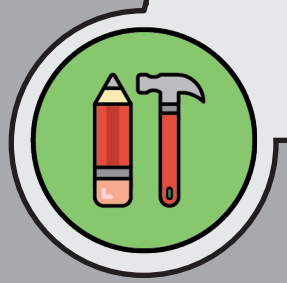
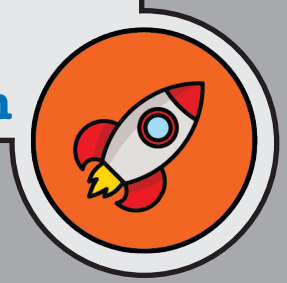
Discover Manufacturing

Design Thinking

FOR 3D PRINTING



Teacher Edition



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Introduction

Discover Manufacturing

Welcome to this **Design Thinking For 3D Printing** course. This course has been designed specifically to introduce you and your students to using Design Thinking as a process for solving problems.

What is Design Thinking?

Design Thinking is an approach used globally by companies, educational institutions, innovators, organisations and communities to discover in-depth insights into the true needs of users for services and products. The world today is much more complex than it ever was and therefore different processes are needed to solve these more intricate problems. Design Thinking is an iterative process combined with a solution-based technique to solving problems. In addition - it can be adopted as a way of thinking and working through difficulties using a hands-on approach.

Notes

- Many of the Design Thinking steps may be revisited or even skipped depending on your project. It is a good idea to both revisit and reuse some of the tools for the different Design Thinking steps during the project.
- Many of the tools are interchangeable - it is advisable to read through all steps and familiarise yourself with the tools before beginning.
- Design Thinking is **always** user-centred, iterative and adaptive.
- Much of Design Thinking is new to both teachers and students alike. Work together with students to understand how it functions.

Specifically, in this course we will be concentrating on using 3D printing to design and print a device to improve health for you or someone in your community.

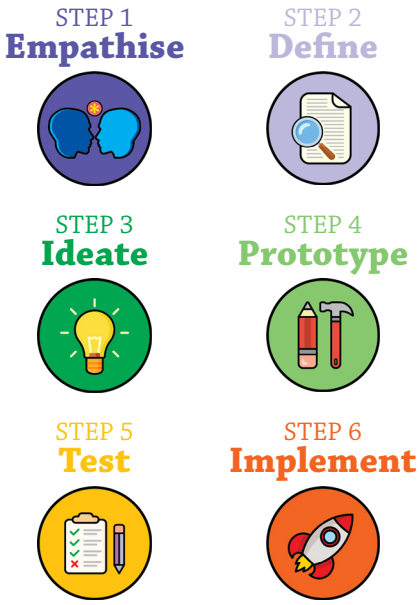
Included in this 3 session course will be three elements:

- **Design Thinking (this document)**
- **Tips & Tricks for 3D Printing**
- **3D Printing Health Challenge**

Content will be provided for you to present the Design Thinking approach to your students and the *"3D Printing Health Challenge"* for them to complete. Further to this, resources will be provided to use for both the Challenge and in your future 3D printing endeavours and teaching practice.

This document is hyper-linked, so look for links throughout - much like the Design Thinking process, you can move freely between pages and even other documents (provided they are all in the same folder). Enjoy!

Design Thinking Steps



Empathise STEP 1

THE VERY FIRST THING you will need to do with your students is ask them to create a "Problem Statement" for the *"3D Printing Healthcare Challenge"*. This will be the basis for the project and give the team(s) a goal to work towards. Advise the students that the user(s) should always be at the heart of their Problem Statement and any solution devised. Steer them away from solutions to problems that may not exist or a problem with a working solution already implemented. Students often want to jump straight to the building and prototyping stage as that is where they may feel most comfortable. However, let them know the process here is more important than a final working product.

When discussing and defining the Problem Statement - read through the questions below. Other ways to guide your students to narrow their decisions is to use the **<2x2 Matrix>** and **<Dot Voting>** tools. These tools will help the students focus their ideas and thoughts to finalise their Problem Statement.

After creating the Problem Statement, you will need to work with each team to "Define Success". The goal of this is to focus students so that they are all working together to achieve a consensus of what success actually is - given their Problem Statement. It should be noted that success is definitely not winning the competition. Use the **<Define Success>** tool to help with this.

3 Types of Empathy

COGNITIVE | EMOTIONAL | COMPASSIONATE

- Cognitive empathy is also known as "perspective-taking" and is "empathy by thought", rather than by feeling. It is about seeing another person's perspective.
- Emotional empathy is when you quite literally feel the other person's emotions as if they were your own. Emotional empathy is good but can be bad as it can easily overwhelm you.
- Compassionate empathy is what we usually understand by empathy: feeling someone's pain, and taking action to help. This type of empathy is usually the most appropriate for Design Thinking.

Define the Problem Statement

QUESTIONS TO GUIDE, ASK AND DISCUSS WITH STUDENTS:

- What is the problem?
- Why is it a problem?
- Who has the problem?
- Who has a need?
- When and where does the problem occur?
- Is it already being solved?

After the students have created the Problem Statement and achieved consensus of defining success - they should move towards the first step in the Design Thinking process. As mentioned previously - the user should always be at the heart of the Design Thinking process - so we begin with **Empathise**. Students should empathise with the user(s) of their Problem Statement before looking directly at a solution. To do this, they will need to employ a number of strategies. Three quick ways for them to begin to develop empathy are observation, interview and immersion.

Discuss with each team how they might do this - then guide them towards the Student Materials. Here, they can use tools such as the **<Empathy Quiz>** to check their own level of empathy - and the **<Empathy Interview>** and **<Empathy Map>** to do research, acquire data and gain insights. (These are included in the **Design Thinking for 3D Printing • Student Edition**. Students will need to conduct some research to develop an understanding of the end-users, their needs and what might best help them.

The aim of this step is to learn as much as possible about the needs of the potential user(s). These findings in turn help students to sharpen the Problem Statement iteratively and come to a common understanding of the problem for their team.

Define STEP 2

THE NEXT STEP in our Design Thinking process is to **Define**. In the first step, **Empathise**, students began to discover their user(s) needs after creating their Problem Statement and Defining Success.

Here - we want students to specifically define the problem before moving to the next step of brainstorming ideas to solve it. Once we complete the **Define** step, students should be completely ready to tackle the next stage of the Design Thinking process - **Ideation.** This is where they will formulate ideas to solve the [now] well-defined problem. The **Define** step in the Design Thinking process is about sharpening and focusing the details of the teams' existing Problem Statement and Empathy research.

The first way to get students to consider this step is to use the **"How might we..."** question. (see across) This will allow the user(s) identified needs to be simplified and defined even further. This step is generally very easy to navigate and quick to complete.

The second way for students to narrow choices is to see what the critical elements of their device are. Use the **<Critical Item Diagram>** to accomplish this. This will also help them concentrate on the upcoming **Ideation** step and begin to get students to think about how their solution and device might work in conjunction with each other. This is just the beginning of the define and design process and will almost certainly change before the final iteration - and certainly before any 3D printing begins.

How might we...?

THIS QUESTION IS SPECIFICALLY DESIGNED TO HELP STUDENTS SWITCH TO A DIFFERENT WAY OF THINKING.

- **"How"** implies there may be more possible ways to solve the question.
- **"Might"** creates a safe space where students know that a potential idea may work and can be attempted.
- **"We"** reminds students they are working as a team, not individuals.
- The question should be followed up with a verb (see suggested list below)

  a verb - eg: design
  a noun - eg: a gripping mechanism
  and
  a user(s) - eg: for people with rheumatoid arthritis

  Question - eg: "How might we design a gripping mechanism for people with rheumatoid arthritis?"

