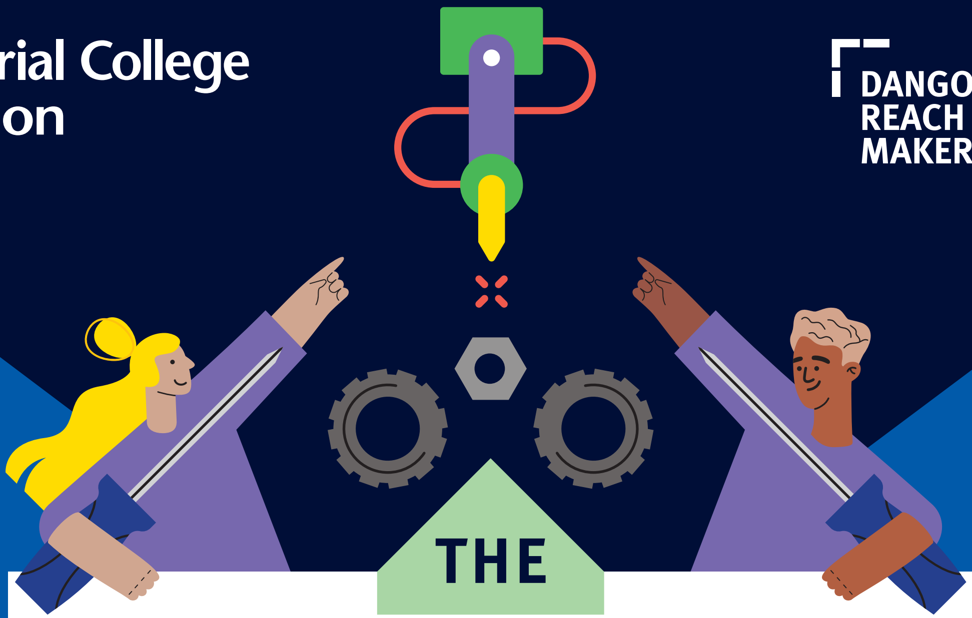
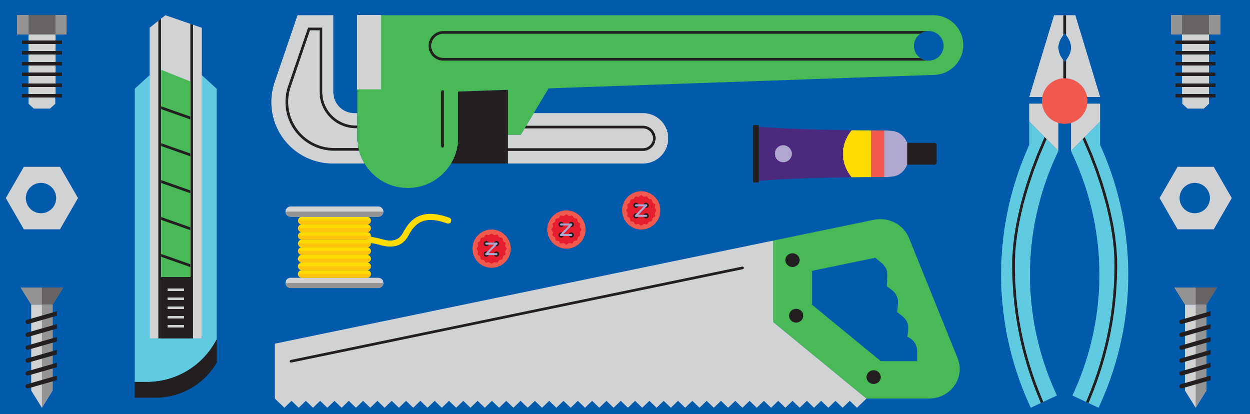
Imperial College London

DANGOOR REACH OUT MAKERSPACE



THE MAKER SPACE MANUAL

A GUIDE TO BRINGING IDEAS TO LIFE



Created in partnership with Imperial College London and the Berkeley Foundation

If you can imagine it, you can make it!

Contents

In memory of Tony Pidgley CBE, Founder of the Berkeley Group and Trustee of the Berkeley Foundation, who was a champion and supporter of the Makerspace Programmes.

1947–2020

About us

Who are we?

The Dangoor Reach Out Makerspace is a creative and supportive space dedicated to independent young people who are curious, inventive and enjoy learning. Based in White City, where Imperial College London has established their new innovation campus, the Makerspace is situated in The Invention Rooms, a larger centre which houses both the College's advanced hackspace and a community engagement space.

As an inclusive space, we welcome those who are completely new to making as well as practised makers and engineering enthusiasts. In our state-of-the-art Makerspace workshop, we teach design thinking, fast building and tinkering, with a focus on hands-on learning that's user-led.

Our programmes are supported by making experts, Imperial students and our Makerspace team, and it's our mission to share and impart our passion for making with others. As part of our programmes, young people learn how to make, create and invent using advanced equipment like 3D printers and laser cutters.

We are dedicated to building a community of empowered and invested young minds who are motivated to embrace their future and get making.

Our programmes

The Maker Challenge

The Maker Challenge is for young people aged 14–18. Over several sessions, students learn how to design, prototype and make using our advanced equipment in our dynamic workshop. We give students a crash-course in 3D printing, laser cutting, woodworking, CAD, programming, and electronics, as well as soft skills like website creation and building a business. We only use software that is freely accessible to students so they can continue to learn at home after the programme ends.

Students create a working prototype which is showcased to judges, community members, friends and family, with curated prizes awarded to innovative projects. Sessions are supported by Imperial students who provide great insight into university life and studying STEM subjects. The programme runs during termtime and the summer holidays. Young people can apply online.

The Proto-Maker Challenge

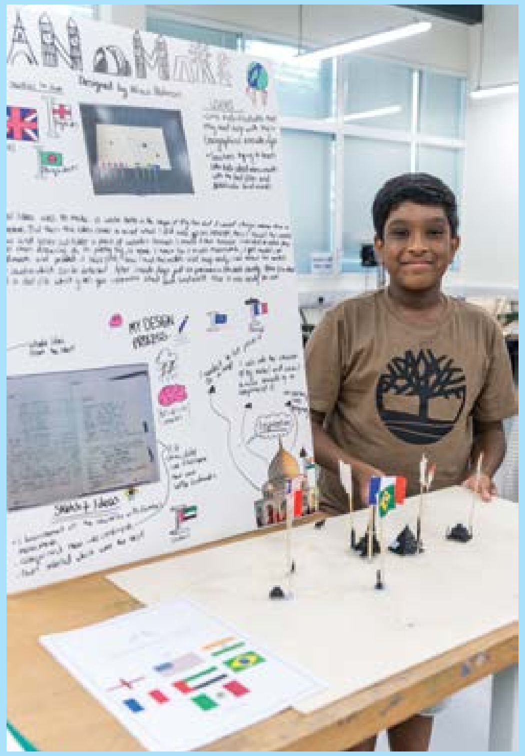
The Proto-Maker Challenge is for young people aged 11–14 who attend schools local to White City. Unlike the Maker Challenge, schools must sign up to take part. Over five sessions at your school and the Makerspace, students develop and prototype solutions to real-world problems such as climate change, homelessness and gender inequality, gaining skills in creative problem-solving, making and product development.

For more info:

Email: makerspace@imperial.ac.uk

www.imperial.ac.uk/maker-challenge-programme

> "More than any piece of equipment, material, or staff member, it is the amazing Maker Challengers who have made the Dangoor Reach Out Makerspace such a special place."



Celebrating imagination

The Makerspace is one of the most unique and incredible education settings in the country. It gives young people the opportunity to experiment with cutting-edge design technologies, unleash their imaginations, and bring their ideas to life.

This is a place for hands-on learning, where you can explore 3D printers, scanners, laser cutters, and digital design tools with the support of Imperial's expert teams. For some, coming here can be a life-changing experience, opening their eyes to a future career and their own creative potential.

At the Berkeley Foundation, we want to create a society in which every young person has the opportunity to thrive. We are incredibly proud to be partnering with Imperial College London to help them extend access to this incredible place of learning to those from less privileged backgrounds.

We hope it will help inspire more young people to embrace STEM subjects and learn the skills to succeed in a rapidly changing world. In my industry of homebuilding, for example, we are beginning to integrate digital design with advanced robotics to create the next generation of precision manufactured homes. This breakthrough will enable us to deliver homes faster, with less waste and to a superior standard of quality, safety, and environmental performance.

But we need makers to make all this happen. We need talented designers, problem solvers, and critical thinkers, as well as people with great technical skills, communication skills, self-belief and a team ethic – all the talents and attributes that are nurtured at the Makerspace.

I hope your experience here will be fun and inspiring. I hope you create something you are proud of, and learn new skills that will help you to step into your future with confidence.

Good luck!

Rob Perrins
Chief Executive, Berkeley Group
Chairman, Berkeley Foundation

A pioneering space

I'm delighted to be sharing this wonderful book with you. It is based on our experience at Imperial College London in setting up and running The Invention Rooms in White City – a pioneering space for making and community innovation, which we opened in 2017.

Making is an incredibly important skill for young people growing up today, especially in a changing and uncertain world. It is hard to think of any other activity that supports the development of such a wide range of skills, knowledge, and experience – scientific, technical, and creative. Our aim at The Invention Rooms is to make it easier and more straightforward for young people living near our White City Campus to access making opportunities. This book aims to encourage and guide the development of makerspaces across the UK.

The importance of making

Making brings together the physical and the digital, theory and practice. It is one of the best ways to develop problem-solving ability, and it offers powerful insights into the worlds of business and entrepreneurship. We've seen first-hand how the experience of making and prototyping can also develop personal confidence and self-esteem. Nothing quite matches the satisfaction you get from having made something yourself.

The skills of making are in high demand in an increasingly tech-driven world, but very often there is insufficient opportunity at school due to a lack of resources and time. We've had business executives from vastly different sectors such as fashion, retail, construction, pharmaceuticals tell us how they are increasingly looking for employees with technical and creative skills – physical dexterity as well as advanced digital literacy.

Our experience at White City

Our White City Campus is located in a part of London where there are significant pockets of disadvantage and where people do not always get access to the spaces and support they need to turn their ideas into reality. We established a community makerspace at The Invention Rooms because we wanted to find a practical way of using the skills and resources we have as a leading science, engineering, medical and business focused university to support and help our local community.

We always wanted our makerspace to particularly serve local young people. When we looked around at other makerspaces, hackspaces, and shared workshops, we found that most only had very limited and highly controlled access for under-18s. We wanted to create an environment where young people felt a sense of ownership and belonging, and where they could develop their ideas freely over a sustained period of time in a safe environment.

Over the last four years, we have supported more than 750 young people in developing their making skills through our maker challenge programmes. It's been a wonderful journey. We've learned so much from the young people who have come to our space, from the Imperial students who provide mentorship and support, and from our inspiring and professional team of staff and technicians who developed the programmes and operate the space.

Making is for everyone

I hope you find this book motivating and beneficial. It can be daunting when you are setting up a makerspace or making an activity for the first time, so we hope you will find lots of practical advice and tips in this book that will help you on your way. These pages also include inspirational stories, career training, and philosophies behind the makerspace idea. There's such a vibrant making community in the UK and worldwide – you will never be alone in your making journey and I can guarantee it will be an incredibly rewarding experience for everyone involved.

I would like to thank all those have who have made this book possible, especially the Berkeley Foundation who have generously supported the makerspace and this book, as well as our other funders and supporters, including the Mohn Westlake family, the Dangoor family, the Elsevier Foundation, and the Worshipful Company of Coachmakers.

Finally, I would like to personally thank the Makerspace team – led by Kate Mulcahy and comprising Mel Bottrill, Annalisa Alexander, Chloe Allen-Greeves, Ahreum Jung, Rebecca Sweeney, and Richard Brown – who have put this book together and without whom the makerspace would not be the magical place it has become.

I wish you all the best with your making journey.

Professor Maggie Dallman OBE
Vice President (International)
Associate Provost (Academic Partnerships)
Professor of Immunology
Imperial College London

The Maker Challenge

In September 2017, the Dangoor Reach Out Makerspace first opened its doors. A brand-new space for young people in the local community, the Makerspace is the first of its kind in White City. We were excited to show everyone all of the equipment that we had assembled, the piles of material waiting to be cut and glued, and more than anything to open our doors to students and invite them to use the space.

The main driver of the planning for the space was the Maker Challenge Programme, a skills and making programme for young people aged 14–18. When we were designing the programme we wanted to make something that would look quite different from school. We wanted students of different ages and from different schools to come together and work side by side. We wanted the students' interests and motivations to lead what happened in the space.

The pressures of the education system and its focus on results and exams can create a restrictive learning environment where students are encouraged to do A then B to achieve C. But at the Makerspace, we asked a different question. If a student could imagine a different outcome, how could we best support them to acquire the necessary skills to achieve their own personally defined goals? We wanted the students to, in a sense, create their own curriculum.

Now let's be honest – that is a lofty and problematic goal. It would be very dangerous to let untrained, un-inducted members of the public into a workshop with laser cutters, bandsaws, and 3D printers, and simply hope for the best. We knew that we had to strike a balance between safety and freedom. We therefore looked at which key skills we could give the students to enable them to use the space as freely as possible.

We chose to focus on a couple of core skills including woodworking, laser cutting, 3D printing, basic electronics, and programming, to name a few. We split the programme into short snappy introductory sessions, each covering one of these topics. These are followed by five 'open' sessions where the students are free to use the space to work on a project of their choice. These sessions are designed to be quick and surface-level. The idea was that students would learn the basics so they could go on and create something using the equipment as quickly as possible. If their passion in any area stretched beyond the topics covered in these introductory sessions, then they could use their free open sessions to explore their interests further with the support of the experienced Makerspace team.

Competitive opportunities

One of the big choices we made in designing the programme was to make it a competition. I worried that students would get overwhelmed by the choices available and end up not getting stuck in quickly enough. One of my greatest anxieties was that the students would be overwhelmed and fail to make use of this time to explore, to fail, and to iterate. I feared they would arrive at the end of the programme feeling as if they had missed an opportunity. To counteract this, we decided to frame the programme as a competition.

We invited the students to work on any project of their choosing, using the materials and resources that are available to them in the space. Quickly we discovered the limitations of the materials we used. We could never have anticipated every random hinge, spring, or magnet needed for each of the students' projects. We quickly pivoted and allocated each student a small individual fund to enable us to purchase any specific items they might need for their project. The idea was that at the end of the programme students would showcase their designs, builds, makes, and inventions before a panel of judges – in a 'science fair' style – and whichever the judges considered the most interesting, innovating, or exciting would win.

The impact of this competitive element was very interesting to us as a team. We found that initially, the students were very motivated by the idea of the competition – particularly when they learned that the winning prize was a 3D printer. But somewhere towards the middle of the programme, this competition element seemed to become stressful. And finally by the end, students were questioning why it was a competition at all. For many, their motivations had shifted and they were much more concerned with taking part and gaining skillsand experience. We still use the competition, as it's a useful way of focusing students at the beginning, but we are happy when it becomes less of a focus for them.

