and cheaply that will provide you with the results you need. Don't waste time on complicated concepts at this stage, and don't sweat the details.



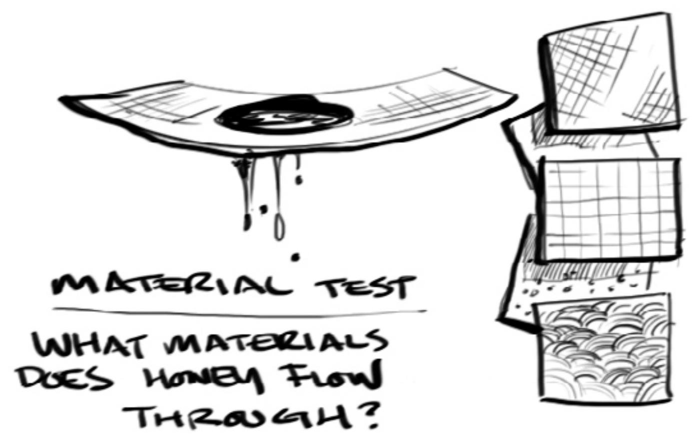
For example, this twist test is has been made to see how much honey comes out of honey come under twisting pressure. It is simple to put together with a few materials. And see if more in depth testing is necessary.



This honey bucket test is meant to see how easy it is to pour honey out of different containers, and clean them as well.



The attachment test tries out various cloth configurations to secure a knot.



The material test is simply meant to gather as many materials as possible, so see how honey passes through them.

Put more ideas here...

Design it to be very fast

Design it for under $2...

Design it to be as lightweight as possible

Design Constraints exercises

Make it modular

Design it for portability

Make it tiny

Make it huge

Design Constraints exercises
Use as few parts as possible or
Use recycled parts

Use only 4 different materials

Make it using only materials and tools that are available within in 20km

Put it together without glue, screws, bolts, rivets or nails

Make it a pair of products

Give it a second use

Design it so it can be assembled in under 10 minutes

Design it to be operated with just one hand

Design it with a partner half your age

Design it with a partner twice your age

Make it out of bicycle parts

Make it out of car parts

Design it for children

Design it for the elderly

Make it powered by the sun

Make it a particular shape
(square, round, triangle, star, etc)

Make it disposable

Make it last 100 years

Your experiment results/notes

Your experiment results/notes

Your experiment results/notes

Your experiment results/notes

CONCEPT EVALUATION

Your next task is to choose which of your many ideas you will concentrate on for your design solution. It is often difficult to do this, as ideas tend to take on a life of their own and you will find that each team member has their own favorite ideas. It is important to judge as objectively as possible. To do this you will need to consolidate your various ideas into designs that you can compare. You might consider grouping together ideas that are similar and combine them into a single solution. Try to narrow it down to three to five different concepts, each of which may be a combination of several of your original ideas.

PUGH CHART ANALYSIS

A Pugh chart is a tool that helps evaluate ideas by setting up a list of characteristics and judging each idea in terms of the individual criteria. This helps to create a more objective and structured selection process. One idea is chosen as the datum, or the idea to which all others will be compared. It is good to choose a fairly simple idea as the datum, as it will be easier to do the comparisons than if you choose one of your more complicated ideas. Sometimes, the datum is an existing solution. Revisit your list of design requirements to determine the criteria and characteristics that you will use to judge your potential solutions. It is important that many of criteria are specific to your project. Everything should be safe, reliable and cheap, think about the characteristics that apply to your project in particular. In the case of the honey press, such criteria might include keeping the wax out of the honey, or the need for processing the honey after using the device. Divide the criteria into two categories: general criteria, which are important for any good design; and specific criteria that apply especially to your project. In then end, you should have about ten criteria that you will use to evaluate the options. If you have many more than this, then none of criteria carries enough weight to make a difference; if you have too few, then your decision may not incorporate enough information.