Read this question aloud to the team to see if it resonates or causes difficulty. It may be the question becomes too broad (eg: tries to improve the whole world) or too narrow (eg: anticipates a solution or doesn't allow for further exploration)

VERBS TO TRY

KNOW	UNDERSTAND	APPLY	EVALUATE	CREATE
Define	Predict	Solve	Frame	Create
Identify	Reflect	Apply For	Compare	Develop
Describe	Demonstrate	Construct	Experiment	Change
Match	Differentiate	Choose	Ask	Paraphrase
Recognize	Discover	Prepare	Check	Generate
Select	Research	Produce	Correlate	Imagine
Investigate	Transform	Show	Separate	Negotiate
Tell	Describe	Judge	Analyse	Design
Visualise	Compare	Transfer	Compare	Structure

Ideate STEP 3

THE THIRD STEP of Design Thinking is **Ideate**. The classic way of ideation is brainstorming - and that's what we're going to look at almost exclusively in this step. A definition of brainstorming is *"a group discussion to produce ideas and ways of solving problems"*. This is exactly what we want to do - **produce ideas**. This step is all about generating as many ideas as possible before they are sorted, combined or clustered into a final solution for 3D printing. Look at **<Brainstorming Rules>** for more information before beginning.

Give students plenty of space to make ideas using lots of tools such as paper, markers, cardboard, Post-its - anything! They shouldn't concentrate too long on any one idea - 3 minutes is a good maximum. We're looking for quantity rather than quality!

Once students generate their ideas - the selection of ideas should take place within a framework of evaluation and voting from the team rather than individuals.

For the selection process - the **<2x2 Matrix>** and **<Dot Voting>** tools are useful here again. Generating ideas is usually pretty easy to do - while the selection of ideas can be more challenging.

What to do next...

How to kick off your Brainstorming Session

- Prepare a clear "How might we..." question.
- Start to Brainstorm! Draw, sketch and write all ideas down!
- Group, cluster and assess ideas at regular intervals to narrow choices - the goal is to finish with a single clear idea.
- When discarding ideas - consider moving them to a "Parking Lot" of unused ideas rather than deleting entirely.
- Check in with students to see if more creativity - or perhaps more focus may be needed.

Brainstorming

Things to generate with students...

- Ideas. Lots of ideas. Lots and lots of ideas!
- Enthusiasm and momentum!
- Creativity and originality!
- No criticism! - All ideas are good!
- Energy and passion! *Early morning sessions are best!*
- Drawings, pictures, text and wordclouds! https://www.wordclouds.com

Prototype STEP 4

WE'VE PROGRESSED RAPIDLY into the next phase of Design Thinking - **Prototyping**. Building prototypes makes all the previously selected ideas tangible and perceptible. There can be many different types of prototypes - from vision prototypes up to a final prototype. Building prototypes (especially for 3D Printing) can require a lot of different materials - we don't necessarily want to jump straight into printing the final device. This is especially true when 3D Printing, as it can take a long time for a 3D printer to create a print - even at its lowest setting. The first stage is for students to take their final idea from the **Ideate** step and create a Vision Prototype (see "Prototyping Categories" below).

After this, concentrate on the next few stages of prototyping. Begin to use a low resolution (Low-Res) to high resolution (Hi-Res) methodology. Use basic physical materials and tools (see below) such as cardboard, paper, glue, wood, straws, elastic bands, wire, string, hot glue, skewers and more in the next two prototyping stages. Students should make physical prototypes from their initial hand-drawn sketches - then move to a slightly more complicated digital format. See **<Digital Prototyping Tools>** for ways to move your prototypes from hand-written to digital. After this - you can try simple 3D printed pieces or even the whole solution - but always be aware this can take a lot of time!

This is an exciting time for your students as their ideas will begin to become reality. It can also be a frustrating time when elements of their design may not work as expected or their expectations are too high. (Manage expectations - it is quite likely students will want to create the design and just print it... without iteration, testing or even prototyping!)

There are many types of prototyping but as this project is for the 3D Printing Health Challenge - 2 things are fundamentally important: the user experience and the functionality of the device. These can be broken into: Critical Experience Prototype (CEP) and Critical Function Prototype (CFP). (See Prototyping Categories below.)

Prototyping Categories

It would be expected to build a minimum of 2 functional prototypes before 3D printing your final project. It's best to go through many small iterations rather than a single large one.

Vision Prototype

» Take your Problem Statement, definition of success and combine it with your How Might We... question then mix in your brainstorming ideas... to create your Vision Prototype! It's better to sketch or draw this prototype.

Critical Experience Prototype

» Now take your Vision Prototype and add in the Critical User Experience. The goal here is to again empathise with the user so their needs are met in conjunction with your Problem Statement being solved. Ask students what the critical experience should be for the user(s).

Critical Function Prototype

» Once you have built the first two prototypes - you now must ensure the functions all work as expected before progressing. Ask students if it functions as expected for the user(s).

Final Prototype

» Now that you have done your prototyping - begin to move towards the Hi-Res version. You can either build this - perhaps using some 3D printed individual parts or move towards 3D printing the whole solution.

The user is always at the heart of what we are trying to accomplish. To this end, their experience and how a device will improve life for them is extremely important. We want to ensure what is designed will ultimately help them. (This ties directly to the first step of Design Thinking - **Empathise**). Also critical is to ensure the device won't malfunction in some way leaving the user at an immediate disadvantage. Not only is experience important, but function is equally as important.

Physical Materials

1. **PHYSICAL TOOLS** : Pliers, scalpels, scissors, drills, rulers, markers, pens, pencils, hot glue guns, staplers, etc.
2. **MATERIALS** : Cardboard; Lego; tape (plain, duct, painter, electrical); paper (heavy, light, tracing); glue (hot glue, Superglue, glue stick); skewers; wire (multiple weights); bottle caps; cable ties; straws; elastic bands; brass fasteners; scraps (wood, fabric and plastic); almost anything!

Don't forget that it's best to from work Low-Res to Hi-Res.

Test STEP 5

WE'VE ARRIVED at the second to last step in Design Thinking. We're not done yet, but nearly there! To better inform this step, let's revisit what the students have completed so far. (See text on right)

If students have access to their user(s) - getting direct feedback from them would be the ideal way to progress. However, this is not always possible. There are still plenty of ways to test their solution. The goal for the students is to get feedback on their project. If their user(s) aren't available - you can ask other teachers, friends or parents to play the role of the user(s).

It's generally not recommended to get feedback directly from the students themselves - they are too close to the project and it can be difficult to get reliable data from them. Also note that parents or close relatives may also lead to unreliable answers.

The two most important things for students to do here are:

- Set up as close to a real-life scenario as possible to mimic a user(s) experience.
- Ask open-ended and detailed questions - but not leading questions.

To guide students in this step of Design Thinking - refer to the **<Testing Sheet>**. This will give them a good guide to know where and how to setup a good testing scenario. Most important here is to guide them on formulating good questions.

Empathise • Define • Ideate • Prototype

WHERE HAVE STUDENTS BEEN AND WHAT HAVE THEY DONE?

- Created a Problem Statement
- Defined Success
- **Empathise**
  Researched their user(s) to better understand how to solve their Problem Statement.
- **Define**
  Further clarified the critical elements of what will make the project successful for their user(s). Sharpened and focused their empathy research while ensuring to always keep the user(s) at the heart of both their Problem Statement and solution.
- **Ideate**
  Brainstormed to find ideas, concepts, plans and solutions for their Problem Statement. Came up with lots and lots of ideas - some of which may formulate their ultimate solution for this project - other ideas may be possible solutions to different projects!
- **Prototype**
  Began building what their solution would look like. They started with Lo-Res drawings and sketches - moved to slightly more complicated digital prototypes, then on to Hi-Res versions. Finally they designed and 3D printed their workable solution.

Implement STEP 6

THIS IS THE LAST step in our Design Thinking process! Now comes implementation. This step is all about taking the device, service or product and putting it out into the world for sale and use. In the case of the **<3D Printing Health Challenge>**, students should begin to look at next steps for the project. The prototyped 3D printed device has been created and they should begin to query the final manufacturing process. The project [probably] won't go to that step - but students should understand the requirements to make it happen. Most devices and products go to large companies to manufacture in bulk - and use a variety of different materials. Steel, aluminium, rubber, plastic, textiles and more can be used in a final product. What would their device require?