Pioneering a new form of outreach

Over the course of the past four years, we have learned so much since we were given an empty shell of a space to fill. Some choices we made have worked really well. Creating a space where students can be inquisitive and feel confident to simply try has worked unbelievably well. Some other choices have not worked well – turns out the hobby micro metal lathe was not a useful piece of kit.

I want to take the time to thank all of the people who have helped get us to this point: The Imperial Student Ambassadors who work in the Dangoor Reach Out Makerspace and are unfailingly positive, patient, and willing to step outside their own comfort zones; the session leaders who have brought their own expertise and passion to leading the sessions, and to supporting the many students in realising their own inventions and quirky ideas. Above all, however, I want to say thank you to each of the students who have taken part in the Maker Challenge.

I am always energised by their flexibility and willingness to try structures and activities which are often very different from their familiar school environment. I will never fail to be amazed at their inventiveness, their resilience, and their optimism. Many of the Makerspace team walk away from sessions inspired to make something themselves or try out a new idea. More than any piece of equipment, material, or staff member, it is the amazing Maker Challengers who have made the Dangoor Reach Out Makerspace such a special place.

KATE MULCAHY *is the Makerspace Programmes Manager as well as a maker, tinkerer, science presenter and passionate believer in the power of creativity who is always looking to inspire new makers.*

"The inspiration came from a combination of my personal interests: basketball, music and trainers. I thought putting music and trainers together would make a basketball game more lively!"

Musical feet for a young innovator

→ There are too many amazing projects to highlight them all, but I wanted to pick out one that has been especially memorable to me.

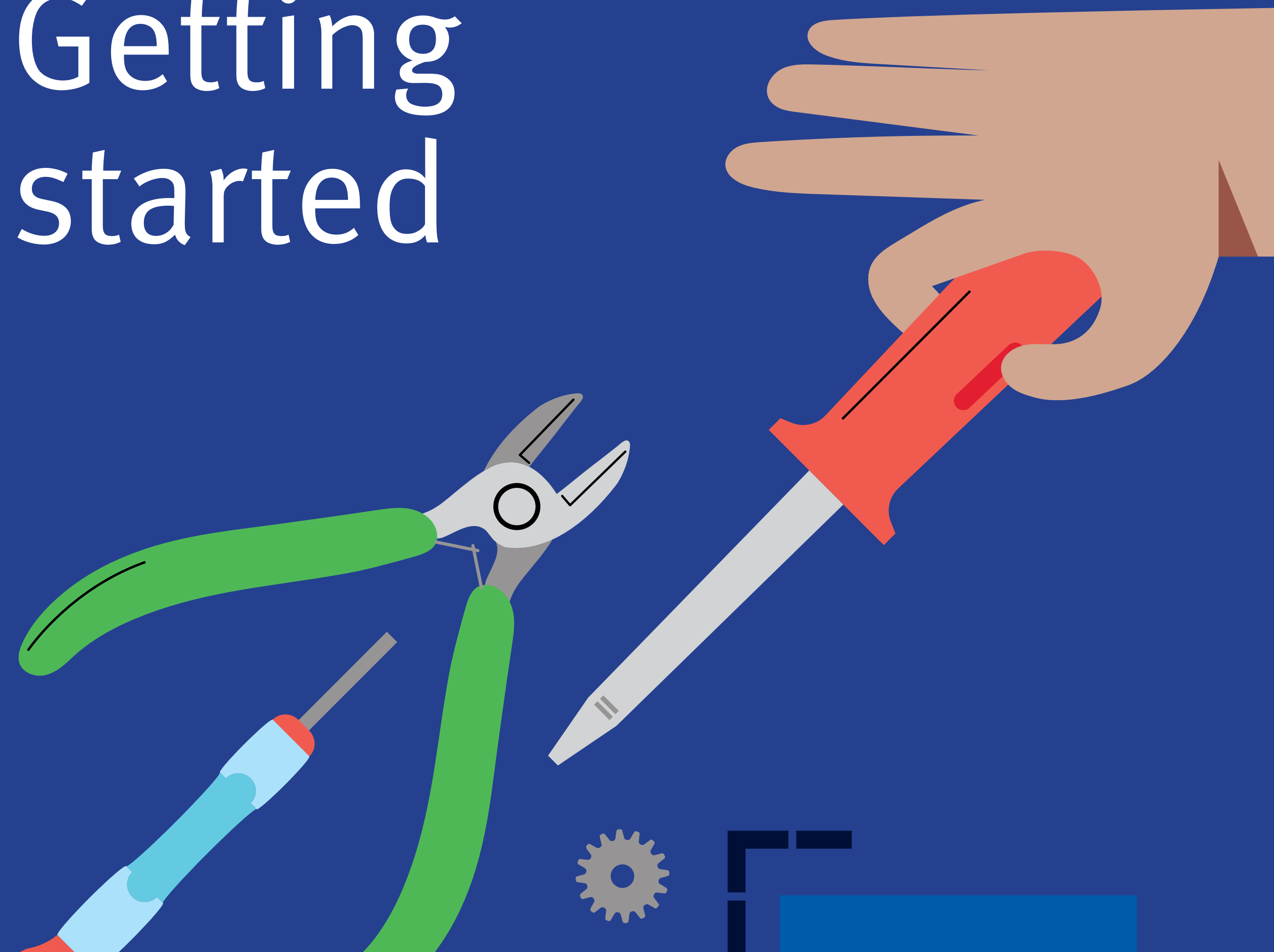
At the end of the first ever Maker Challenge programme back in autumn 2017, we were learning on the job, adjusting as we went along, and were not sure what the outcome of the programme would be. Had we made the right choices? Would the programme work?

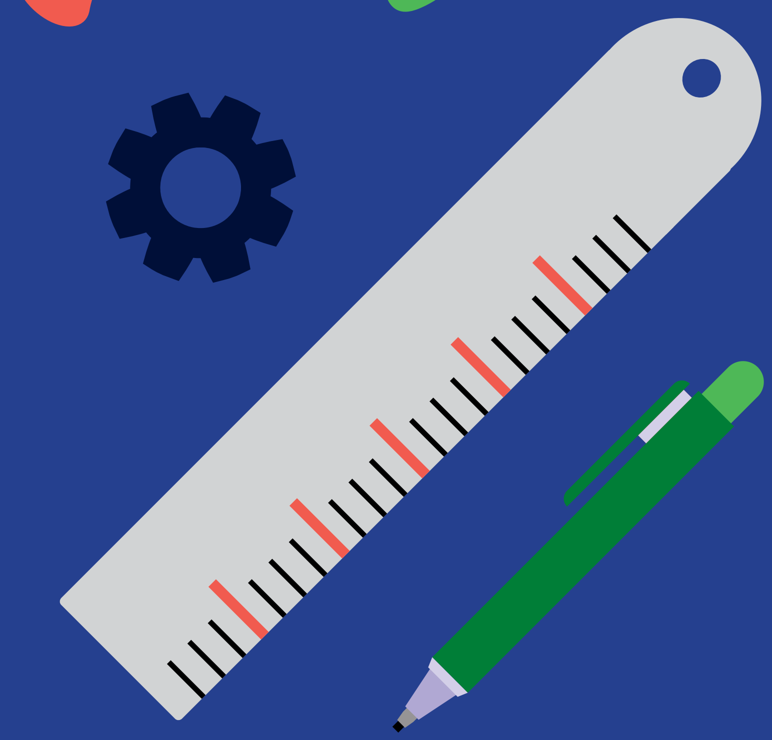
At the end of 12 weeks, as the participants stood before the judges, one project shone out. The unassuming and shy Cindy Xhebro quietly explained the motivation behind her invention, which was to combine her passions of sport and music.

She wanted to make something that would make a positive contribution, so she had used Bluetooth technology to design speakers that could wirelessly play music through her shoes. It was no mean feat. She had learned to code, to use electronics, to build, to hack, and at the end, had produced an amazing functioning prototype.

It was at that moment that I truly knew that this wacky idea of the Maker Challenge could and would work – we were on to something. Since then, more than 750 young people have come through our doors, with many going on to pursue a path in making and engineering.

Getting started





What turns an ordinary space into a makerspace?

In this section, you'll learn about different kinds of makerspaces, the tools and materials usually found in them, and how to stay safe while creating.

A brief history of makerspaces

From using sticks and rocks as basic tools to constructing engineering marvels, the desire to make stuff and create a space in which to make has existed for millennia. But what makes a makerspace a makerspace?

The origins of the maker movement

The idea of a makerspace as we know it is relatively new. It may have started in Germany in 1995 with the creation of the first hackerspace, CBase. The idea was to have a space where like-minded people interested in programming and tinkering with technology could meet, work, and learn from each other. Although the term 'hacker' conjures up images of someone hacking computers to steal data, this was never its initial meaning. Modern hacker (or hack) spaces use the term more expansively and positively to mean someone that will strip things down to see how they work or to make them better. Hacking now also means to repurpose or reappropriate materials or technologies, and is the antithesis of modern society's throwaway culture.

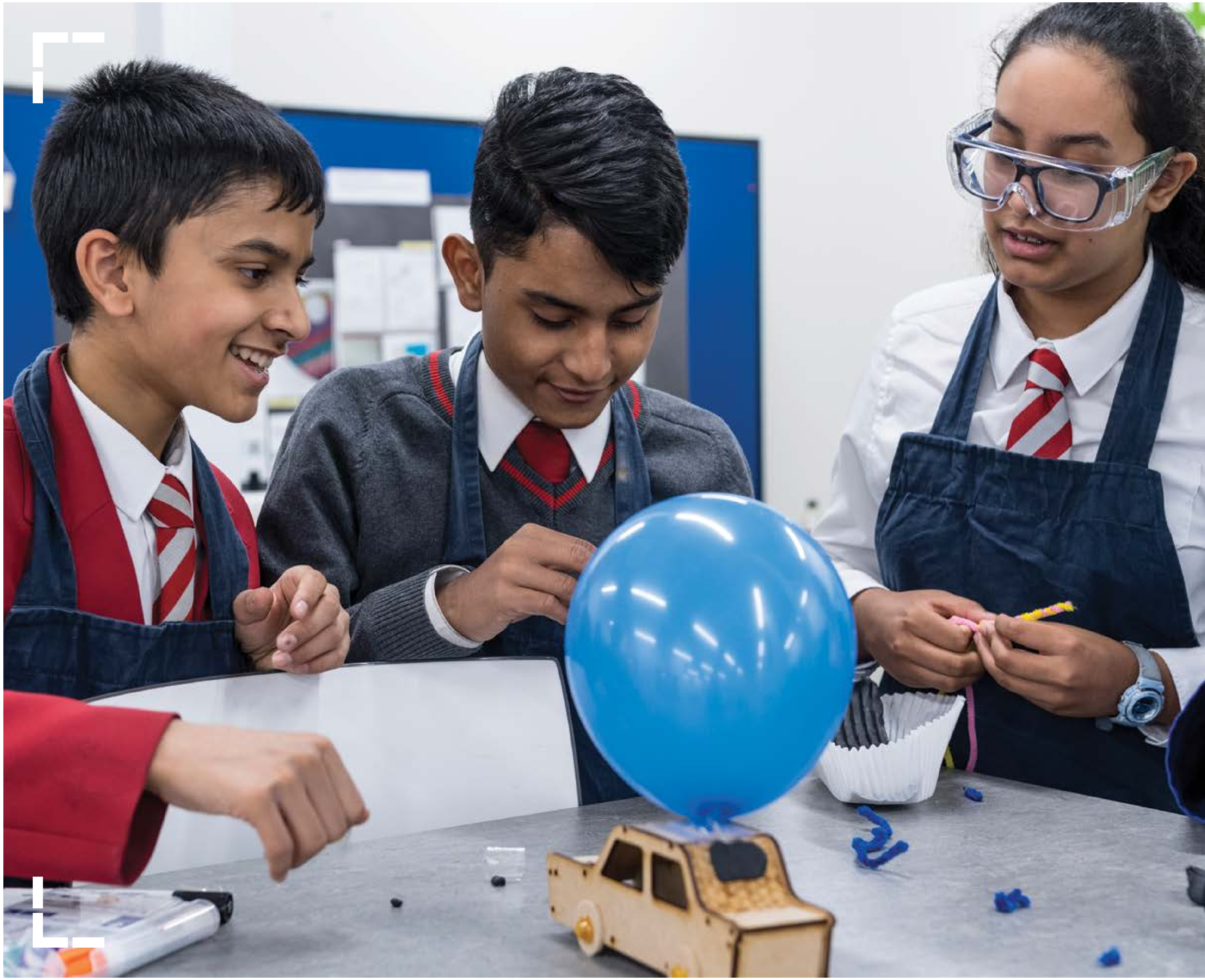
Fab Labs (short for Fabrication or Fabulous Laboratories) were developed by Neil Gershenfeld of the Massachusetts Institute of Technology (MIT) in 2005. Fab Labs' aim was to create a space where one could design and digitally manufacture custom objects, particularly with tools that were not commonly available. All Fab Labs follow – and must comply with – the 'Fab Charter'. They must use the same hardware and software. So regardless of where the Fab Lab is located, there are no restrictions to distribution and dissemination of ideas or items. These are very much business-orientated clubs.

The term makerspace is associated with the magazine *MAKE*, created in 2005. Makerspaces encourage creating and tinkering for children, but also aim to broaden the concept of hackspaces and distance them from the negative stereotype of 'hackers' and 'hackerspaces'. Makerspaces are usually located within an educational facility or library. The core users include children or young people. They tend to host a broader selection of tools and activities, and not just the more technical pursuits of electronics, coding, and robotics. They often champion traditional methods of making alongside high-tech machines capable of rapid prototyping.

Imperial's hub of community innovation

For the team at the Dangoor Reach Out Makerspace, a makerspace is about providing a creative time and inspiring space for people who want to share, build, learn and explore with other like-minded people. We strive to be open to all forms of making, from the purely physical construction and assembly of materials (including the repurposing of existing items), to the crafting and manipulation of digital designs, and everything in between. This can be for a specific individual need or mass market appeal, but ultimately, it's always for fun. We aim to create a space where collective collaboration of ideas and personalities generate an environment that softens boundaries and encourages expansive thinking.

We want young people to embrace the generally terrifying prospect of failure and develop creative courage and resilience. We know that it is only with this courage and willingness to fail that young people can develop, grow, and ultimately succeed. Above all, we want to empower our users to succeed in whatever they pursue.

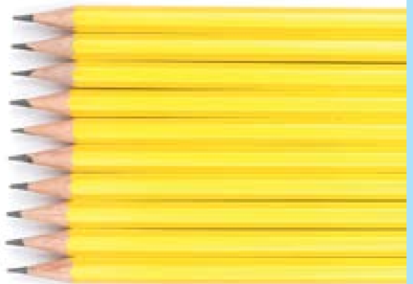


Basic tools for a makerspace

→ A makerspace is simply a space that you set aside for making and exploration. This space doesn't need to be fixed and there are many great examples of portable makerspaces where tools and materials are made available only at specific times.

You can start a makerspace with very little equipment or materials. In fact, limiting the materials available to students can often enable the most dynamic creativity.