For each of the criteria, decide if the option you are evaluating is the same (0), better (+) or worse (-) than your datum. Tally the results for each option and determine which idea is the best. You may want to weight some of the criteria more heavily (for example, safety might be deemed more important than portability when evaluating your idea, and therefore you may choose to double the weight of that criterion). When making your decision, you should pay more attention to the specific criteria You may also find that when you make your final selection, you will choose characteristics from different options and combine them to form the final design; however if you do this you should be careful not to make your project too complex.

	Criteria	Lever Press	Rollers	Impact	Spinning
specific	throughput	0	+	+	-
	quality of honey	0	0	-	0
	yield (x 2)	0 (x 2)	+ (x 2)	- (x 2)	+ (x 2)
	after-processing?	0	0	-	+
	power needed	0	+	-	+
	ease of cleaning	0	+	0	0
general	ease of use	0	0	+	0
	safety	0	0	-	+
	simplicity	0	-	0	-
	cost (x 2)	0	-	+	-
	Total	0	+3	-3	+2

FIGURE 4: SAMPLE PUGH CHART

Your Pugh chart...

	Criteria				
specific					
general					
	Total				

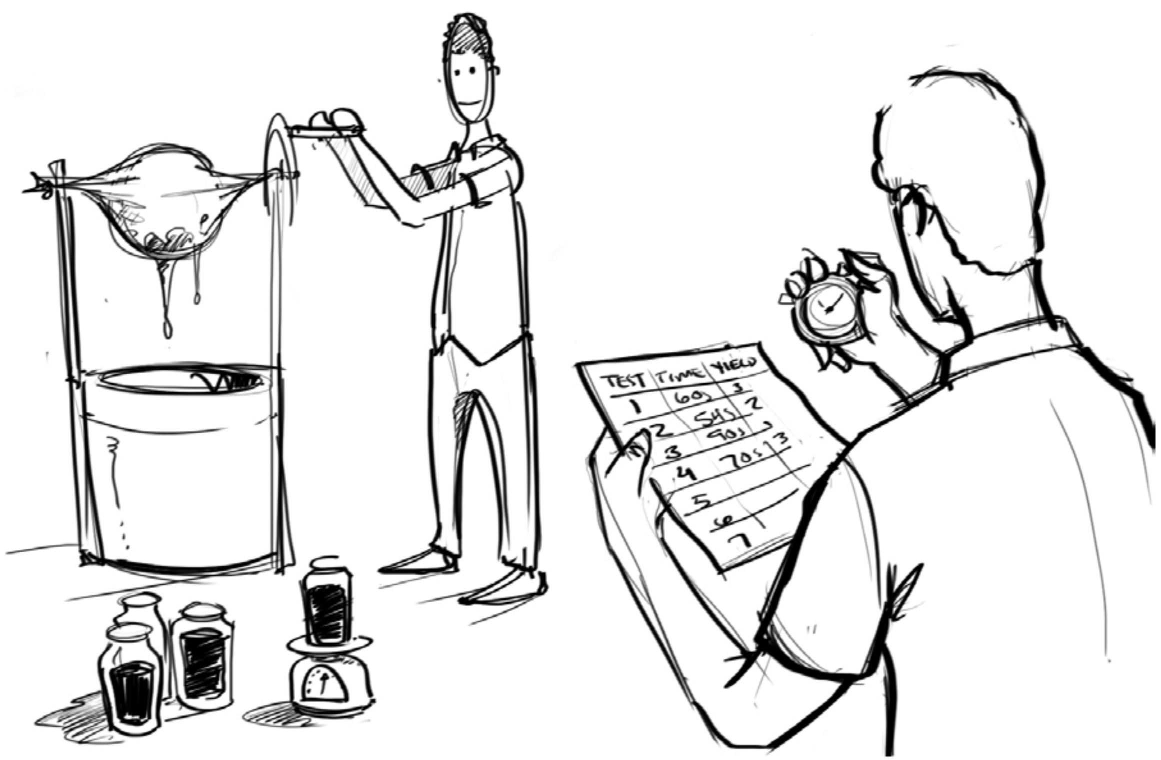
Your Pugh chart...