Students should query the larger questions such as funding, manufacturing plants, development costs, ownership, intellectual property rights, business setup, legal challenges and more. They don't necessarily needs answers to these questions - but should be aware of the questions and give them consideration.

Example questions to ask

Students should explore one final step in the Design Thinking process - bringing their prototyped device to the manufacturing stage. Give students some example questions (See below) to think about.

WHO
- ...will purchase the device? ...needs the device?

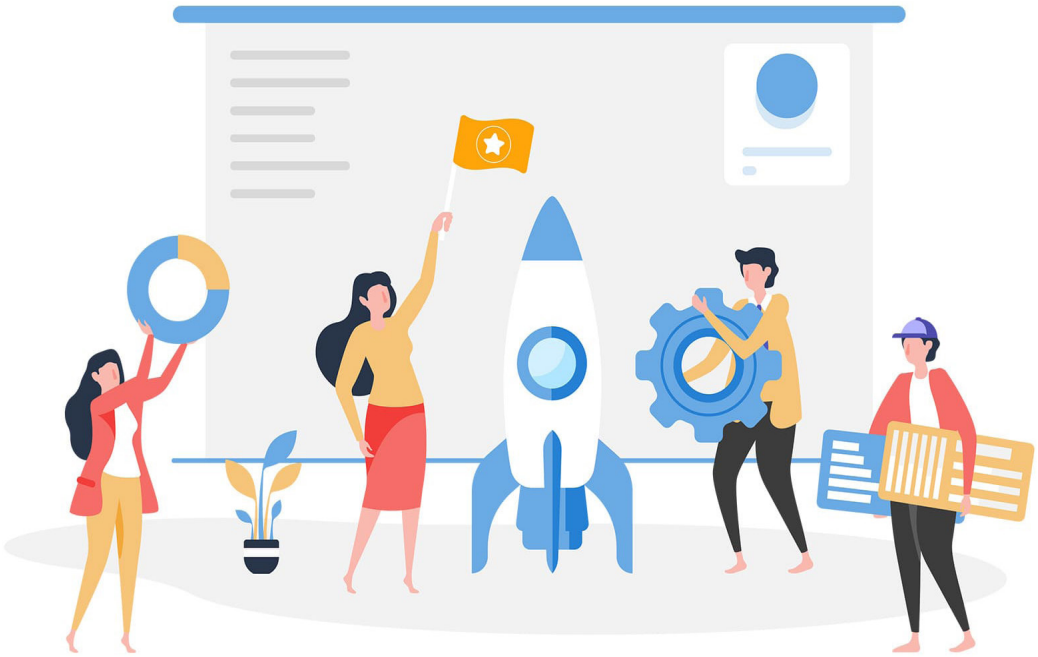
WHAT
- ...will it cost? ...colour will it be?

WHEN
- ...will it be available publically? ...can it be ready to sell internationally?

WHERE
- ...will the funding come from? ...can we get it manufactured?

WHY
- ...was it worthwhile to solve the problem?

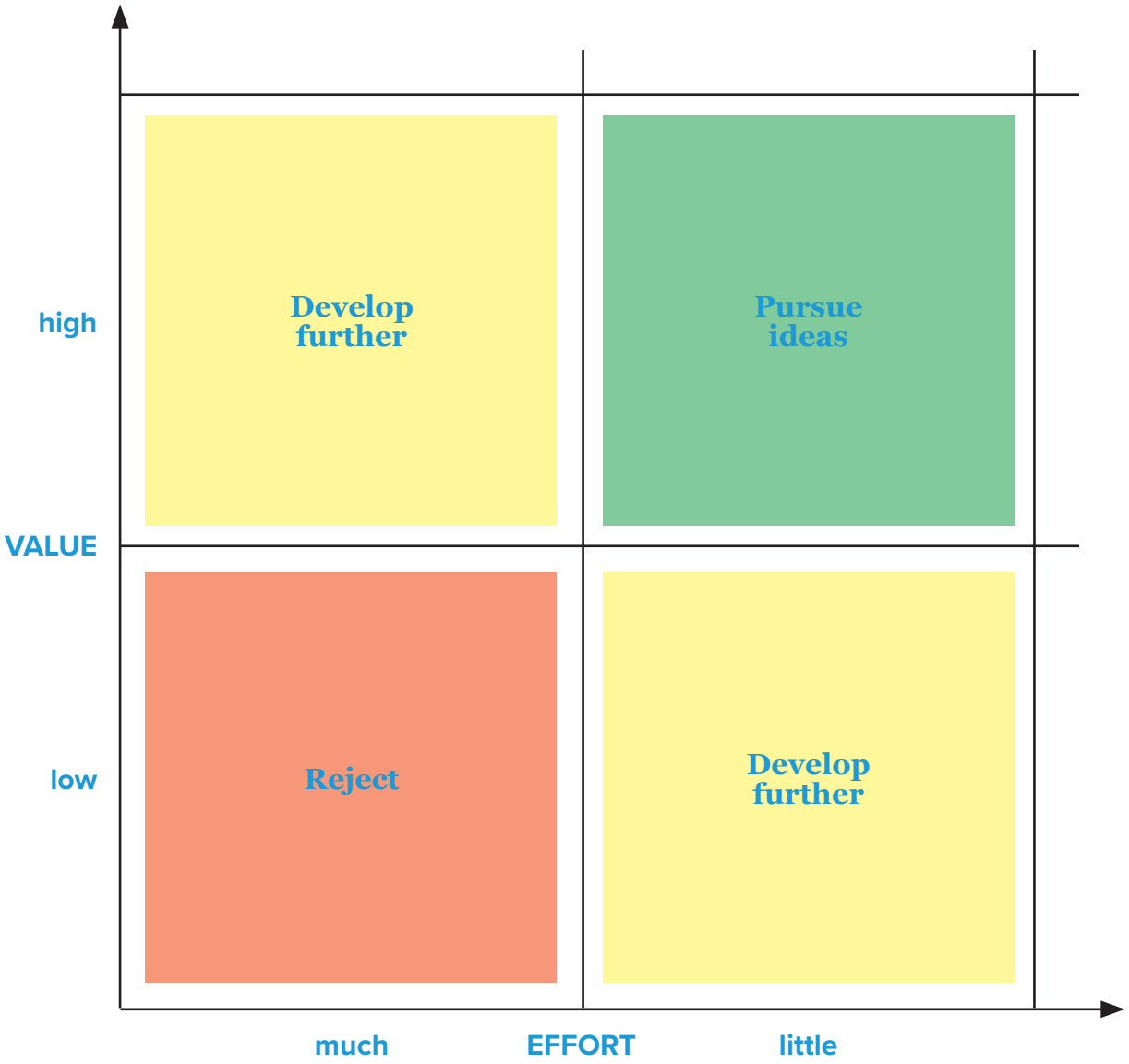
HOW
- ...would it be marketed?



Expert Tips

- This Step is about thinking further than the boundaries of this project.
- Use the **<5W+H>** method as a reflection tool.
- Many times adults have short-sightedness when considering problems and solutions. Explain to students they still have a very fresh perspective on the world and how things work.
- Use the **<6x3x5 Method>** to explore infinite possibilities with students. "What if..." they had unlimited budget, time, resources and materials?

2x2 Matrix



How to use this tool:

1. **DEFINE THE AXES** : Think about and sketch different possibilities how the axes can be labeled. Put this on a whiteboard / large sheet of paper; project or print out copies for each student.

2. **POSITION THE IDEAS** : Students should fill the matrix with their ideas.

3. **FINDINGS** : Record their findings and get them to work towards a single, simple idea.