Setting up a workshop for a makerspace can seem daunting and prohibitively expensive, but it doesn't have to be. This guide to basic tools will show you the possibilities – however small or large the budget, space, or commitment.



Pencils

The most important piece of any tool kit and usually the first tool used when beginning a project.

Utility knife/box cutter

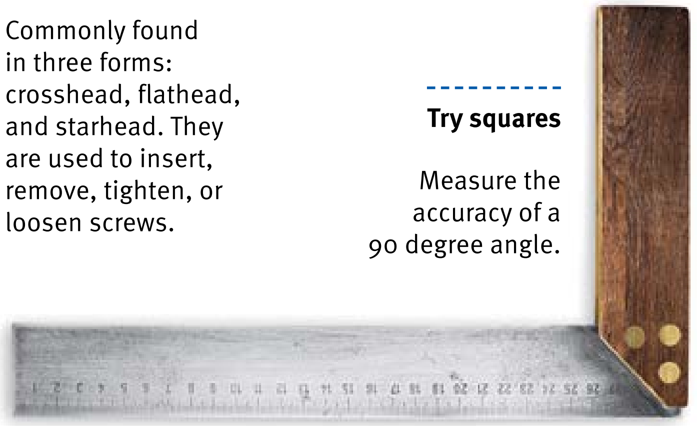
Have a retractable blade which can be replaced when blunt. They are used to cut and score sheet materials like cardboard, foam board, leather, etc.

Pliers

Multifunctional tool that can be used to pull, grab, cut and bend.

Screwdrivers

Commonly found in three forms: crosshead, flathead, and starhead. They are used to insert, remove, tighten, or loosen screws.



Try squares

Measure the accuracy of a 90 degree angle.

Spanners

Come in different sizes as well as adjustable variations. They can be used to undo or tighten nuts.

Claw hammers

Have a flathead for hitting nails and a claw for removing them.

Hand saws

Versatile hand saws normally used to cut across large sections of wood. They cut on both the push and pull strokes, making them quick and easy to use.

Flat files

One of the most common files used for smoothing and removing small amounts of material.

Levels

Used to ensure work is hung or sitting, straight, flat and level. If the work is level, the indicator bubble will be positioned directly in the middle.

Scrapers

Normally used for removing 3D prints from the printer bed. They can also be used to clean up 3D prints by scraping off the raft.

Craft/hobby knife

Scalpel style knife that is ideal for fine angled cuts and detail work.

Steel rulers

Used to measure, mark, guide, and draw straight lines.

Staying safe

It is important to ensure that makerspaces remain as safe as possible for staff and students. Here are some strategies for building a culture of safety with your learners.

Safe spaces

Think about the layout of the space for ease and safety. This includes clearly defined making areas, paths and access, and adequate lighting.

Safe equipment

Simple steps like wearing personal protective equipment (PPE) can help prevent long-term injury and provide protection in the event of an accident.

Here is some of the basic PPE that should be included in the makerspace:

⚠ Personal protective equipment for all levels

- ☐ Closed toed shoes
- ☐ Hearing protectors (e.g. earplugs, ear muffs)
- ☐ Eye/face protection (e.g. safety glasses, goggles, face shields)
- ☐ Disposable nitrile gloves for handling chemicals
- ☐ Cut-resistant gloves used with saws
- ☐ Dedicated space for sanding materials
- ☐ Face/dust masks
- ☐ Aprons or workshop coats (these can also make students more aware of conducting themselves safely and help identify active makers)
- ☐ First aid kit
- ☐ Fire extinguisher

Safe practices

- Do not operate power tools while wearing long sleeves, gloves, loose jewellery, loose long hair, neckties, hoodie strings or anything else which could get caught and pull you into the machine or set something on fire.
- Set aside a dedicated area for sanding materials. In a professional workshop this might include a dust extraction table. Having a dedicated space is very useful as dust is a fire hazard, a slip hazard, and a respiratory hazard. Having a dedicated space enables the most efficient monitoring and cleaning after sessions.
- Manage glue gun use. Glue guns can be very useful, but the hot ones especially are a potential hazard as they can easily be left on after use.
- Control blade access and use. Self-healing cutting mats can be used to protect surfaces, but make sure they are non-slip. It is also a good idea to get cutting edges. These are used to cut straight lines and are very different from rulers which should never be used as a cutting edge. Finally, a check in/check out protocol for blades ensures that all of the blades stay safely in the space between sessions. An alternative is for the staff to directly supervise use of blades.
- Plan for fume extraction. The fumes produced by a laser cutter may be harmful, so use an extraction unit with the cutter.

Entry-level makerspace

Contains the basic tools and materials needed for most simple projects.

Tools

- ☐ Various lengths of rulers and tape measures, plus ways to measure angles, such as protractors, tri-squares and set squares
- ☐ Hot glue guns and glue (low melt if possible) with heat-resistant boards
- ☐ Scissors
- ☐ Utility knife/box cutters
- ☐ Craft/hobby knives
- ☐ Sewing machines
- ☐ Self-healing cutting mat

Materials

- ☐ Markers
- ☐ Water-based paints (these are useful in portable spaces, as they are easier to clean)
- ☐ Paint brushes of various sizes
- ☐ Paint tray palettes and rinse cups
- ☐ Large rolls of brown paper or plastic sheeting for tables
- ☐ Lego bricks
- ☐ Plasticine/modelling clay
- ☐ Different types and thickness of paper: craft paper, origami paper, corrugated cardboard, paperboard, chipboard, foam board
- ☐ Foam board or Kappa board
- ☐ Soft modelling wire
- ☐ Tapes with different adhesion qualities, widths and colours (adhesive Velcro tape, duct tape, masking tape, electrical tape, cellotape, double sided sticky tape, washi tape, clear packing tape)
- ☐ String, twine, wool, rope, ribbon, and other ties
- ☐ Water-based, solvent-free glues
- ☐ Thumb tacks
- ☐ Rubber bands
- ☐ Fabric: felt, cotton, muslin, canvas, aida cloth, leather scraps, mesh, etc.
- ☐ Sewing supplies: sewing scissors, needle, thread, pins
- ☐ Craft supplies: coloured pipe cleaners/ chenille stems, pom poms, googly wiggle eyes, feathers
- ☐ Lolly sticks, tongue depressors, coffee stirrers, craft sticks, toothpicks
- ☐ Straws, cups
- ☐ Stapler and staples
- ☐ Guillotine paper cutter

Intermediate-level makerspace

Expands on the materials and tools used in the entry-level space. Some of the materials are messier and the tools take up more space, so a fixed dedicated space is best for these projects.

Tools

All the tools included in an entry level space, along with:

- ☐ Stitching awl
- ☐ Mallet
- ☐ Level
- ☐ Try square
- ☐ Scraper
- ☐ Mitre boxes
- ☐ Vinyl cutter
- ☐ Wire cutters
- ☐ Wire stripper
- ☐ Snap setter, snaps
- ☐ Scalpel knife
- ☐ Wrenches
- ☐ Riveter, rivets
- ☐ Pliers
- ☐ Clamps + vices
- ☐ Hammers
- ☐ Spanners
- ☐ Files, chisels, rasps
- ☐ Vacuum former
- ☐ Tweezers
- ☐ Rotary tools, bits

- ☐ Basic saws (rip cut handsaws, razor saws)
- ☐ Screwdrivers (big and precision sets)
- ☐ Allen/metric hex keys
- ☐ Soldering iron, solder, flux
- ☐ Standard and junior hacksaws, fretsaws, tenon saws and possibly a battery-powered jigsaw
- ☐ Electric hand drills (battery) and drill bits
- ☐ Portable fume extractors and stripboards
- ☐ Programmable boards (Arduino, Raspberry Pi, Microbit and accessories)
- ☐ Electronic components: breadboards, transistors, resistors, LEDs, switches, motors, sensors, wires, battery holder, charger, batteries
- ☐ 3D printers – some are more suitable for ‘plug and play’ and are very user-friendly with limited capability for tinkering, while others are very adaptable but require more knowledge and training for the operator
- ☐ Laser cutter

Materials

All the materials included in an entry level space, along with:

- ☐ HIP or PET/PETG material for 3D printing
- ☐ Casting materials (plaster or silicone moulding rubber)
- ☐ Stirrer (tongue depressors work well)
- ☐ Polyshape polymorph hand-mouldable plastic
- ☐ Balsa, dowels, tubing (various sizes)
- ☐ Wires (various sizes/materials)
- ☐ Nails, screws, nuts, bolts, washers
- ☐ Magnets (various sizes/strength)
- ☐ Hinges
- ☐ Polystyrene/Styrofoam
- ☐ Solid acrylic (various types/thickness)
- ☐ Plywood, medium-density fibreboard, veneers
- ☐ PVC pipe, PVC connector
- ☐ Adhesives (wood glue, PVC cement, super glue, super glue remover, epoxy, spray adhesive)
- ☐ Dense polystyrene foam
- ☐ Zip tie assortment
- ☐ Permanent markers (Sharpies)
- ☐ Paint pens
- ☐ Swivel casters
- ☐ Digital scale
- ☐ Sandpaper (various grit from medium to very fine)
- ☐ Sanding pad/sponge (medium to fine grit)

Advanced-level makerspace

Expands even further on the tools used in the intermediate-level space. Many of the tools are specialised and may require training to use.

Tools

All of the tools included in the entry and intermediate level spaces, along with:

- ☐ Advanced hand saws: back saw, bow saw, hole saw, keyhole saw, coping saw, mitre saw, scroll saw
- ☐ Power saws: band saw, chop saw, circular saw, compound mitre saw, panel saw, radial arm saw, reciprocating saw, rotary saw, table saw
- ☐ Pillar drill/drill press
- ☐ Disk/belt sander
- ☐ Lathe (wood and/or metal)
- ☐ Milling machine (CNC)
- ☐ Vacuum chamber
- ☐ Line bender and matching cooling jig
- ☐ Heat gun
- ☐ Hot wire foam cutter
- ☐ Vinyl cutter
- ☐ AC/DC power supplies
- ☐ Helping hands
- ☐ Digital multimeter
- ☐ Wood-burning pen, tips
- ☐ Wood-carving kit: wood-carving knife and hook knife, stropping leather, polishing compound, safety tape
- ☐ Staple gun, staples

Soldering guide

→ Soldering allows electrical components to be joined semi-permanently. They are held together securely, but can also be de-soldered and separated if necessary. Soldering is done by melting a soft metal (the solder) onto the two metal pieces to be joined, usually wires or the legs of electrical components.

Flux

A chemical cleaning agent used before and during the soldering process.

Soldering iron or station

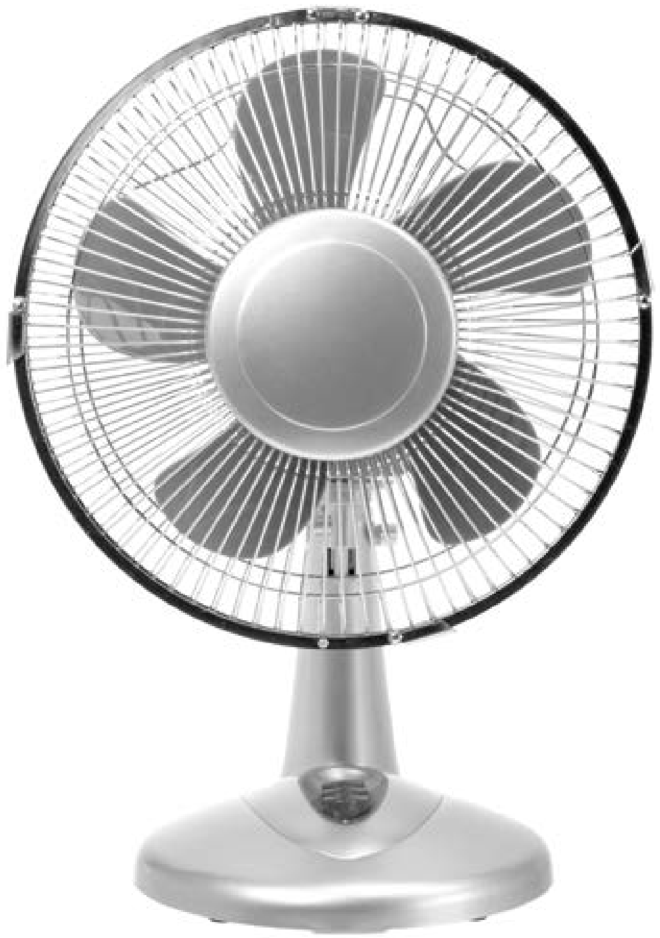
Mains soldering irons can be bought for as little as £3. For a lot of soldering, or soldering small components, a soldering station (about £15) can be useful for controlling the heat or power of the iron.

Heat-resistant gloves

While soldering it's important to wear protective gloves. It reduces the absorption of chemicals through the skin and protects your hands.

Safety glasses

Eye protection must be worn when soldering and clipping wires.



Fan

Solder creates small fumes which can be toxic and should be blown away. Fans also cool down the metals faster, offering more control over heating.

Sponge

Damp sponges are to clean the soldering iron tip when hot.

Solder

Unleaded solder is safer. Use solder that is around the same thickness as the wires being soldered. Small components with 0.4–1 mm legs work best with thinner 1 mm solder wire.

Iron stand

Holds the soldering iron when hot to make sure it doesn't burn anything.

Soldering safety

Soldering is an essential and fundamental skill needed to create in the world of electronics. Learn how to solder safely with these techniques and tips.

Essential safety tips before you begin:

- Never solder without a responsible adult nearby.
- Check the workspace to ensure it is clean before turning on the iron. Make sure the soldering iron isn't going to touch any live wires.
- Wear goggles as the solder can pop or spit when heated which can send solder flying.
- Wear heat-resistant gloves.
- Use a mask if you are concerned about fumes.
- Never try to solder or connect anything while it is connected to a power source of any kind.
- There is a risk of burns, as the tip of the soldering iron can reach 200 to 480°C (392 to 896°F).
- Return the iron to its stand when it is not being actively used.
- Always unplug the unit when finished.

IMPORTANT

- Do not eat or drink in soldering areas.
- Discarded lead solder, dross (oxidised solder), and clean-up rags are hazardous wastes and should be managed as such.

Joining wires

1. Strip 5–10 mm of plastic insulation off each end of the wires, to expose the metal that will be soldered together. Thicker wire may need a longer piece stripped.
2. Twist the exposed ends of the wires together so that they stay in place. Find something to hold this join steady. Spare crocodile clips, clothes pegs, or even some tape and a couple blocks of wood offcuts will work.
3. Turn the soldering iron on and wait for it to heat up. Turn on the fan and point it at the soldering joint.
4. Hold the soldering iron like a pen. No force is needed, but fine control is – think of it like writing or drawing.
5. Unwind a small section of solder wire (around 5 cm) and hold it in your other hand.
6. To make sure the soldering iron is hot enough, gently touch the end of the solder wire to the tip of the iron, and make sure it melts, leaving a small shiny blob of molten solder on the iron tip.
7. Touch the tip to the twisted wire joint, applying a small amount of pressure to make sure there is good contact between the solder tip and the twisted wires. Heating up the twisted wires melts the solder.
8. Touch a small amount of solder to the point between the wires and the tip of the iron. If everything is hot enough, the solder will wick along the wires like water into rope or fabric.
9. Add more solder directly to the wires until it fills the gaps between them. No need for a large blob – just enough to fill any little spaces between the wires.
10. Wait for the joint to cool (2–3 minutes) before touching it.