	Criteria				
specific					
general					
	Total				

Phase 3: Implementation

ANALYSIS & EXPERIMENTATION

Now that you have chosen the final concept, it is necessary to be sure that critical subsystems will perform as required. In many cases, their performance can be predicted by calculations; in other cases, experimentation will be required. The experimental setup may closely resemble the prototype that you envisioned, or it may be a more traditional laboratory experiment. The choice would depend on the information needed and the resources available. These experiments will be more rigorous than the ones that you performed during your concept evaluation process, as they will impact the final design of your product. Think about what you need to know for each system, and devise and perform the necessary experiments, models or analyses.



DETAIL DESIGN

Once the experiments have shown how the subsystems can work, it is necessary to work out all the details that will make a functioning prototype. This will vary greatly from project to project but includes aspects such as: dimensions and tolerances, material selection, kinematics of assemblies and sub-assemblies, and calculations of energy and power requirements. Every component of your project should be designed to best fulfill its purpose. Your first layout will not be your final one; continual refinement is possible until you run out of time, but the difference in quality from the first layout to the last can be enormous.

Keeping all these considerations in mind, start the process of producing technical drawings of your proposed design. Good drawings will ensure that team-mates are in agreement about the details of the design, and that technicians and artisans can accurately make the parts that you need. Whenever possible, you should use materials that can be obtained locally and affordably, that do not need to be custom-made.

Another important thing to consider when working out the details is to think about how your device will fail. It will fail, all devices do; you want to be sure that your device fails in a safe way, and in a way that is easy to repair. Look carefully over your design to identify the potential points of failure, and then think about which need to be prevented and which are acceptable modes of failure. Try to design the device so that it fails in the safest, most easily fixed manner.

FABRICATION

Now it is time to turn your ideas into reality—generally one begins by building a proof-of-concept prototype. Your first prototypes can be very rough, you just want to see if your ideas will work when assembled together. As you repeat the design cycle, you will refine your ideas and refine your prototypes.

Whenever possible, use off-the-shelf parts if they meet your requirements and are not too expensive. You can also save a lot of time by using parts or systems from existing devices, especially in early versions. In most prototypes the parts are typically fabricated on an individual basis and may not be made in the same way, or of the same material, as the final product, but as you get closer to your final design, you will use materials and methods that are closer to the final manufacturing processes.

Careful planning of the fabrication phase will save you valuable time, prevent unnecessary waiting times for your raw materials or components, and reduce stressful last-minute hard work. Develop a work plan so that you and your teammates can work together effectively and efficiently.