   ◊ **NOTE** : Matrix on the left is an example only. Define your own options (or let the students define them!)

Expert Tips:

» The 2x2 Matrix is a visual way of categorising ideas.

» Use this tool to quickly determine which ideas should be used and which should be discarded.

» This tool reduces the complexity of ideas generated.

» Use opposite attributes such as “benefits” and “feasibility” or a “cool” and “doable” axis.

» A “SMART” approach can be a valuable way to use this tool. (Using the guidelines of: **S**pecific; **M**easurable; **A**chievable; **R**ealistic and **T**imely to focus students.)

» The 2x2 Matrix is highly modifiable as any type of meaningful axis attribute can be used. The versatility of this tool makes it ideal to quickly focus students.

» This tool may also be used throughout the Design Thinking cycle.

Dot Voting

CRITERIA	VOTE	COUNT / EVALUATE / CLUSTER / DECIDE
Suitability		
Need		
Opportunity		
User(s) Requirements		
Time		
Achievable		
Define your own criteria...		

How to use this tool:

1. **CRITERIA** : The criteria of the vote should already be decided upon, but clarify so everyone understands how to vote.
2. **POST-ITS** : Place all Post-it options on the board.
3. **DOTS** : Everyone should get a limited number of dots with which to vote (usually between 3-5). Dots can be stickers or coloured markers. (Less than the total number of options)
4. **VOTE** : Each person votes on an idea - in private or at the same time (to avoid "popularity votes") - simply by placing a dot on an idea.
   - ◊ **NOTE** : Table on the left is an example only.

Expert Tips:

- » Dot Voting is visual, flexible, fast, simple and fits the Design Thinking mindset perfectly.
- » Individual students OR teams can provide answers when voting. (Depending on questions to be answered and criteria to be decided upon)
- » When writing answers and explaining - no discussion or comment should take place - yet. Wait until all answers have been given, then discuss.
- » While discussing answers - begin to combine and eliminate some - and begin to form "clusters" (similar types of answers). Then narrow the focus towards a single vision.
- » If equal dots are recorded - dismiss and vote again - or use the **<2x2 Matrix>** to simplify quickly.
- » Make use of a "Parking Lot" for ideas - don't throw them away - use them for another project.

Define Success

DEFINE QUESTIONS	ANSWERS	EVALUATE & SELECT
How will the project give value to the end user?		
What happens if the project is not finished?		
How do you define success?		
Where can the project be used?		
Who can benefit from the project?		
Why is the project happening?		
Define your own questions to suit your class / project or Problem Statement.		

How to use this tool:

1. **DEFINE** : Define the questions to ask. (See examples)
2. **ANSWERS** : Consider answers to the questions.
3. **EVALUATE** : Evaluate answers and begin to define the characteristics of those answers.
4. **SELECT** : Have the team create a Success Statement.
   - ◊ **NOTE** : Table on the left is an example only.

Expert Tips:

- » If students are finding it difficult to narrow focus, you can use the **<Dot Voting>** tool.
- » This step can often seem long-winded and frustrating as it seems there is no point to this decision. The reason this step takes place is to ensure students have a common goal. As the facilitator, you can refer to this throughout the rest of the steps during the project. Try to ensure students understand the value of this so that everyone is in agreement of the team's goals.
- » The secondary reason is that when the goal is met - there is greater value in both the process and the result. If the goal is not met - you can clearly show the work that has taken place and find exact reasons why it wasn't achieved. These are all good learning points.
- » Teacher leadership here is very important. Once students begin the process, they will be able to move forward - but getting over this step can be problematic and time-consuming. Try to focus students early.

Empathy Quiz

University of California - Berkeley

This quiz was developed by the University of California, Berkeley's "Greater Good Magazine". It draws from 3 scientifically validated scales researchers have created to measure empathy: the *Toronto Empathy Questionnaire*; the *Interpersonal Reactivity Index* and the *Emotion Specific Empathy Questionnaire*.

Go to this URL and take the quiz:

https://greatergood.berkeley.edu/quizzes/take_quiz/empathy

How to use this tool:

1. **GO TO THE URL** : Take the Empathy Quiz.
2. **ANSWER** : There are 28 questions - answer the questions as honestly as you can - there are no right or wrong answers.
3. **SEE SCORE** : When complete - submit. You will get your score immediately. It will tell you how empathetic you are and suggestions on how to improve your empathy.
4. **DON'T SHARE** : This quiz is purely for you to measure your empathy. It is only a rough guide, so don't take any definitive results from it. Lastly - there is no need to discuss your answers or suggestions with others - this is just for you.

Empathy Interview

Existing assumptions about the user(s) and the problem.

How might we empathise with the interviewee so they share more details of their story?	Key questions for the story…	Keywords and topics for the user(s) emotions.

Outline of the user(s) story…

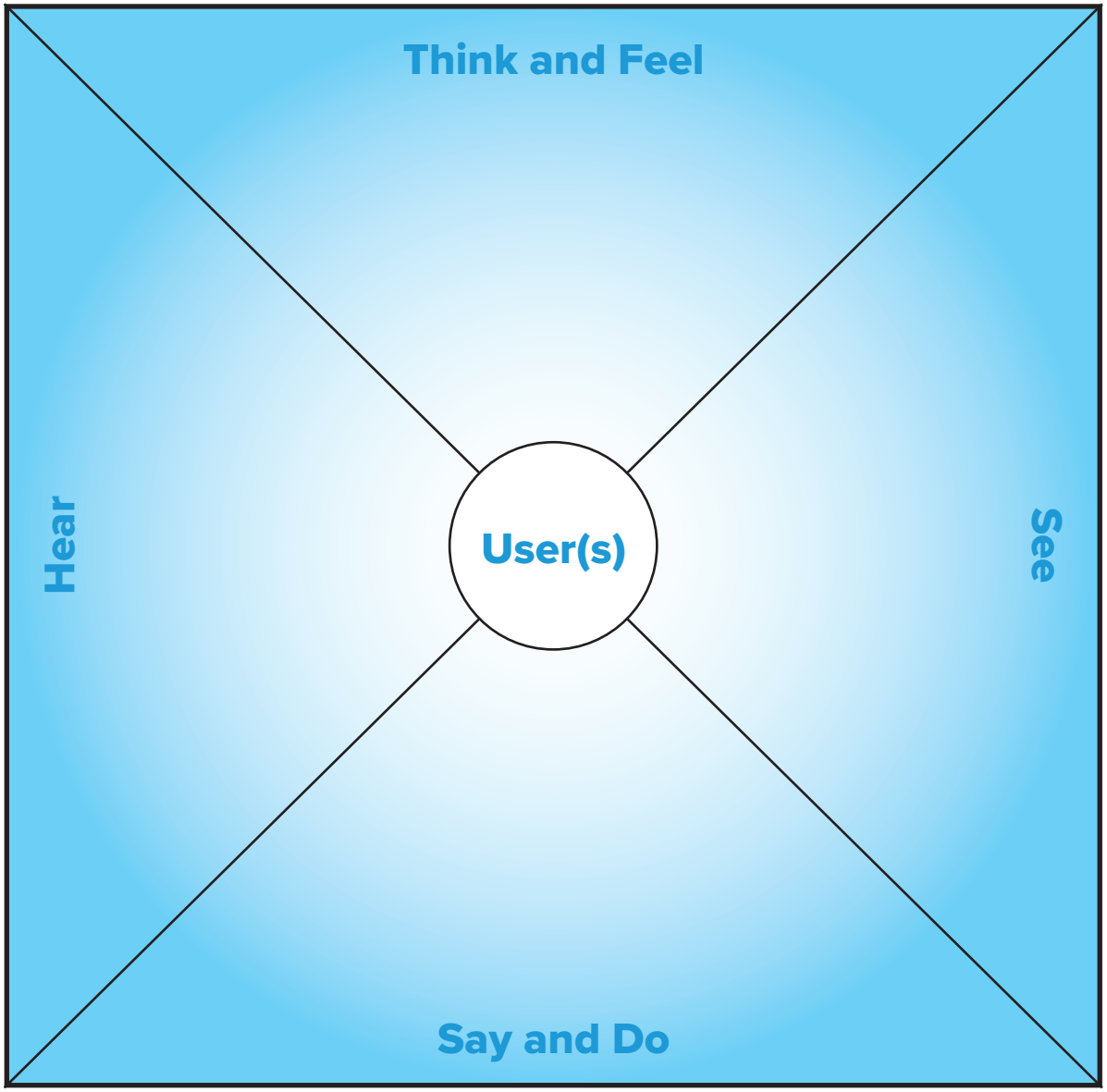
How to use this tool:

1. **PUT DOWN YOUR EXISTING ASSUMPTIONS** : Discuss with your team what you think is happening for the user(s) already.
2. **PREPARE** : Write out your questions beforehand and discuss with the team what they think.
3. **CONSIDER EMOTIONS** : This may be difficult for the interviewee - consider how they may feel.
4. **OUTLINE** : After the interview - write the outline of their story.