Connecting components to a board

Boards are useful for making smaller, compact circuits without having a large mess of wires. They can either be a printed circuit board (PCB) or stripboard, which is great for prototyping. This tutorial uses stripboard as an example, but soldering to a PCB is the same.

1. Push the legs of the component through the holes in the board from the dull side, so that they stick out of the side with shiny copper tracks.
2. Pull the legs as far through as you can, so that the component sits snug against the board, then bend them out slightly so that the component can't fall out when the board is upside down. If doing multiple components, it can be easiest to start with the shortest components (which protrude the least from the board) and work up to the tallest.
3. Turn the soldering iron on and wait for it to heat up. Turn on the fan and point it at the soldering joint.
4. Hold the soldering iron like a pen.
5. Unwind a small section of solder wire (maybe 5 cm) and hold it in your other hand.
6. To make sure the soldering iron is hot enough, gently touch the end of the solder wire to the tip of the iron, and make sure it melts, leaving a small shiny blob of molten solder on the iron tip.
7. Touch the tip of the soldering iron to the base of the leg, so that it is in contact with both the leg and the shiny metal pad around the hole. Heating both makes a good join.
8. Feed solder into the point where the iron, the component leg and the shiny pad touch. Make sure it melts onto both the leg and the pad. If it isn't melting onto one of them, add a bit more heat to it by moving the tip of the iron to touch that part more.

Problems?

Too round?

The pad might not have been hot enough to melt the solder.

Too blobby or irregular?

There might be too much solder. Make sure the solder doesn't touch any other pads or tracks around the one you are trying to connect as this can produce a short circuit.

Too flat?

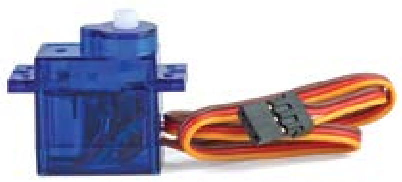
Add a bit more solder.

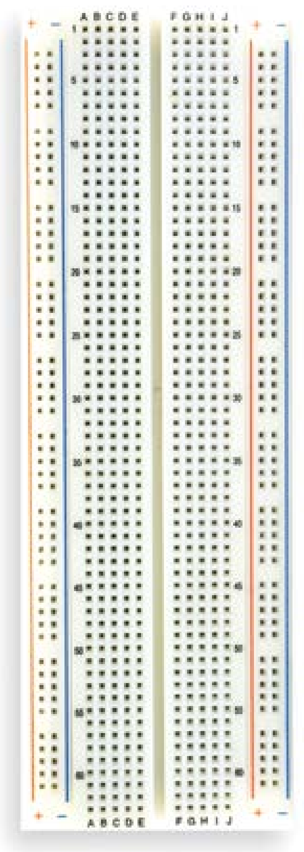
Electronic parts guide

→ Simple circuits are easy to learn. Once you've mastered a basic circuit, you can combine them to produce more complex systems. Electronics can either be completely analogue, with only passive components connected in a circuit, or can have a microcontroller 'brain' like an Arduino, which allows you to code the system to achieve things like blinking lights, sounds, more interactivity, and even things like robots that follow a line of tape.

Batteries

Batteries provide power for mobile or small projects. They can be rechargeable or disposable, and usually provide a low voltage like 1.5 or 3V. To produce 5V, multiple batteries can be stacked. Never connect the terminals of any battery together without something resistive in between, or they could short circuit and cause fires. Construct your circuits before you provide power to them.



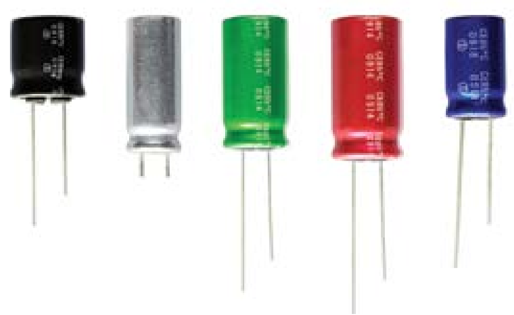


Breadboard circuit boards

Construction base for electronics projects. Its grid of holes are usually connected in sets of five, to quickly con nect components without any soldering or twisting wires together.

Motors

Motors take electricity and turn it into physical rotation. The easiest to use are basic DC motors, as they only have two wires that need to be connected to a power source or battery. Servo motors have extra wires that control when or how far they turn. These are very useful for robotic-style projects, such as opening or closing things, or moving arms. They usually spin much slower but more powerfully than basic DC motors.

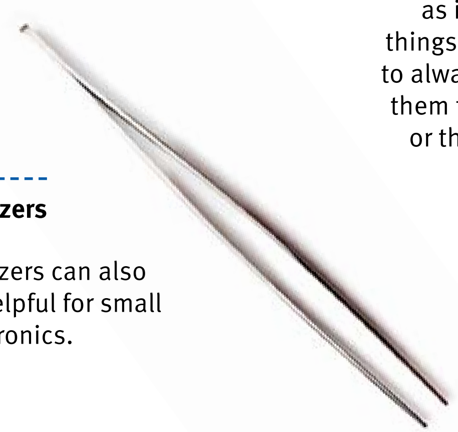


Capacitors

Capacitors hold voltages, like very short-term batteries. They are usually used to smooth rapidly changing voltages, as opposed to storing energy, or for short bursts of energy.

Needlenose pliers

Pliers are used to pick up, move, or position things, such as wires or components.

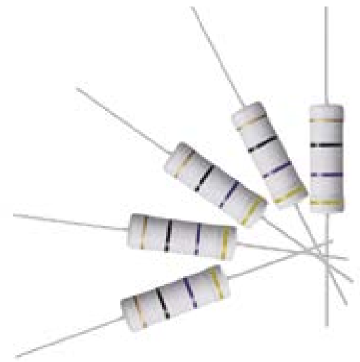


Tweezers

Tweezers can also be helpful for small electronics.

LEDs

LED lights do not get hot and use less energy than filament bulbs. They come in all kinds of colours, sizes, and bright-nesses, and can be used as indicators, or to make things look nice. Remember to always use a resistor with them to control the current, or they can burn them out very easily.



Digital multimeter

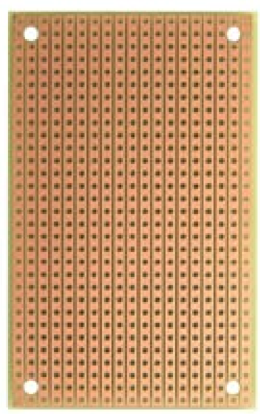
Multimeters can measure voltage, resistance, current, and in some cases temper-ature. If something in a circuit isn't working, a multimeter can check if all the components are properly electrically connected, if there is the right voltage in the right place, or if current is flowing.

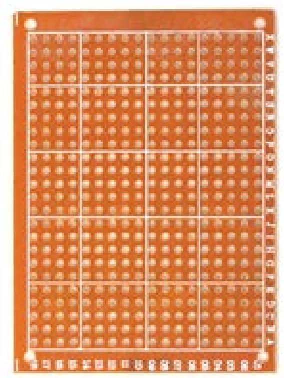
Resistors

Components that resist the flow of electrical current. Without resistors to limit the amount of current that flows, things would heat up and might catch fire. They can also be used in sensing circuits to reduce voltages. Resistors can also act as sensors that change how much they limit current in response to changing temperatures or light.

Stripboard circuit boards

Similar to breadboard, this has a grid of holes that are connected in lines of copper cladding. Strip-board requires soldering and usually has all the holes in a row connected, not just five. Stripboards are good for projects that have a lot of components that need connecting.





Padboard circuit boards

Similar to stripboard, except that the conductive tracks are broken into sections with with plated-thru holes. This makes it easy to align components on top and bottom.

Power supply

Most of the electronics you will make will be low voltage direct current (DC), between 5 and 12V. Wall sockets are high voltage alternating current (AC), between 230 and 240V, which can be dangerous. Power supplies turn it into the safer and easier to use low voltage DC.

Wire stripper

Tools used to strip the insulating plastic sheath off wires without damaging the metal core.

Sensors

Sensors take a physical event, like a change in force, temperature, movement, or light, and turn it into an electrical signal. The electrical signals they produce can be simple, like a voltage, or more complicated, like a message that needs to be interpreted by a micro controller such as a Micro Bit or Arduino.

Snips/wire cutters

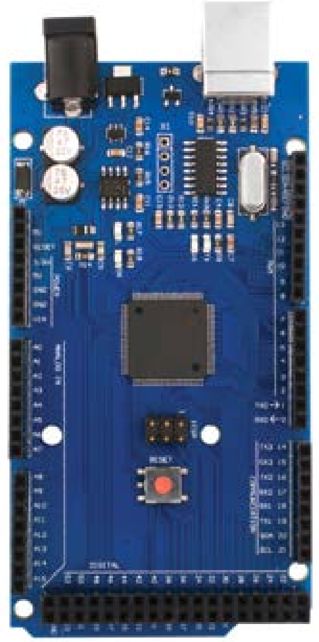
Tools to cut wires or the legs of components to the desired length. Wire strippers often have wire cutters as well, but different sizes and shapes can also be useful.

Test leads (alligator clips)

Test leads are great for connecting components together to test a circuit without the need for soldering.

Development boards

Boards with some components already mounted in some useful circuits. A lot of projects use development boards like Arduinos, because they can be quickly programmed with simple code to do a wide variety of things and can be connected to other components such as motors, lights, or heaters.



Wire

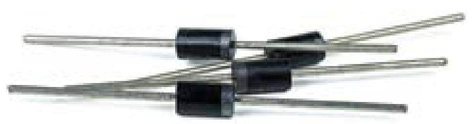
Wire carries electrical current between components. Its outer insulating plastic needs to be stripped at the ends to connect to other wires. Some wires come with ends already prepared with pins called headers to make them easy to use.

Soldering

Soldering involves melting a soft metal (the solder) to join two other pieces of metal, usually the pins, legs, or wires of components. This connects them both electrically, allowing current to flow from one to the other, and physically, so they won't fall apart.

Diodes

A diode allows electricity to flow in one direction and blocks it from flowing the opposite way. The diode's primary role is to route electricity from taking an unwanted path within the circuit.



Switches/buttons

Switches control electronics by breaking or connecting the circuit, allowing current to flow or not. They can be instantaneous (where the connection is only made or broken while pressing the button or switch) or latching/toggle, where they stay in one position until moved, like a light switch.

Digital design tools

→ Maker software provides pupils with useful tools for design and creation. Here are some of our favourites!

Graphic 2D vector software

GRAVIT DESIGNER

Platform: Browser, Windows, macOS, Linux, Chrome OS

→ **www.designer.io/en**

Gravit Designer is a full-featured vector design app from the company behind CorelDRAW. It's suitable for all sorts of design jobs, from screen, app and icon designs to presentations, illustration, and animation.

VECTR

Platform: Browser, Windows, Linux, Chrome OS

→ **vectr.com**

Available both as a browser-based web app and as a standalone desktop app, Vectr is a free editor for creating 2D vector graphics. Versatile enough for day-to-day design tasks, it also contains a wealth of options for using filters, shadows, and fonts. Its live collaboration and synchronisation options are particularly handy, as they essentially enable anyone to watch a live design, making it easy to create in tandem or send feedback. This is a genuine alternative to Adobe Illustrator CC.

SVG-EDIT

Platform: Browser

→ **github.com/SVG-Edit/svgedit**

SVG (scalable vector graphics) is an open format that allows you to reproduce your vector drawings programmatically, and one of the nicest projects is SVG-Edit. This is built entirely on HTML5, CSS3 and JavaScript without requiring any server-side processing. As it's open source, you can also download and modify the code using one of the best code editors.

INKSCAPE

Platform: Windows, macOS, Linux

→ **inkscape.org**

As with many of the free options available, Inkscape focuses on the SVG format as its primary file format. This highly capable editor has very good SVG integration, supporting many of the more advanced features that aren't always available in other apps – such as alpha blending, cloned objects, and markers.

3D modelling software

FUSION 360

Platform: macOS, Windows

→ **www.autodesk.co.uk/products/fusion-360/students-teachers-educators**

Although a commercial program, Fusion 360 is effectively free CAD software for students and educators, with a three year educational license. It is considered by many as a program that unites the best tools from cutting-edge programs like Rhino, Inventor, SolidWorks, Vault, and AutoCAD.

TINKERCAD

Platform: Browser

→ **www.tinkercad.com**

TinkerCAD is an easy-to-use and free 3D modelling software created by Autodesk. It teaches all the basic concepts of 3D, allowing you to convert an idea into a CAD model by simply dropping and dragging primitive shapes, such as cubes, cylinders, and spheres. You can move, rotate, and scale each shape, and then group them together to create an intricate 3D model.

SKETCHUP

Platform: Browser

→ **www.sketchup.com**

Originally created for architects, designers, and filmmakers, SketchUp is great 3D modelling software for beginners and advanced users alike. You can design large and complex objects without limitation. It also comes with an endless array of user-generated models you can adopt, as well as 10GB of cloud storage.

MESHMIXER

Platform: Windows, macOS

→ **www.meshmixer.com**

Meshmixer is simple 3D modelling software developed by Autodesk, created to help users manipulate, add to, splice, and merge 3D models with ease. Meshmixer has features that are tailor-made for 3D printing. You can add support structures, orientate the model on your print bed, and use the convert-to-solid feature to prepare your design for the 3D printer.

BLENDER

Platform: Windows, macOS, Linux, Steam

→ **www.blender.org**

Blender is the free and open-source 3D creation suite. It supports the entirety of the 3D pipeline – modelling, rigging, animation, simulation, rendering, compositing and motion tracking, video editing – and the 2D animation pipeline.

Coding software

ARDUINO IDE

Platform: Windows, macOS, Linux

→ **www.arduino.cc/en/software**

The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. The environment is written in Java and based on Processing and other open-source software. This software can be used with any Arduino board.

3D Printing

→ 3D printing, sometimes called additive manufacturing, is a rapid prototyping process involving the creation of a 3D object either from CAD (computer-aided design) or a digital 3D mesh model.

Having a 3D printer in your makerspace can be a great resource for students to use. The most common and accessible types of 3D printers are FDM (Fused-Deposition Modelling) printers such as the one pictured here. FDM is a 3D printing process which involves building up layers of melted plastic onto a bed, like squeezing icing through a nozzle. Each layer is gradually built up one on top of the other.

The 3D printers used in the Dangoor Reach Out Makerspace are all FDM printers. There are now many different ways of 3D printing using resins, powders, plastics and even metal fibres suspended in plastic, which are the cleanest and most cost-efficient to use.

Planning + designing

Your makerspace is full of tools and materials – now what?