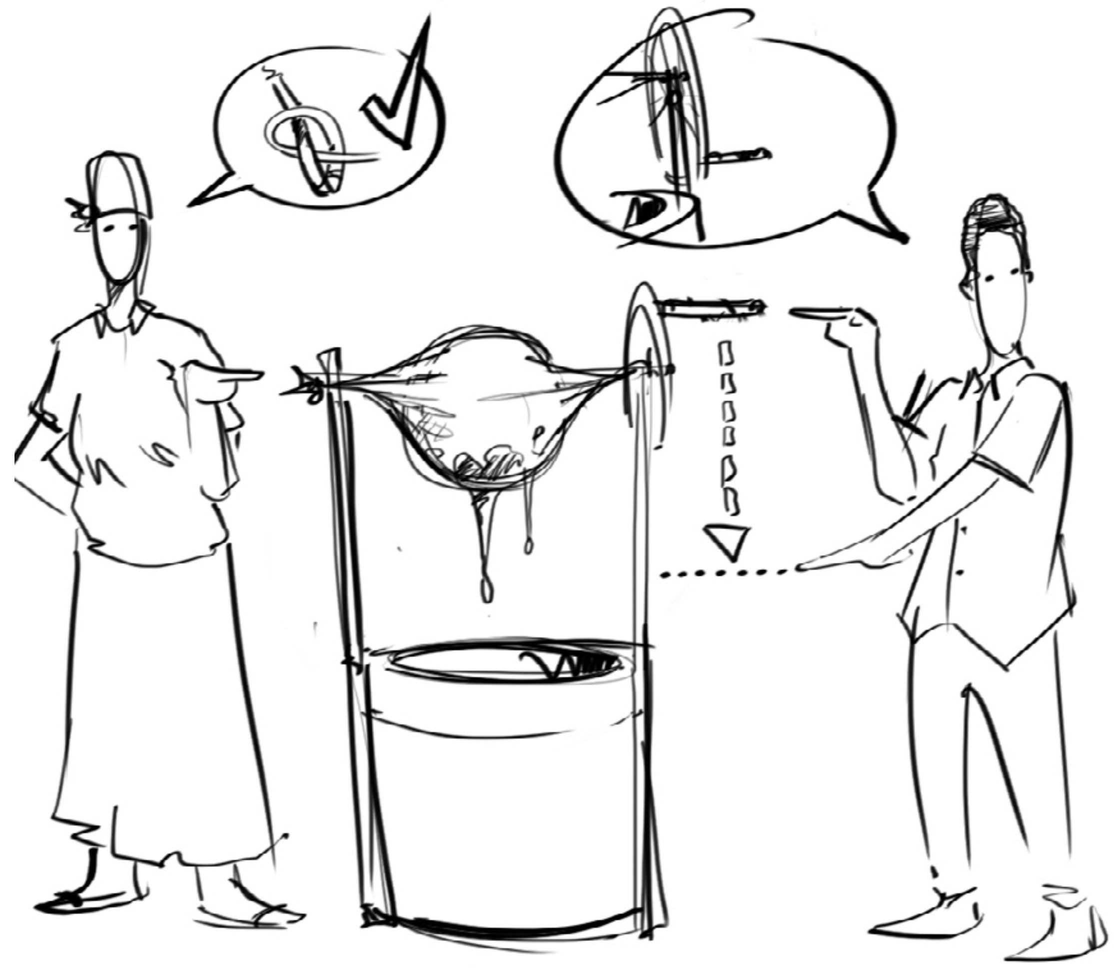
TESTING AND EVALUATION

Once you have built a prototype, it is necessary to test it and see if it does what it is supposed to do. Now is the time to go back to the design requirements outlined in the early stages of the design process and verify that the device satisfies the requirements. Devise techniques for measuring the performance of your device for each of your design requirements. As part of this exercise, think of how your device could be improved. Are there ways you can make it cheaper, faster, better? Try to lower the part count or remove material. Is it as simple as possible?

USER FEEDBACK

Not only should the technical performance of the device be tested, but also the human factors; test for usability and ergonomics. Have people try your device and get their feedback. Whenever possible, have the actual users try the device, if this is not feasible, try to find people with as close to the same background as possible. Have users try your device without as little instruction or guidance as possible, and analyze their interactions. You can observe how intuitive, easy and/or safe the device is to use.

Use the information gathered at this stage to prepare for the next journey around the design cycle. Consider revising the design requirements and the original ideal and desired values. Identify the subcomponents that need to be redesigned, and outline the goals for how to move the project forward. It is usually necessary to go around the cycle several times in order to refine your design and achieve the simple, cheap and beautiful solution.



Congratulations
You've been around the cycle once, Now lets go again!
Here are some extra pages for you...

Analysis and Experimentation

Its often useful to show your data in a graph

Notes

Analysis and Experimentation

Its often useful to show your data in a graph

Notes

Design Requirements chart

Customer Need	What are you going to measure	How to measure it (units)	Good Value	Better Value

Design Requirements chart

Customer Need	What are you going to measure	How to measure it (units)	Good Value	Better Value

Put your ideas here...

Your Pugh chart...

	Criteria				
specific					
general					
	Total				

Your Pugh chart...

	Criteria				
specific					
general					
	Total				