Expert Tips:

- Each team member should have a role. One to document (audio and video if possible), one or two asking questions and one to record answers.
- Build trust with the interviewee. Help and assure them that their information is not being made public. Explain the parameters of your project to them.
- Build a personal relationship. Try to see things from the interviewee's point of view. Avoid saying things like "I understand you - my cousin has the same problem." This inhibits the interviewee telling their story and giving their own insights.
- Try to get the interviewee to tell you different stories about their problem. This will provide better information and emotional experiences of the user(s).
- Avoid closed questions that cannot be answered by "yes" or "no". Use open-ended questions instead. {See **<5W+H>** for ideas.}
- Observe non-verbal information such as body language and eye-contact for more clues.

Empathy Map



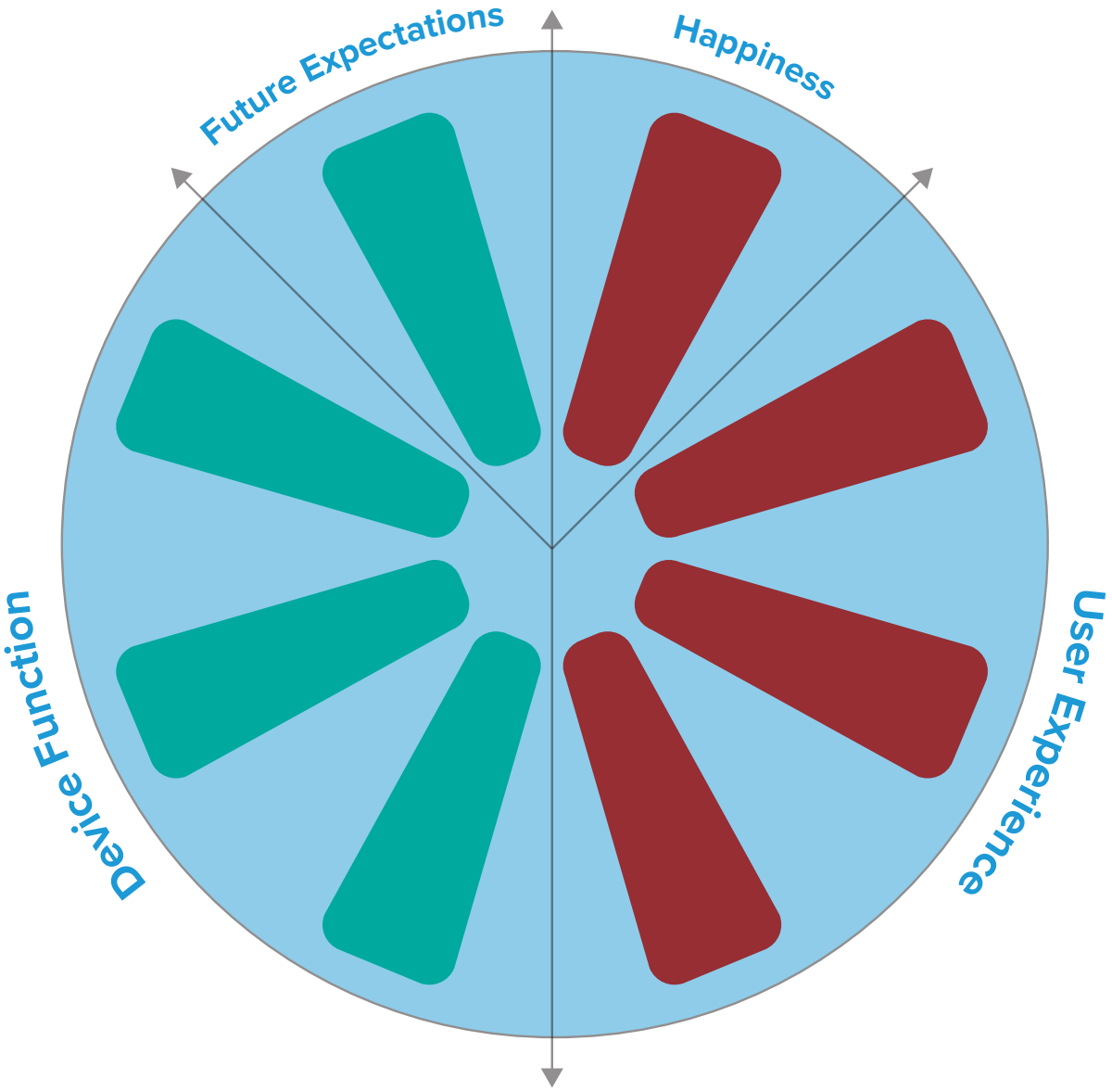
How to use this tool:

1. **THINK OF QUESTIONS FOR THE USER(S)** : Come up with questions to ask your user(s).
2. **FILL IN THE CHART** : Ask questions about the user(s) needs. This tool is used to identify feelings, thoughts and emotions.
3. **THINK AND FEEL** : What emotions does the user(s) have? What do the user(s) think?
4. **SAY AND DO** : What do the user(s) say? What must the user(s) do?
5. **HEAR** : What things do the user(s) hear? Who speaks with the user(s)?
6. **SEE** : What does the user(s) environment look like? What does the user(s) see?

Expert Tips:

- Try to frame your questions in terms of verbs (activities) instead of nouns (solutions).
- For even more insights - after asking questions - consider using the “Pains” and “Gains” idea. This is simply asking yourself 2 questions after interviewing the user(s).
  - What are the user(s) biggest challenges?
  - What are the opportunities the user(s) may have?
- Pay attention to body language, tone and word selection - these can give more information than spoken words.
- Look for contradictions. Sometimes what user(s) say and what they do can be different - try to understand why this could be the case.

Critical Item Diagram



How to use this tool:

1. **QUESTION** : Ask students to ponder the question - "What is absolutely critical for a successful solution to this problem?"
2. **DRAW** : Sketch a "Critical Items Diagram" (example on left) and discuss with the team which functions are critical for the user(s).
3. **WRITE** : Each team member writes eight critical elements - divided into... 4 User Experiences and 4 Device Functions.
4. **CONSOLIDATE** : From all answers, ask students to choose only 8 in total. (4 from User Experiences and 4 from Device Function).

Expert Tips:

- This section should go quickly - try to encourage the students to begin to iterate quickly.
- Individuals rather than teams should give their answers.
- A good idea during the **3. WRITE** section of the tool is to ask students to:
  - Make 1 of their 4 answers from Device Function be "Future Expectation". This helps students contemplate how the device will be seen as the user(s) grow.
  - Make 1 of their 4 answers from User Experience be "Happiness". This firmly places the user(s) experience in the students thoughts.
  - This can make the exercise a bit easier and also get them to solidify thinking about the user(s) and how the device will work for them in the future.