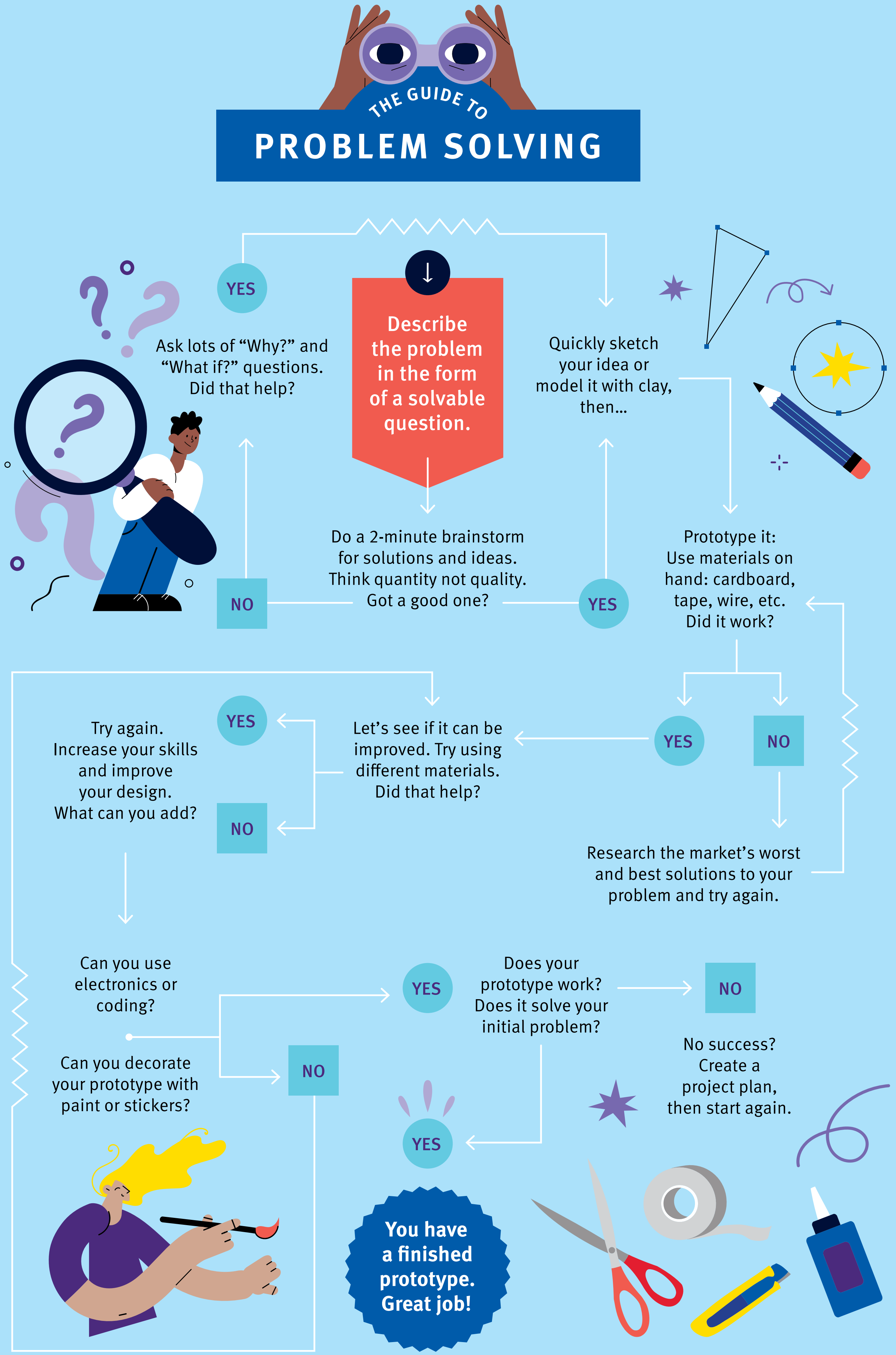
In this section, you'll learn how to think all the way through a project – from idea to creation – and how to visualise your project at early stages.

Create, innovate, ideate

In today's ever-growing and changing world, being able to think creatively and innovatively are essential skills. One of the best ways to develop creative solutions and inventions is to brainstorm. Here are some tips on how to brainstorm your idea successfully.

Six tips for brainstorming

1. **What are you trying to achieve?** Brainstorm what you want to do. Define and refine your ideas.
2. **Have you done your background research?** Try looking online, chatting with people, and looking at the world around you.
3. **Do you know exactly how you are going to build/make your project?** Read books, look online, and ask friends, family, and teachers for help.
4. **Have you considered potential issues or problems?** Think about what might go wrong.
5. **Do you have all the materials you'll need?** Source them and consider what you can repurpose. Beg, borrow, and beg some more!
6. **Do you have a project plan?** Write down the steps you'll take.



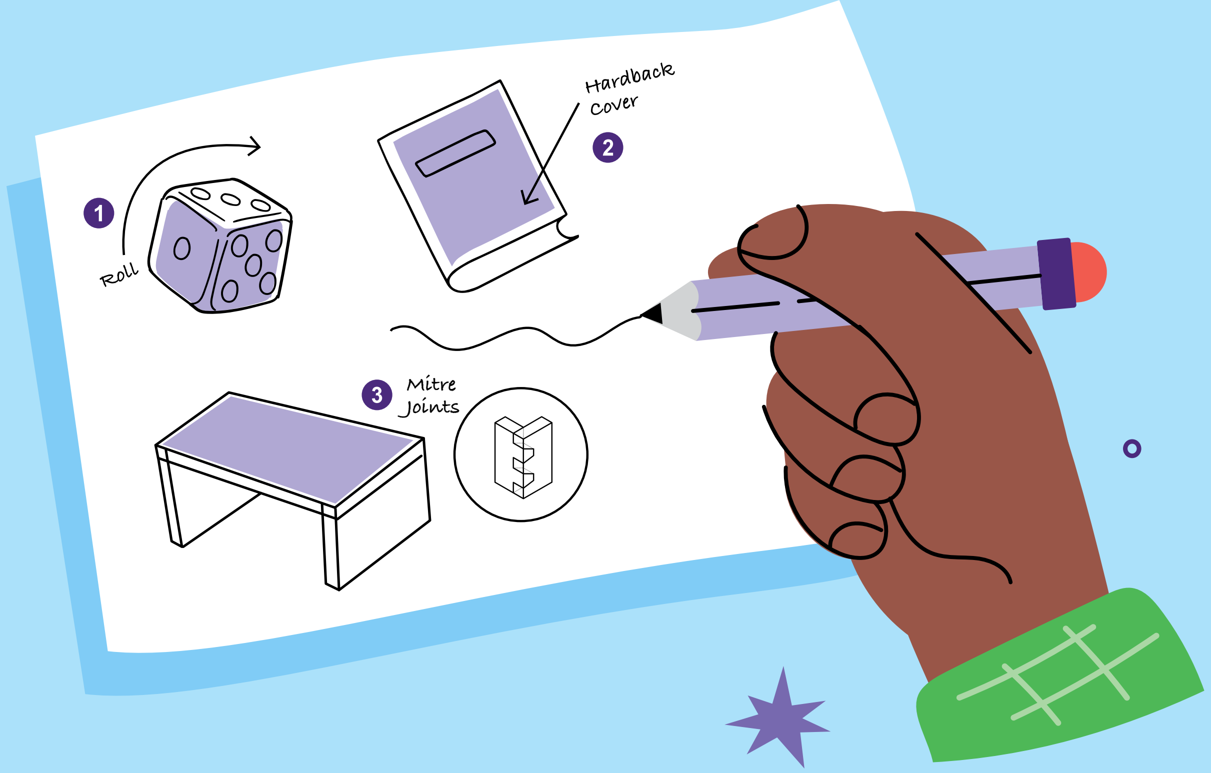
Sketching your ideas

→ Contrary to common belief, sketching an idea isn't about drawing well, but about making information clearer. Sketching is really a way to transfer the idea in your head onto paper, so that you can re-evaluate your assumptions and other people can understand your thought process. Often, sketching the project can be faster and more illuminating than jumping straight into words, equations, or 3D models.

Depending on what you're sketching, a good sketch communicates the following:

- How does it work?
- What are the defining features?
- What does it do?
- Who uses it?
- How is it used?
- When/where is it important?

The last four of these are not about the product itself, but rather the context of the product. If the sketch shows proper context, even the most basic drawing can convey your meaning.



SKETCHING EXERCISE 1:

Draw a rectangular cuboid, adding details that you think will show that your cuboid is a book, or a table, or a die. It's important to show enough identifying characteristics like the form of the object and the context in which it is used. Including too much extraneous detail, or too much context, can actually confuse the message.

Other tools you can use to make sketches clearer are annotations, detail views, and action lines.

1. **Action lines** use arrows, dots, dashes, and other symbols to indicate action and movement.
2. **Annotations** are notes about aspects of the sketch. Try to keep the lines that connect the sketch and the words parallel or perpendicular when annotating components. This removes visual clutter.
3. **Detail views** are sketches within a sketch, highlighting the features that have more detailed aspects to better explain them. Avoid trying to fit too many details into one sketch.

SKETCHING EXERCISE 2:

Try using these tools to draw a drone that delivers letters between friends. How would you show the function of different components, details of the drone body, and mechanism motion?

Or go back to Exercise 1 and use these techniques on your cuboid to show actions or items such as making a phone call, a faulty battery, a recipe book, or posting a letter.

Rapid prototyping

→ The formal definition of rapid prototyping is the fast fabrication of a physical part, model, or assembly using 3D computer-aided design (CAD). Informally, rapid prototyping is the process of taking an early idea or notion and quickly building or creating something that makes your idea more tangible. It doesn't matter how good or bad the prototype looks or feels. If it gives you a better understanding of what your idea is going to be like, it is a good prototype.

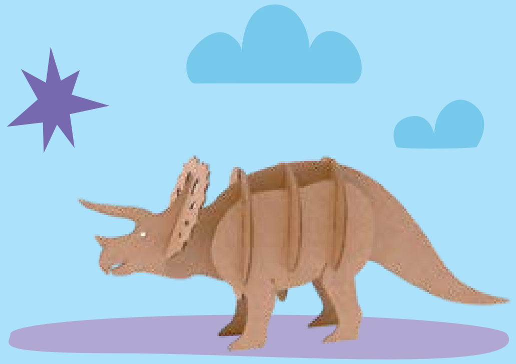
Why make a prototype?

Prototyping is a useful way to develop an initial concept and to find errors and fix them. This is exactly why early prototypes or rapid prototypes shouldn't be perfect. You want the prototype to highlight areas for development.

- **Workalike prototype** does not need to look good, but it needs to do the job you wanted the product to do. If you want to build a hat that changes colour with temperature, for example, you might build a prototype that has a small piece of material that changes colour with temperature
- **Lookalike prototype** does not need to work at all, but it should resemble how the finished project or product will eventually look. Workalike and lookalike prototypes can be combined into a final prototype.

Cardboard and EVA foam are two good materials with which to make prototypes, because they are easy to cut, shape, and glue. If you already have a CAD model or the prototypes need to be very rigid, it would be easier to have it made by laser cutting or 3D printing. Laser cutting is fast and accurate and great for making repeated patterns and fine details. 3D printing, on the other hand, is much slower (from few hours to days to make a part) but the outcome is a plastic product identical to your CAD model.

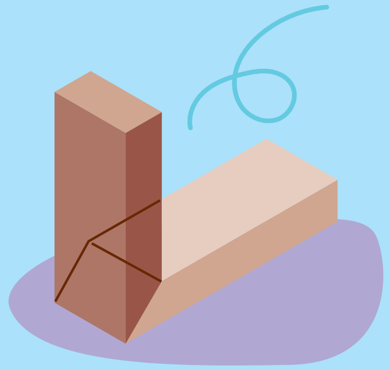
Tips and tricks for making a prototype



CROSS-SECTIONS

If you want to make a 3D model of a shape you can do it by creating cross-sections that can be put together.

The easiest way to start this is to draw the silhouette of what you are trying to make looking at it from one simple angle. Try cutting out several silhouettes, from above and in front, then cut a slit in each to halfway and slide them together. Add pieces to hold them at right angles and give them more shape and detail.



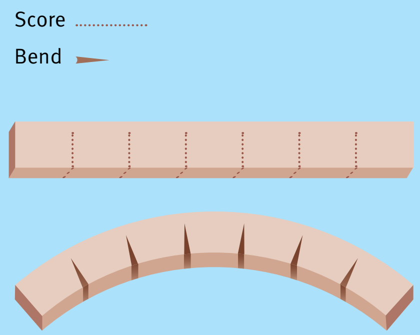
SHARP EDGES + SMOOTH JOINS

To get clean sharp edges, where the inside of the cardboard can't be seen, use a sharp utility knife and cut the pieces at an angle, like the corner of a window or picture frame.

For very sharp points, like the front of a fish fin, it might be easier to leave a flap that folds over both. For this, cut at an angle along the usual cut line, but not all the way through one piece. Cut the outside skin of the cardboard 1–2 cm past the fold line, then fold it like paper along the edge you want. Put the pieces together and glue the flap to the surface of the other piece, giving a nice crisp folded edge. You can also use this to make a smooth join where two curved edges meet.

CURVES

Curving cardboard is a great way to make smooth looking prototypes and more organic-looking shapes. You can use this technique on its own, or to put a 'skin' over a shape made from cross-sections. Start with simpler shapes like cylinders or rounded edges of boxes before trying to do things like balls or bent tubes.

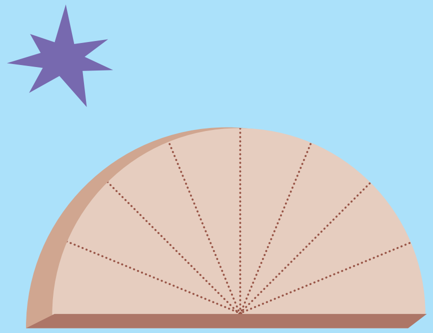


You can do this from the outside by first marking out the edges of the bend on its outside. For example, to make a folded edge curve smoothly, mark lines parallel to the fold on either side of the fold line. Add a few more evenly spaced lines between these lines. Carefully take a knife or scalpel and score the material along each line. The cardboard should bend smoothly, with the cuts on the outside of the bend.

From the inside, mark out lines parallel to the fold line on its inside. Mark two or three lines evenly spaced between them. Angle the blade and score either side of the lines, so that you take 'V' sections out where the lines are. The cardboard should bend towards you, leaving a smooth finish on the outside of the bend.

CONES

If your curves aren't completely straight like a cylinder, but taper like a cone, you can still use both of these techniques. Instead of drawing your cut lines parallel, have them all meet at a point (the tip of the cone).



If you don't need to go all the way to the tip of the cone, another way of marking this is drawing a trapezoid, spacing the same number of points evenly along each parallel side (so the points on the shorter side will be closer together), and then connecting the points together to give you lines that converge.

Design thinking challenges

→ Design thinking isn't just about building a prototype. Thinking like a designer can transform the way you approach the world when imagining and creating new solutions for the future.

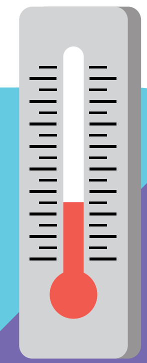
It's about being more aware of the world around you, believing that you play a role in shaping that world, and taking action toward a more desirable future. Design thinking gives you faith in your creative abilities and a process through which to take action when faced with a difficult challenge.

Try out a few scenarios that can encourage that kind of mindset with our design thinking challenges.

Come up with a future technology that can replace mobile phones and describe what would make it superior to mobile phones of today.

Generate ideas to make food or medical aid easier to deliver and store locally in rural areas during a crisis.

On 28 January 1986, space shuttle Challenger exploded only 7 seconds after take-off, killing all seven astronauts on board. We now know that the accident was caused by a failure of the O-rings which formed the seal for the rocket boosters, due to cold conditions. What choices would you make if you were the head of a team responsible for fitting O-ring seals in the face of a cold weather rocket launch?

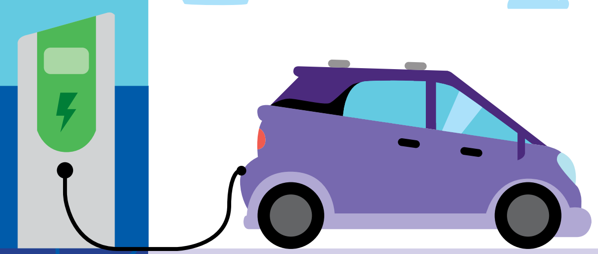


A top tech company recently installed motion-activated lights in their bathrooms but employees complain that lights often switch off while they are in the bathroom. How would you tell the boss to solve this problem?

Cultivate your curiosity

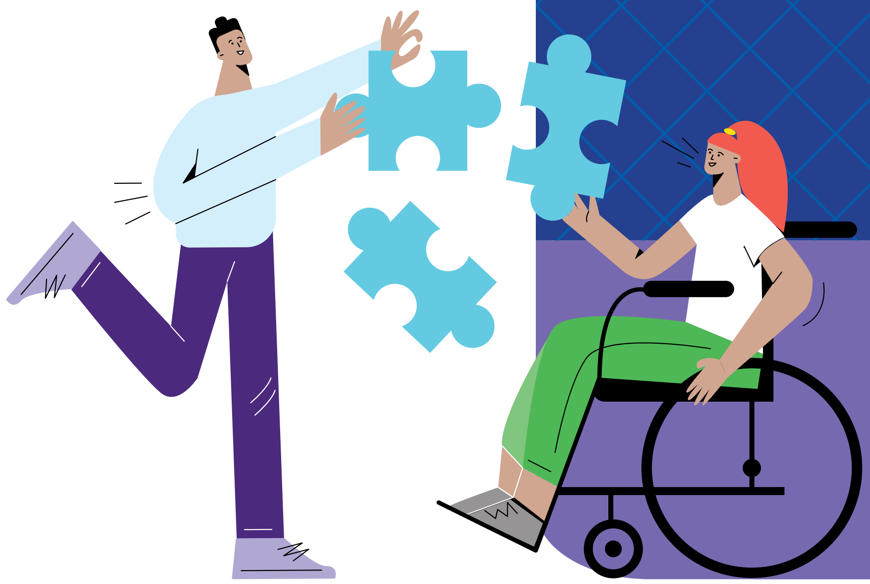
Computing technology has rapidly evolved from the 1990s until now. What improvements have these changes brought? What is still left to be improved?

In 2015 the UN announced 17 Sustainable Development Goals to address the global challenges related to poverty, inequality, climate change, environmental degradation, peace and justice. Come up with an idea for an app to that could help to achieve one or more of these goals by 2030.



Think about advances in engineering like changes in printing, cars, or television in the past 10 years. What have these advances allowed us to do that we were not able to do before?

Some hospitals reported a lack of oxygen and problems distributing it to sick patients through pipes during the COVID-19 pandemic. How can we avoid situations like this in the future?



If you're feeling creatively stuck, try 'Imagine if'. Come up with as many statements beginning with 'Imagine if' that can act as a starting point for a creative solution to a real-world problem.

Inspiring makers

Designer/Entrepreneur/DJ

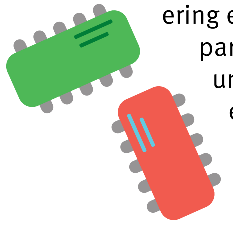
Virgil Abloh

Virgil studied engineering and architecture, but his interest in fashion and hip-hop culture was his springboard. He was inspired by streetwear culture as well as skateboarding, graffiti art, and hip-hop culture. He and his friends would send concept sketches to Nike all the time even though they never accepted any of the designs. His creative visions have led him to be Kanye West's creative director and the first black creative director for Louis Vuitton.

Entrepreneur/Inventor/Social Activist

Ayah Bdeir

Ayah started littleBits, an open-source kit of electronic modules that snap together with magnets for prototyping and play. Her work has centred around empowering everyone to be an inventor. She has particularly focused on empowering under-represented communities, especially girls, with the tools to become tomorrow's changemakers.



Furniture Designer

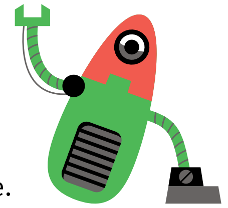
Sebastian Cox

Sebastian is a young British furniture designer, champion of traditional crafts revival, and self-confessed wood nerd. He is committed to zero-waste and sustainable design. The carbon footprint of every part of his design process, from idea to construction to delivery is carefully calculated.

Inventor/Maker

Simone Giertz

Simone is a self-taught Swedish inventor, maker, tinkerer, and professional YouTuber. She loves to make rubbish robots and believes passionately in playing, experimenting, and the importance of failure.



Architect/Designer

Zaha Hadid

Hadid was the first woman to win the Pritzker Architecture prize amongst other awards. She was well known for her curved architectural buildings and designed many famous buildings including the London Aquatics Centre.

Engineer/Cartoonist/Writer

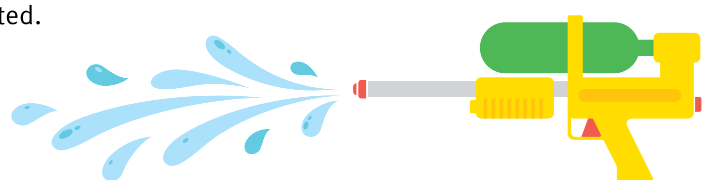
Tim Hunkin

Tim studied engineering but did not want an office job. He became a professional tinkerer and inventor. A self-taught artist and illustrator, he became a cartoonist for the *Observer* newspaper – for about two days a week and enough to pay the rent. Since then he has been tinkering and making mechanical gizmo machines and drawing and animating cartoons.

Inventor/Engineer

Lonnie Johnson

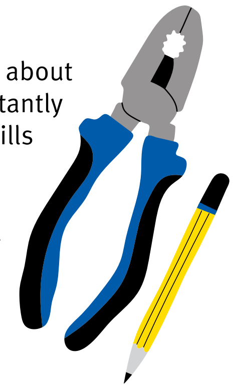
Lonnie grew up as a tinkerer and inventor in Alabama, USA. He ended up working as an engineer for NASA. Despite this, he is most famous as the inventor of the Super Soaker water pistol in the 1980s. The proceeds from this successful invention (over one billion dollars) enabled Lonnie to set up two research institutions which now focus on developing clean energy.



Maker/Designer/Presenter

Laura Kampf

Laura is passionate about making and is constantly challenging herself to learn new skills through the projects she makes. She documents her projects and processes via her YouTube channel which is an amazing source of maker inspiration.



Architect

Diébédo Francis Kéré

Diébédo was born in Gando, a small village in eastern Burkina Faso in West Africa. While still a university student, he set up the association 'Schulbausteine für Gando e.V.' With this association he was able to raise enough funds to build the Gando Primary School. His objective was to combine the knowledge he had gained in Europe with traditional building methods from Burkina Faso.

Fashion Designer

Adebayo Oke-Lawal

Adebayo is a Nigerian self-taught fashion designer who founded Orange Culture in 2011 when he was 20 years old. Embracing androgyny and breaking gender stereotypes, he created a movement through his clothing that champions liberation, freedom, and African culture. He has made Orange Culture one of the biggest labels in Nigeria and indeed Africa.

Technologist/Social Innovator

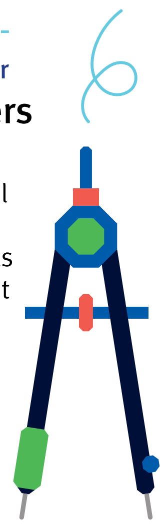
Kimberly Bryant

Kimberly is the founder of Black Girls Code, a nonprofit with a mission to teach girls of colour the technology skills they need to succeed and flourish. The programme transformed from a basement experiment into a global non-profit that is making tech more inclusive.

Architect/Designer

Richard Rogers

As a child Richard struggled in school with severe dyslexia, but he overcoming his academic setbacks to become one of the world's most celebrated architects. He is noted for stunning designs such as the Pompidou Centre in Paris and the Millennium Dome, as well as his pioneering views on sustainable cities.



Industrial Designer

Sha Yao

Sha is a Taiwanese industrial designer who invented Eatwell, a complete assistive tableware set designed to help people with cognitive, motor, and visual impairments maintain their ability to eat independently.

After watching her grandmother struggle to eat without assistance due to her worsening Alzheimer's disease, Sha was inspired to create something to make her life easier. She created Eatwell after volunteering at care homes and speaking to caregivers.

Make it yourself

Ready to get started in the makerspace?

In this section, we share some makerspace projects for all levels, along with inspiration for group projects.

Collaborative projects

→ At the Dangoor Reach Out Makerspace we are keen to give young people the opportunity to use tools and equipment to get making as quickly as possible. We want more makers in the world. Students usually work on projects by themselves, but there are some amazing examples of group making projects where communities and groups of people have come together to make incredible things.

Here are some of our favourites as well as some suggested activities that you might want to try with a group of friends or part of a school club.

Suggestions for group-making projects

- Build a wildflower garden to boost insect population under threat from pesticides and lack of vegetation
- Build a giant marble run
- Build outdoor furniture from recycled materials
- Build an insect hotel to help support biodiversity in the environment
- Build a composter
- Build an outdoor structure or playground
- Build bike storage or a bike rack
- Create a mural
- Build a drone obstacle course
- Build an outdoor gym

THE CRAFTIVIST COLLECTIVE

The Craftivist Collective is an inclusive group of people who use crafts and craft projects to gently protest issues they see in the world and to push for positive change.

Founded by Sarah Corbett in 2009, the group brings people together to make things which draw attention to societal issues. They have under-taken many public projects, including raising awareness of the rights of fashion workers by dropping information notes into the pockets of clothing and stitching prompts onto fabric patches which are then left in public spaces.

NAMES PROJECT AIDS MEMORIAL QUILT

The NAMES Project is the largest piece of community art in the world. It is a memorial to those people who have died from AIDS-related illness.

The quilt is made up of panels each measuring approximately 8 × 15 cm. Each panel recognises a person who has died from an AIDS-related complication or illness. The panels are submitted by individuals or groups and the design of each panel and the way it is made is determined by the people who are creating it.

Historically, AIDS-related illness was surrounded by social stigma and fear, and many people concealed their illness. People who died of AIDS-related complications were even denied public funerals. The quilt aims to raise awareness of the illness and its toll.

The quilt currently weighs 54 tonnes and is the largest piece of community collaborative art ever created.

1,000 PAPER CRANE PROJECT

On 6 August 1945, an atomic bomb was dropped on Hiroshima in Japan. A young Japanese child named Sadako Sasaki was injured during the explosion and suffered great illness due to radiation exposure for the next ten years of her short life. While being treated in hospital, Sadako was told about a famous legend that says anyone who folds 1,000 paper cranes (‘senbazuru’ in Japanese) will be granted a wish by the gods.

She began folding paper cranes with whatever paper she could find. While it is not certain she completed her task before her death, her classmates continued her legacy of folding paper cranes. This became a symbol of world peace in Japan.

Since then, many groups and artists have gone on to undertake senbazuru. The project has come to symbolise hope and healing during challenging times.

Brilliant idea or absolute failure?

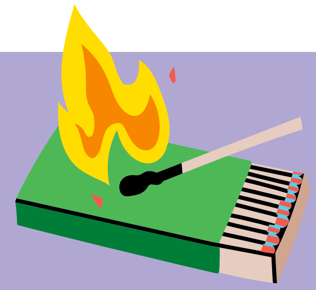
1693

Champagne

Dom Pérignon's batch of wine failed as a second fermentation created bubbles. Rather than scrap the wine, he tasted his creation and exclaimed, "Come quickly! I am drinking the stars!"

1826

Matches



While mixing a combustible paste for guns, John Walker accidentally scraped a mixing stick on a hearth, and the stick suddenly erupted into a flame. Matches revolutionised how fires could be started.

1938

Chocolate Chip Biscuit

Replacing baker's chocolate with sweetened chocolate broken into small pieces to make chocolate cookies, Ruth Wakefield expected the chocolate to melt. But the little bits stuck and so did the biscuits.

1853

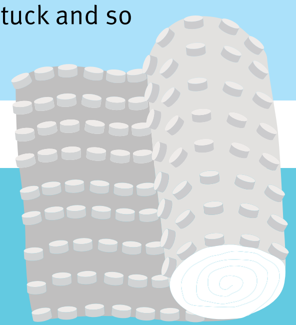
Crisps

When a customer sent back chips that were not fried enough, chef George Crum in anger sliced the potatoes super thin and fried them "crisp". They were an instant hit.

1886

Coca-Cola

John Pemberton's syrup cordial made from wine and coca was originally concocted as a cure for headaches and hangovers. An alcohol ban striped the wine from coca syrup and left it needing to be diluted. Add soda water and the rest is history.



1957

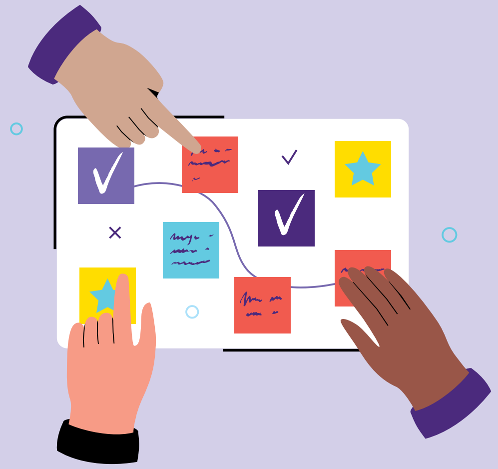
Bubble Wrap

Designed as a wallpaper, Alfred Fielding and Marc Chavannes' bubble trapped material failed. Rather than give up on the idea, more than 400 uses were explored. Finally, in 1960 it revolutionised the shipping industry as protective packaging.

1968

Post-it Notes

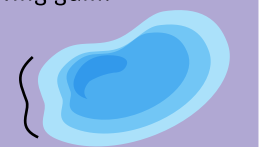
While trying to create a strong adhesive, Spencer Silver created a weak non-marking glue. It took a further 10 years and the vision of a colleague to see the potential of mild adhesive paper bookmarks.