Brainstorming Rules

Brainstorming Rules:

1. **CREATIVE CONFIDENCE** : Encourage students to be as creative in as many ways as possible using as many tools as possible. There is no wrong way to be creative when brainstorming.
2. **QUANTITY BEFORE QUALITY** : The goal of brainstorming is the generation of ideas... we don't care how pretty they are, if they'll actually work or even if they are absurd - get them out there!
3. **VISUAL IDEAS** : Most people learn easiest visually - encourage students to draw or sketch their ideas. Use stick figures, perspective (such as out a window), give it a face or personality, use rough sketches and quick notation. What's it like under water or on a muddy country lane?
4. **USE GESTURES** : When people begin to explain their idea - encourage the use of gestures to get their point across. This can lead to freeing up the brain to think of more ideas.
5. **BUILD ON THE IDEAS OF OTHERS** : Let students take other people's ideas and run with them. In this case, it's not "stealing" - it's adapting and building. Remember, it's your team and you already have a goal to work towards!
6. **ONLY 1 PERSON SPEAKS** : Each team gets a chance to explain their idea - if this sparks an idea in a team member - ask them to write, draw or sketch it out while someone else is speaking.
7. **NO PREJUDICES** : No idea is bad. Save crazy ideas for later - you never know when you might need them.
8. **CONTINUE TO BRAINSTORM** : Let others spark your imagination and when the session ends, don't stop considering your ideas.
9. **FAIL EARLY AND FAIL OFTEN** : Be unrealistic and impractical early in the discussion. Accept some things aren't workable right now and move on. Create a "Parking Lot" of ideas that are exciting but don't contribute to the solving the problem.

6-3-5 Method

Problem Statement

1.1	1.2	1.3
2.1	2.2	2.3
3.1	3.2	3.3
4.1	4.2	4.3
5.1	5.2	5.3
6.1	6.2	6.3

Clustered and narrowed ideas:

How to use this tool:

1. **GRID** : Create a grid similar to the one on the left. There should be as many rows as team members. (The columns remain at 3)
2. **IDEATE!** : Each team member gets an individual sheet. (as example shown). The Problem Statement is written at the top by all team members. Each team member writes 3 ideas on their sheet within a defined period of time. (2-5 minutes is good). No discussion of ideas - the exercise is done in silence until the end.
3. **ROTATE** : The sheets are passed clockwise to the next team member. Repeat the Ideate process. Team members may build on previous ideas or create new ones.
4. **CLUSTER AND NARROW** : After each team member has filled in all the sheets - have a quick discussion, then cluster and narrow ideas in the final box. Then further narrow and cluster your ideas by combining sheets.

Expert Tips:

- Start off your process with a “How Might We...” question - making sure it is narrowed down to a unique perspective.
- Focus. The question should be very specific so that participants all understand what is trying to be achieved.
- Show - Don’t Tell! It can be very useful to sketch or draw ideas instead of describing them with words. It can speed up the process as well.
- Don’t always come up with new ideas - build on others ideas. Iterate, change and narrow them down.
- At some point - you need to begin to narrow your ideas down... begin to cluster similar ideas together and either move unused ones to a “Parking Lot” of ideas or discard.

Post-it Notes

Download on the App Store | GET IT ON Google Play | Download on the Mac App Store

Apple / iOS: https://itunes.apple.com/us/app/post-it-plus/id920127738?mt=8

Apple / Mac: https://apps.apple.com/us/app/post-it/id1475777828?mt=12

Google / Android: https://play.google.com/store/apps/details?id=com.mmm.postit&hl=en_US

The Post-it app will also interact directly with both Miro and Trello.

(Free online collaboration and whiteboard software)

Miro: https://www.miro.com

Trello: https://www.trello.com

miro Trello

How to use this tool:

1. **ASSIGN COLOURS** : Give teams or individuals their own colours.
2. **ANSWERS** : Have students (or teams) write their answers either with text or visually. (Shorter, neater words are better)
3. **COLLECT** : Collect and collate data from answers. Begin to form clusters to narrow choices and decisions. For further narrowing, use **<Dot Voting>** to help!

Expert Tips:

» **COLOURS** : A variety of colours is very useful. Use different colours for thoughts, ideas, groups, individuals, clusters and more!

» **BRAND** : You don't need the official Post-it brand - there are plenty that are as good and available from many other sources.

» **USAGE** : Writing text or sketching visual ideas - as individuals or groups. It helps focus students both by limiting space and allowing for quick iterations. Use to brainstorm, iterate, discuss, vote and more!

» **DIGITAL** : Become a Post-it Master by using both the paper and digital versions! There is a free app available for both Apple (iOS) and Google Play (Android) stores. The App allows you to take a photo of wall full of Post-its and it automagically reads the text, colour and position of the note. You can then re-organise, add, delete, edit and change how you like. An excellent tool for documentation!

Digital Prototyping Tools

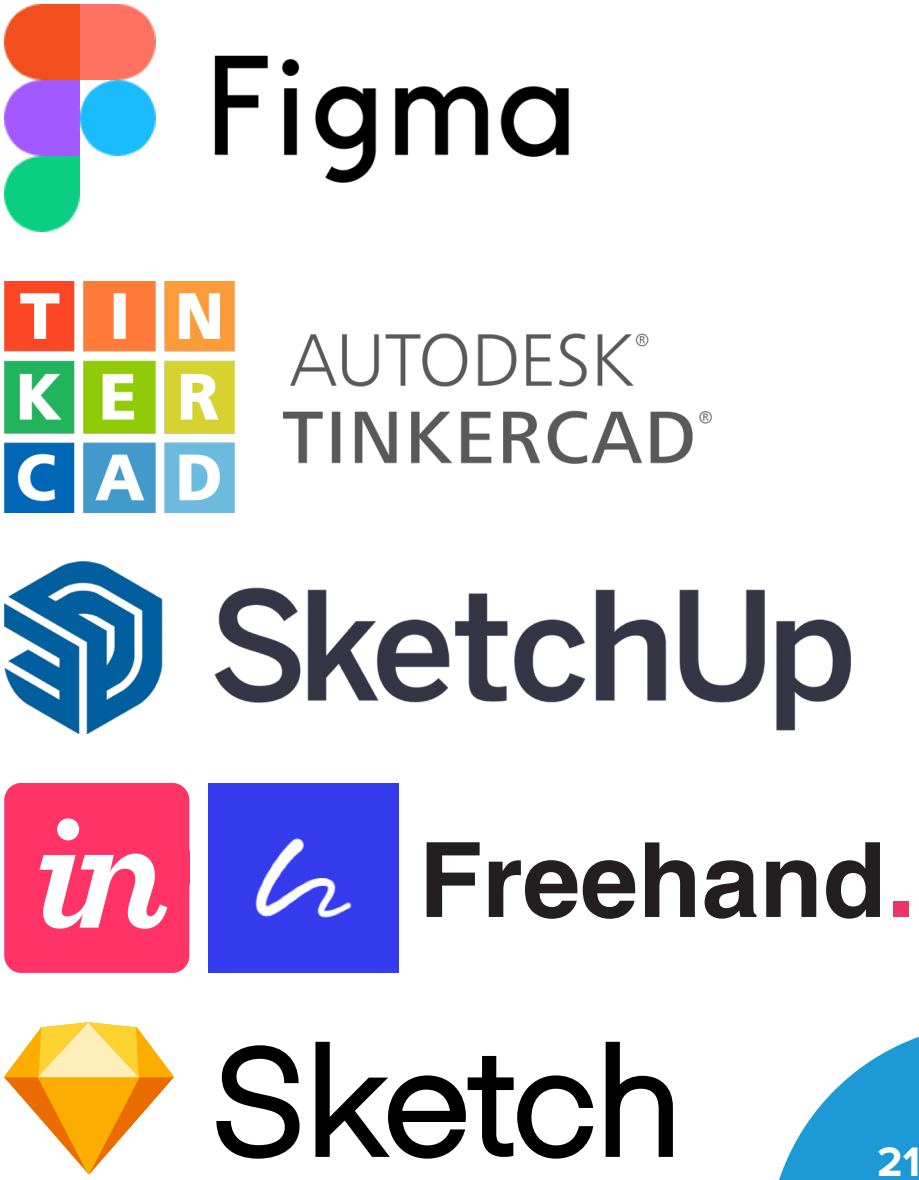
How to use these tools:

1. **ACCOUNTS** : Most of these tools are free to use, but will require you to sign up for an account. Students should use their own email address to sign up and sign in. Some of these tools are collaborative (such as InVision) - whereby students can share data and work together on the same project. Others will let you manage accounts from a single teacher account (such as Tinkercad).
2. **USAGE** : Almost all of these tools are easy to pick up and use with little training required. However, some require guidance (such as the drawing/3D modelling tools Tinkercad, Sketch and SketchUp). The “free-flow” style of Figma and Freehand may at first be confusing to students. This is the nature of prototyping. Ideas are generated and tested, then refined. Remember to begin Low-Res and move to Hi-Res.
3. **TEST** : It is always recommended for the facilitator to test these tools themselves first before introducing them to students.
4. **INTUITIVENESS** : Students will always approach software tools as being simple and intuitive. This is true for most Apps and many pieces of software. However - in this case, students are moving to use professional tools with many options and variables. This can lead to frustration when things don’t work as expected. Look out for this and suggest other ways to approach prototyping such as physical making or 3D printing!

Digital Prototyping Tools

DIGITAL TOOLS TO HELP YOUR PROTOTYPE DEVELOP...

Figma	https://www.figma.com
Tinkercad	https://www.tinkercad.com
SketchUp	https://www.sketchup.com/products/sketchup-for-web
InVision Freehand	https://www.invisionapp.com/freehand
Sketch	https://www.sketch.com



Testing Sheet

Test Scenario

Brief description of test scenario	Test criteria

Procedure	Roles	Questions

Test Results

Documentation	Summary

How to use this tool:

1. **TEST PLANNING** : Consider where the test should take place. Ideally at the user(s) location in their own environment - but if not possible, try to recreate as much of the scenario as possible. (Refer back to Empathise and Define stages)

   Assign roles to testers and plan the sequence of how it will work. Different people asking different questions can be better than one single person.

2. **TEST PROCEDURE** : Run the test and observe the user(s) keenly. Ask for honest feedback. Beware user(s) who will want to please the testers with just positive feedback. Write down any and all important quotes from user(s).

3. **TEST DOCUMENTATION** : Document the test with photos or better yet, short videos of the most important findings. Summarise the findings.

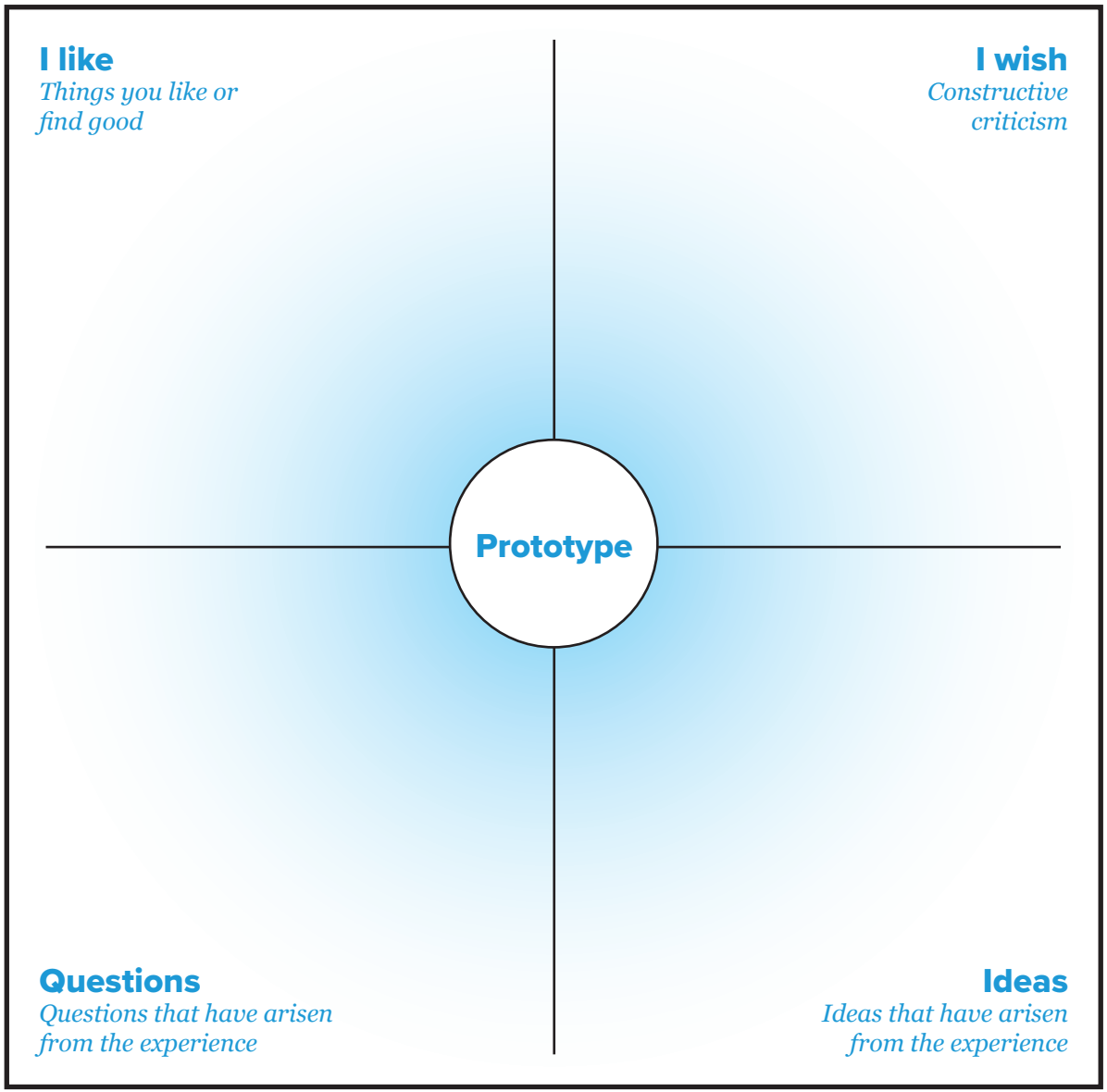
Expert Tips:

» It is vital to ensure students ask relevant questions keeping the Problem Statement and solution in mind. Questions similar to “Is it OK?” are poor questions.

» Questions should be not be leading. Instead, they should be detailed and open-ended. “Could the button be moved to a better place?” is a leading question.

» Sometimes (but not often) user(s) may completely reject the device. Don’t be disheartened - this is excellent feedback! Get students to try and understand why this is the case. Ask very detailed questions and consider revisiting the **Empathise** and Define steps.

Feedback Capture Grid



How to use this tool:

1. **CREATE GRID** : Create Feedback Capture Grid on a whiteboard or flip chart.
2. **TEST** : Always start a Feedback Capture Grid by actually seeing and experiencing the prototype.
3. **FILL IN THE FIELDS** : Document the test by filling in each quadrant of the grid. Use Post-its or markers and pens.
4. **ASK "WHY?"** : When answers are submitted - ask yourself (or user(s) "Why?". You may get better information by querying why the answers were given.

Expert Tips:

» Don't just use this tool with yourself or your user(s). Ask people who don't know anything about the project and no idea why it exists. The answers you get may be surprising.

» Listen, watch and try not to ask questions or explain the prototype at first. Let the device explain itself.

» Don't explain the idea to the user(s). If too much explanation (other than how it works and what it is for) is required... it may be too complicated.

» Write down exact quotes or comments from the user(s). These will be valuable to making any last minute changes or adaptations

I Like, I Wish, I Wonder

TEAM / PROTOTYPE	I Like…	I Wish…	I Wonder…	What if…?

How to use this tool:

1. **MAKE A TABLE** : Use the diagram above to make a chart for students to fill in.
2. **STUDENT SUBMISSION** : Students should be given 3 Post-its and write their answer to each question on them.
3. **VERBALISE** : Each team member reads their answer aloud but holds their Post-its, until everyone is finished.
4. **REFLECT** : At the same time - all students attach their Post-its to the chart. Students can now chat, provide positive feedback with the last "What if…?" question in mind. Allow students to answer this question.

Expert Tips:

- The purpose of this exercise is to generate positive interactions for the project and team members.
- Avoid a discussion of feedback for individual student answers. This will inevitably lead to negative interactions or criticisms.
- A good way to view any feedback (as a recipient) is as a gift - they're lucky to receive it!
- Anyone providing feedback should always show respect and consider how they may feel hearing the same feedback.

Questions:

» Who?
» What?
» When?
» Where?
» Why?
» How?

WHO	What	When	Where	Why	How
Who is involved?	What do we know about the problem?	When did the problem start?	Where does the problem occur?	Why is the problem important?	How could this problem be an opportunity?
Who is affected by the situation?	What would we like to know?	When do people want to see results?	Where was this resolved before?	Why does it occur?	How could it be solved?
Who makes decisions?	What should we look at?	When does it happen?	Where did similar situations exist?	Why was it not yet solved?	How often does it happen?

How to use this tool:

1. **ASK** : Use this tool to gain deeper insight into a project, research, interview or observation.
2. **ASK AGAIN** : It can be valuable to ask the same questions repeatedly to gain further insight. Much as a child will continually ask "Why"? - it provides further information gathering when we continue to ask the same question.
3. **CHART QUESTIONS** : Use the chart on the left to record answers.
   - ◊ **NOTE** : Chart on the left is an example only. Define your own questions that are relevant to your project.

Expert Tips:

» If a question does not fit the particular context of what you are looking to learn more about - just skip it.

» Change the question around by using negative perspectives. eg: "When does the problem NOT occur?" or "Who is NOT affected?".

» Use to augment a brainstorming session.

» Facts only. While it is possible to have silly and untrue answers, this won't help the project. Stick to the facts.

» This is a favourite tool of researchers, writers and authors. When these questions are asked, they generally require in-depth answers rather than simple one word responses.

5x Why

1. Why is it a problem (Problem Statement)?	Consequence
Answer	What is the problem? What are its symptoms?
2. Why?	**Direct Impact**
Answer	Why does the problem occur? What technology is used?
3. Why?	**Cause – Effect**
Answer	What could be another cause of the problem?
4. Why?	**Organisational hurdles**
Answer	How could the problem be avoided?
5. Why?	**Systematic hurdles**
Answer	What systematic approach might prevent the occurence?

How to use this tool:

1. **DESCRIBE THE PROBLEM** : Using as much detail as possible, describe the problem. You could also use photos or sketches to illustrate it.
2. **ROOT CAUSE ANALYSIS** : Ask "Why" as often as possible. Try to counter each answer with another "Why" question.
3. **STOP** : There will come a time when it is no longer relevant or makes sense to ask "Why". Stop here and look to a different problem or explore in a detailed discussion with the interviewee their answers.

   ◊ **NOTE** : Matrix on the left is an example only. You can define your own questions!

Expert Tips:

» Try not to make assumptions of the root cause of a problem.

» There is no guarantee that five why questions are enough to get to the bottom of things. Keep asking until it is uncomfortable or you feel you have discovered the root cause.

» Let your interviewee tell their story - listen attentively - then ask further questions should something still be unclear.

» Check results with reverse questions. In order to verify the problem, reverse questions in the form of an "if-then" sentence are great.

Example: **Q:** *Why did you get sick?* **A:** *Because I spent time outside in the fresh air.*

Reverse Example: **Q:** *If you hadn't spent time outside in the fresh air, would you be sick now?* **A:** *The lack of a jacket was probably more of a cause than being in the fresh air.*

Therefore the fresh air is only PART of the cause - with more "Why" questions the root of the problem can be further broken down.

AEIOU

ACTIVITIES	What happens? What are the user(s) doing? What is their task? What activities do they carry out? What happens before and after?
ENVIRONMENT	What does the environment look like? What is the nature and function of the space?
INTERACTION	How do the individual systems interact with one another? Are there any physical interfaces? How do the user(s) interact among one another? How does the operation work?
OBJECTS	What objects and devices are used? Who uses the objects and in which environment?
USER(S)	Who are the user(s)? What role do the users play? Who influences them?

How to use this tool:

1. **RESEARCH** : Do some research first before using this tool.
2. **OBSERVE** : (If possible) observe the user(s) in their own environment. If not possible - try to extrapolate the user(s) in context of the problem statement.
3. **TEMPLATE** : Use the AEIOU template to gain insight and answer specific questions.
4. **GROUP & CLUSTER** : Group and cluster like answers together. Begin to narrow your choices.

    ◊ **NOTE** : Table on the left is an example only. Create your own questions!

Expert Tips:

» This tool is about observation in order to better understand your user(s).

» The questions in AEIOU can (and should) be adapted to suit your own project.

» AEIOU is not a rigid framework - it only provides categories that have proved useful. Be flexible!

» Sometimes drawing and sketches tell a greater story and help focus ideas better than text. Don't be afraid to draw!

Storytelling

Team Member	User(s)	Characteristics	Interpretations	Conclusion	Insights

How to use this tool:

1. **CHART** : Reproduce the chart on the left. Use a large whiteboard, flip chart along with pens, markers and Post-its.
2. **USER(S)** : List your user(s) - even make up similar user(s) but with similar problems.
3. **CHARACTERISTICS** : Each of your team members should list a characteristic, quote or special feature of your user(s).
4. **INTERPRET** : From all answers, progress the story by adding emotions, setting, direction, highs/lows, actions, plot and conflict all the way through to resolution.
5. **CONCLUSION** : Conclude your story and hand it over to your team members. Now your team members should draw 3-5 insights from it as they understood it - these should be noted on the whiteboard, etc. After everyone has told their story and drawn conclusions - begin to cluster thoughts and ideas to summarise your findings. Now you have an idea of your user(s) journey that they may take.

Expert Tips:

- Don't just write words on your chart or template - use drawings and sketches as well.
- Experiment with different types of stories - introduce cliff-hangers; love; action/adventure; comedy; rags to riches and more!
- You aren't limited to your own story - use other team members (ask first!) stories and add to them, change or adapt them (in a meaningful way!) Even use existing stories from literature, film or songs!

Definitions / Terminology

Discover Manufacturing

Team	The group of students who will submit an entry to the competition. Minimum of 3 per team. Each team can submit only 1 entry.
School	Name of the school submitting an entry. Schools can have more than one Team.
Class	Class year within the school. Classes may have more than one team.
Design Thinking	A methodology used to solve problems.
.stl file	A 3D printing file. {Stereolithography}; {Standard Triangle Language}; {Standard Tessellation Language}. Files can be created from various pieces of software. Used to describe surface geometry only, rather than colour, texture or other attributes.
User(s)	The actual person(s) who will use the product the teams develop. {The end user}
Iterate	To develop (a product, process or idea) by building upon previous versions or “iterations”, using each version as the point of departure for refinements, tweaks and changes.
Problem Statement	A simple statement of a difficulty describing a complication or impediment. Usually arrived at through a process of understanding the user(s) and empathy.
Innovator	A person who designs, develops and introduces new methods, ideas or products. You!
21st Century Skills	21st century skills refers to a broad set of knowledge, skills, work habits, and character traits that are believed - by educators, employers and others to be critically important to success in today’s world. Broadly these are: critical thinking, creativity, collaboration, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity and social skills.