1969

Blu Tack

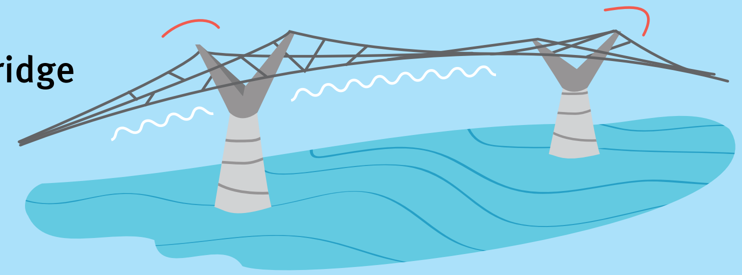
A failed sealant, scientists used the 'goo' to stick up messages. Blu Tack, originally white, was coloured blue so as not to mistake it for chewing gum!



2000

The Millennium 'Wobbly' Bridge

Taking £18m and two years to build, but 'synchronised footfall' made Norman Foster's bridge wobble. It took 91 dampers, £5m, and two years to fix.



2001

Contrarotator Washing Machine

James Dyson's washing machine had two drums and two motors to mimic the motion of hand washing. Like the bagless vacuum, it challenged convention. But it was too expensive to compete and was pulled in 2005.

2001

Segway

Costing $100m to develop, Dean Kamen's Segway was envisioned as a revolutionary way to travel. It was technologically great, but socially awkward, expensive, heavy and a little silly. Consumers didn't know what to make of it.

2016

Samsung Galaxy Note 7

In the Apple versus Samsung battle for smartphone dominance, Samsung won the launch race but seriously lost when its phones started to combust!

DEVELOPED BY
Ela

YOU CAN CREATE IT!

Mobile phone amplifier

BEGINNER

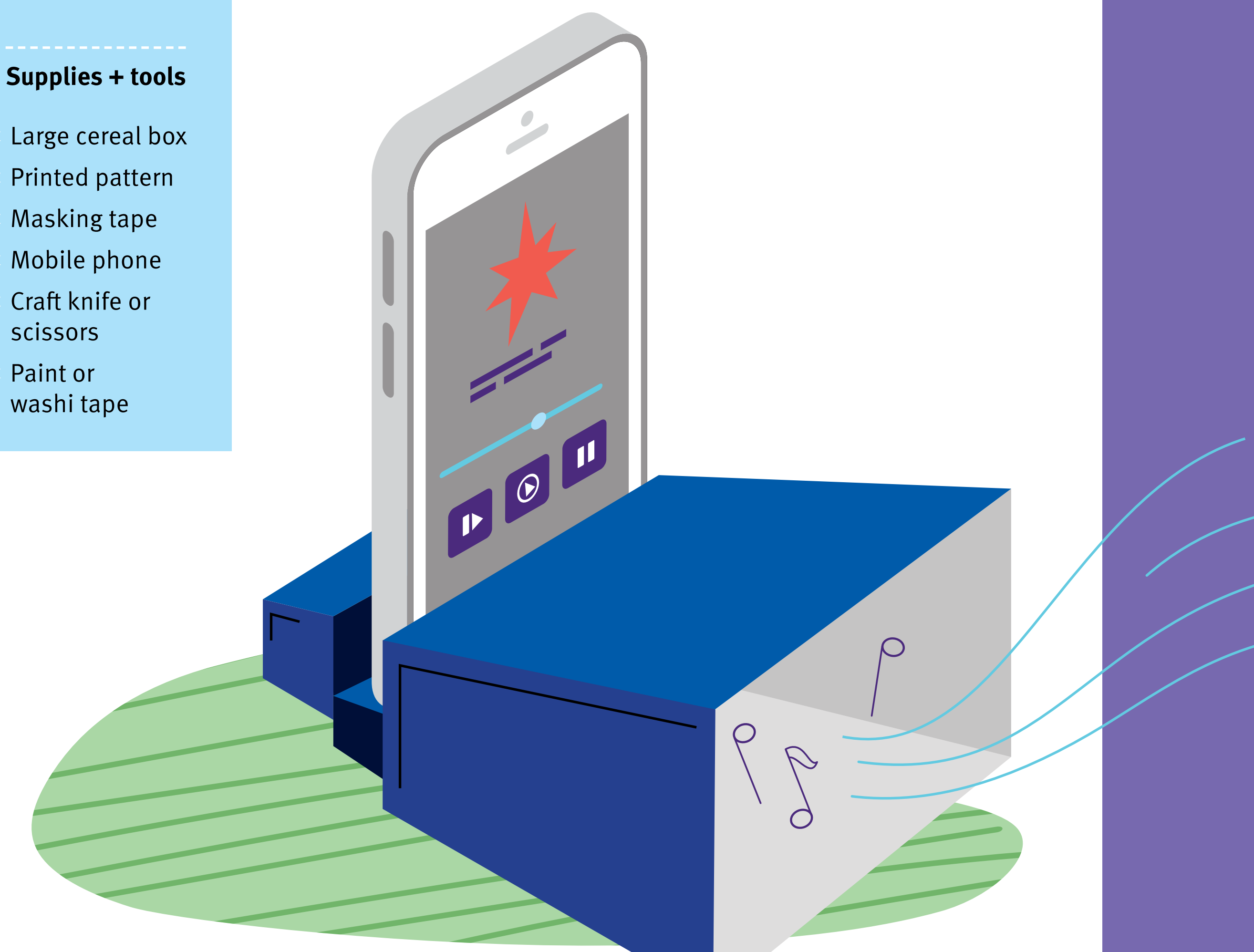
20

20 MINUTES

Supplies + tools

- Large cereal box
- Printed pattern
- Masking tape
- Mobile phone
- Craft knife or scissors
- Paint or washi tape

→ Want to boost your sound? No problem. Broadcast your mobile phone's music by making an amplifier out of cardboard, with no power supply needed. The design does all the work. Rather than the sound dispersing in all directions, the amplifier horn focuses the sound waves so the resulting sound (music) is intensified in the direction the horn is facing.



01 Unfold cereal box into one flat piece of cardboard. Place patterns for amplifier horn and phone slot support on top of unfolded box. Align creases in the cardboard with the pattern's fold lines as much as possible. Keep pattern's top faces clear of cardboard creases.

02 Secure the aligned pattern to the cardboard with tape. Cut out the patterns, including openings for tabs, so that there are two pieces of cardboard. Use the back of the craft knife to lightly score the fold lines marked on the pattern. This will make it easier and neater to fold the cardboard.

03 Crease the scored fold lines. Note that the phone slot support folds in two different directions.

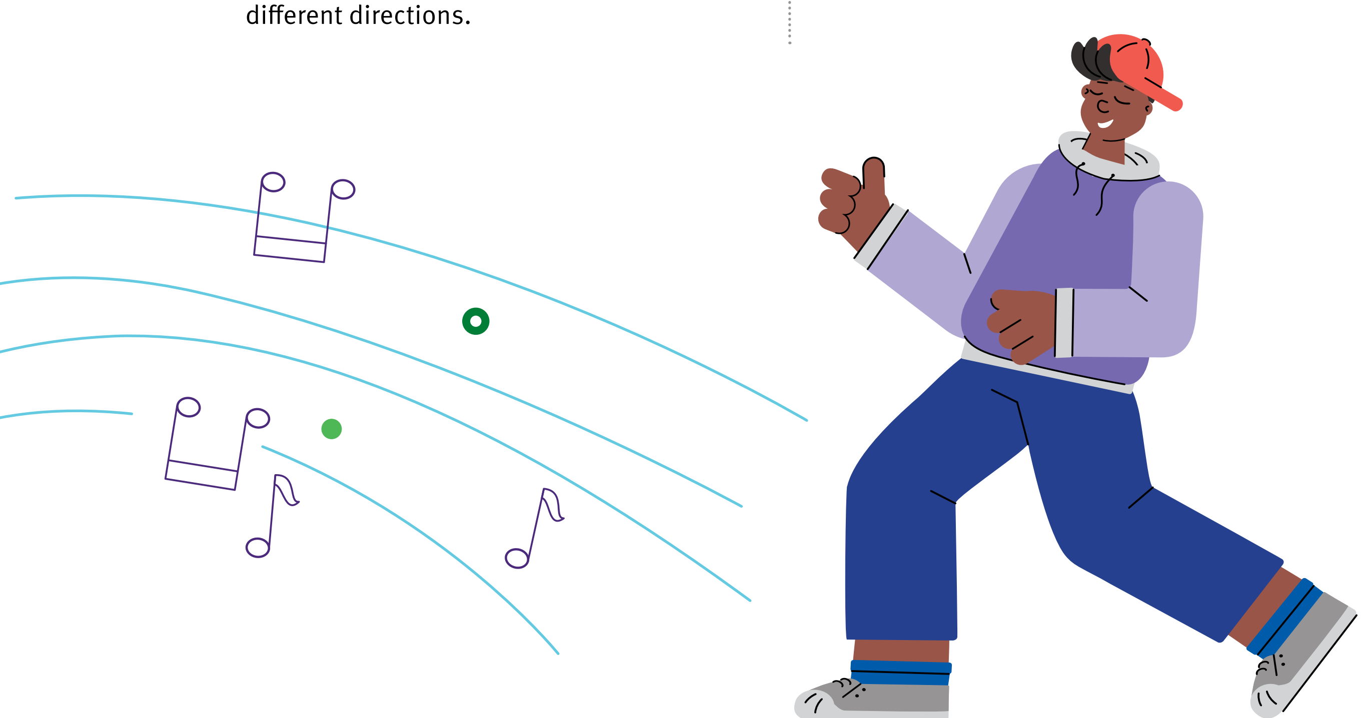
04 Fold the amplifier horn and secure edges with tabs.

05 Align "top face front" section of phone slot support with "top face front" of amplifier horn. Pinch phone slot support as shown here to fit into amplifier horn.

06 Wrap the phone slot support around the amplifier horn and secure with tabs.

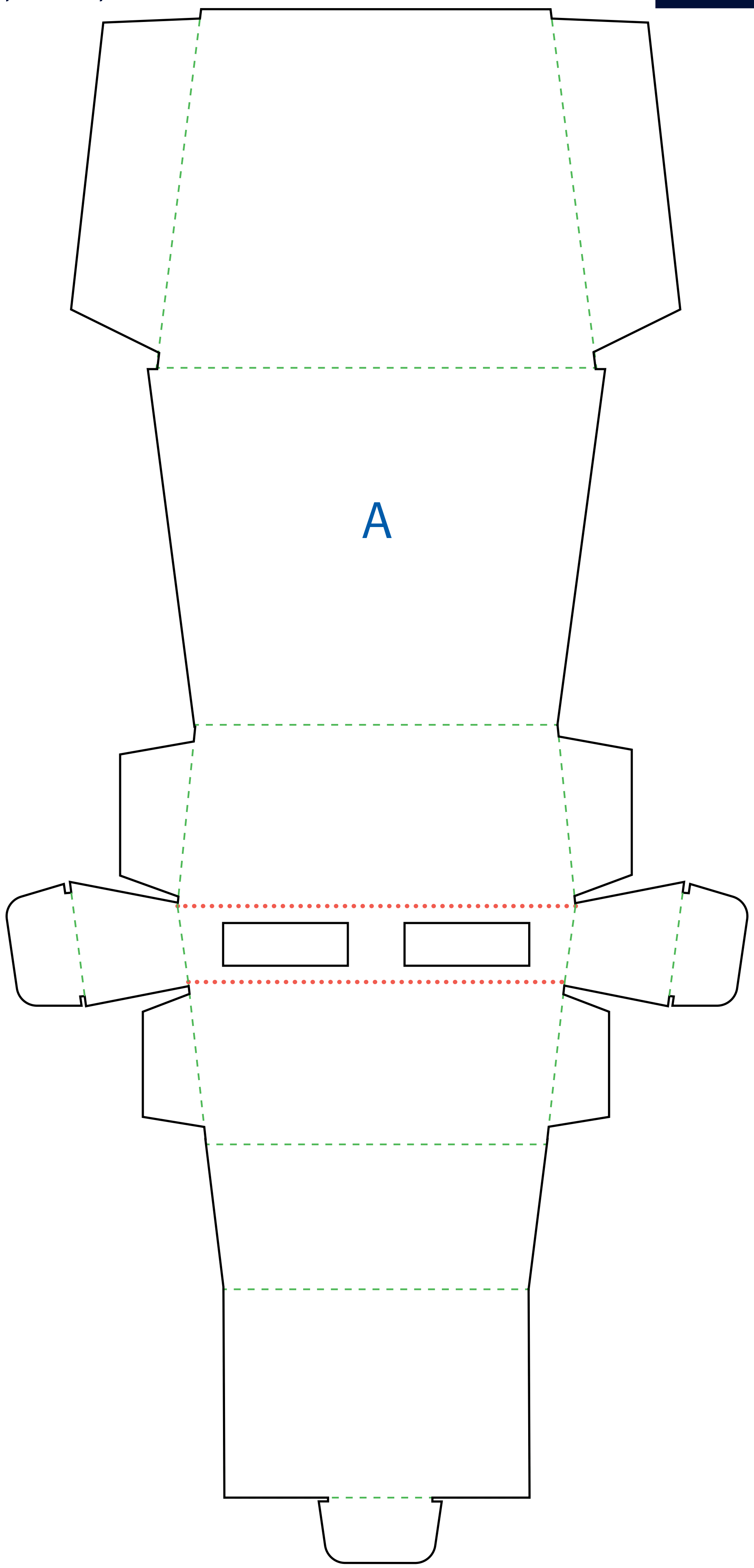
07 Fold top front section inside the horn and secure in place with the slot tabs at the back of the horn. Decorate the finished speaker with paint, washi tape or decoupage for a more finished look.

Watch the online tutorial:
https://bit.ly/30G6iru



What's next?

- Would a bigger speaker boost the sound even more?
- Does the speaker sound different when it's made out of something other than cardboard?
- What shapes other than a horn can amplify sound?
- Sound and light both travel in waves. Could this design amplify light too?

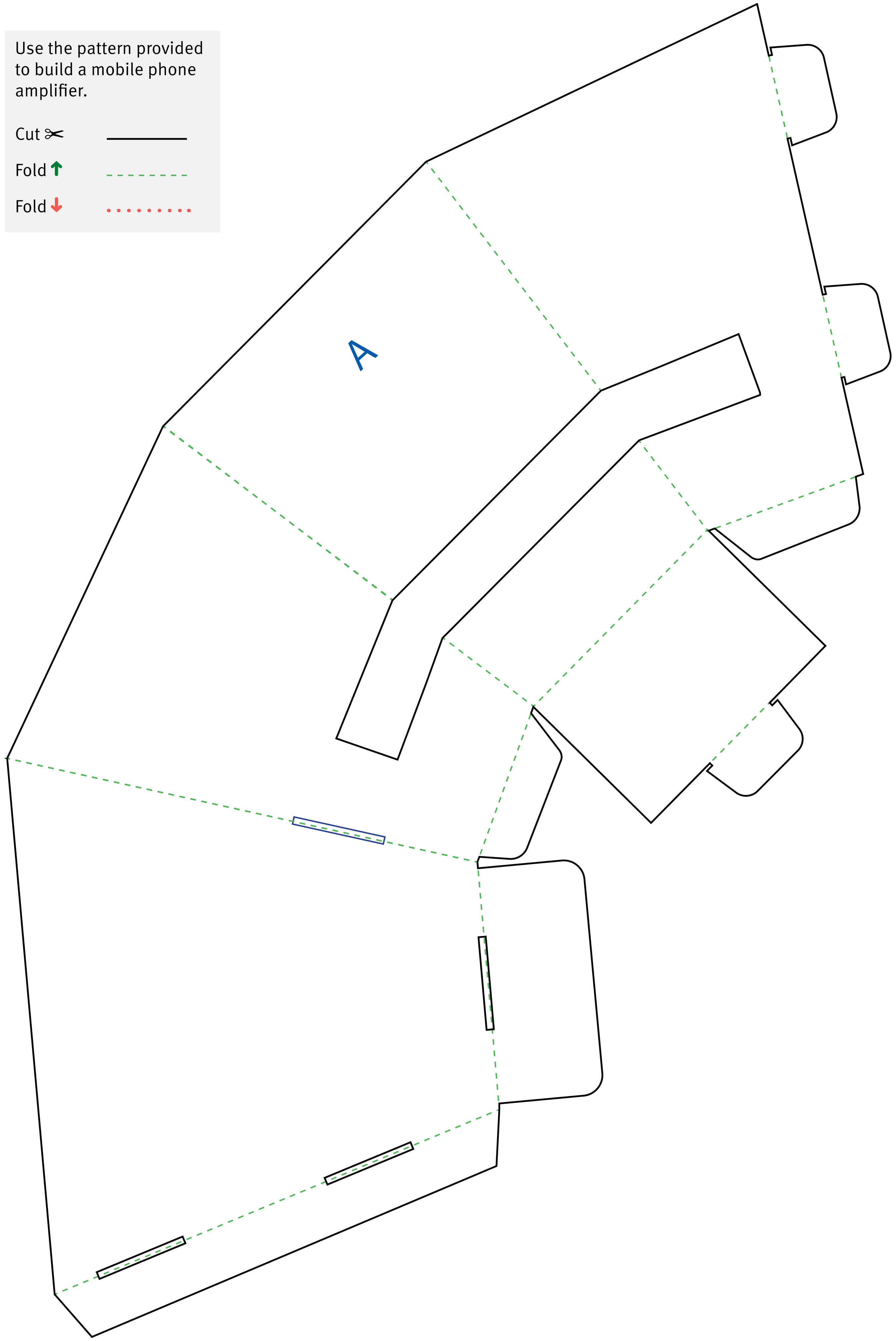


Use the pattern provided to build a mobile phone amplifier.

Cut ✂

Fold ↑

Fold ↓



DEVELOPED BY
Richard

YOU CAN MAKE IT!

Thor's pencil

BEGINNER

30

30 MINUTES

Supplies + tools

- Thin cardboard (cereal boxes work well), to make two pieces of 25 × 15 cm and 12 × 7 cm
- Ruler
- Pen/pencil
- Craft knife/scissors
- Clear sticky tape or masking tape
- Big thick-stemmed marker pen
- Newspaper (about 15 sheets)
- Full roll of toilet paper
- Water-based glue (PVA), thinned with extra water
- Paint brushes and rinse cups
- Paints and palette (acrylic or poster paint work well)

→ Designers sometimes make replicas of an object to help them understand its materials, shapes and dimensions before they build the real thing. Replicas are also used sometimes in films and on television. On screen, something that looks like metal or glass may actually be made of painted and textured wood, foams, cardboard or plastic.

Make our giant pencil and prove that in this case, the pencil is mightier than the hammer. You won't need mythical strength to be worthy enough to pick it up.

01 Draw a large rectangle (at least 25 × 15 cm) on a piece of cardboard, and cut it out.

02 Using the ruler, draw lines to divide the rectangle into six equal-sized smaller rectangles. Score gently along the lines.

03 Fold the rectangle along these scored lines. Overlap the two end rectangles and tape them together firmly. You should have a pentagonal tube as your pencil body.

04 Roll the remaining piece of cardboard into a cone shape. Aim to make the open end of the cone approximately the same width as your pentagonal tube. This will form your pencil tip.

05 Push this cone into one end of the pencil body. Expand or contract the cone so that it fits neatly into the tube. Most of the cone including the pointed end should extend outside the tube.

06 Tape the cone to the inside and outside of the body securely. You can add more tape or cardboard to ensure that the body and tip are securely attached.

07 Snip off the end of the cone tip with the scissors, so that the thick marker can be inserted through this hole. Don't cut off too much at once. Cut off a little at a time until the marker will fit snugly inside, with 1 cm of the pen and lid sticking out the tip of the cone. Tape the marker firmly into position on the outside of the tube.

08 Place the open end of the pencil body over a remaining piece of cardboard and trace the opening on to the cardboard. Cut out the tracing and set aside for later.

09 Scrunch up some pieces of newspaper or toilet paper and stuff them into the pencil body, using the rule to firmly push them down into the tip. Fill up the pencil body to the top of the tube in this way.

10 Firmly tape the cut-out tracing to the top of the pencil body to seal the tube.

11 Dilute PVA with water (approximately a 2:1 glue to water ratio) and apply to the whole surface. Apply toilet paper sheets to outside, to every surface except the marker tip, keeping them as flat as possible. Repeat this step, letting each layer dry before applying the next layer, until your pencil has an even, hard surface

12 Finish with a layer of the diluted PVA as a final sealant and leave to dry overnight.

13 Decorate your pencil with paint.

▶ Watch the online tutorial: **https://bit.ly/3oG6iru**

What's next?

For your next replica, try building an object at different scales. What kinds of dimensions would you have to measure to make a pencil that is half the size of a real one? Five times the size?

Do different kinds of material work better for different scale replicas?

What's the most important feature for a replica design? Size? Materials? Decorations?

DEVELOPED BY
Oisin

YOU CAN CRAFT IT!

Schrödinger's cat-cam

Rotary cams are mechanical systems that turn circular motion into straight line or oscillating (up and down or back and forth) motion. There are two main parts: the cam, which rotates, and the follower, which is held in a straight line and moves along the outside of the cam. Different cam shapes create different linear or oscillating motions.

BEGINNER

20
20 MINUTES

Supplies + tools

- Printed template
- Scissors
- Pencil
- Solid glue stick
- Non-corrugated cardboard (a cereal box works well here)
- Masking tape
- Hot glue sticks and glue gun

Some of the most common shapes include:

Circle	A circle-shaped cam uses an off-centre pivot to cause the follower to bob up and down during a rotation.
Pear	A pear-shaped cam causes the follower to bob up and down twice during a rotation.
Heart	A heart-shaped cam causes the follower to bob once during a rotation.
Snail	A snail-shaped cam causes the follower to move in a sawtooth motion, rising steadily over one rotation and then dropping sharply to start again.

01 Cut out Piece 1 from the template.

02 Roll it around a pencil in the direction indicated by the arrow, then glue the ends together to make a tube. Slide the tube off the pencil.

03 Using the glue stick, paste the rest of the template onto a piece of cardboard.

04 Cut out the rest of the template pieces along all remaining cut lines.

05 Fold along the dotted lines of Piece 2. Hot glue the ends together to make a short box open at two ends.

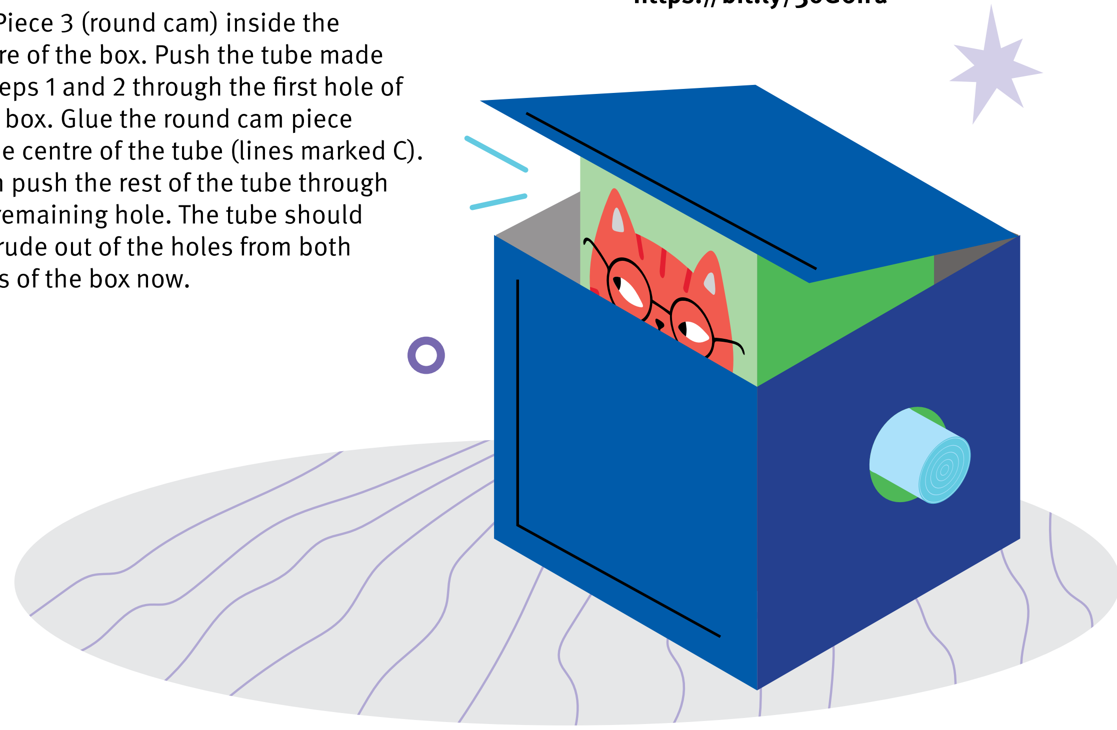
06 Put Piece 3 (round cam) inside the centre of the box. Push the tube made in steps 1 and 2 through the first hole of your box. Glue the round cam piece to the centre of the tube (lines marked C). Then push the rest of the tube through the remaining hole. The tube should protrude out of the holes from both sides of the box now.

07 Hot glue the lines labelled D to each other, making sure the cat face is pointed outward. Glue the lines labelled E to each other. Finally, glue the lines labelled F to each other.

08 Place this piece you have just made inside the larger box with the lines marked G aligned, and tape it so that it forms a lid to the box, hinged along G.

09 Turn the round tube using the end sticking out of the box, and watch the cat peek out the top and hide again.

Watch the online tutorial:
https://bit.ly/3oG6iru



What's next?

What other kinds of shapes would make a good cam?

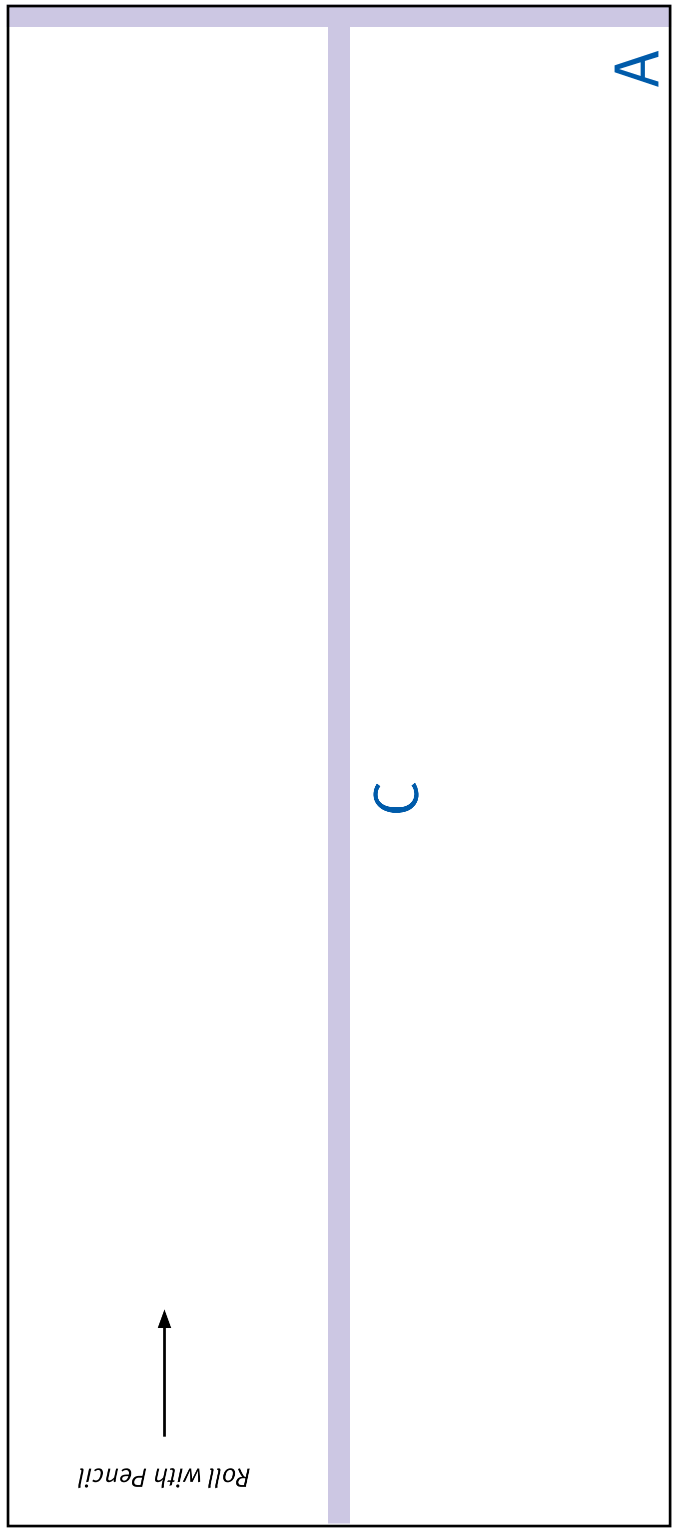
What would you use a cam-driven machine for in your life?

What happens when you put more than one kind of cam shape into the same machine?

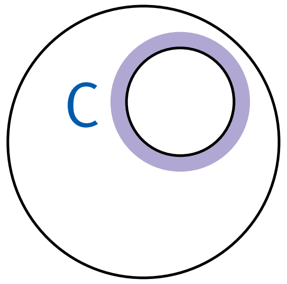
Use the pattern provided to build a simple cam-driven machine.

- Glue lines
- Cut ✂
- Fold ↑

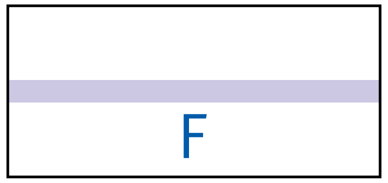
PIECE 1 • The tube



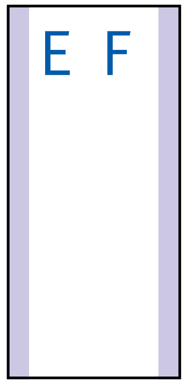
PIECE 3 • The cam



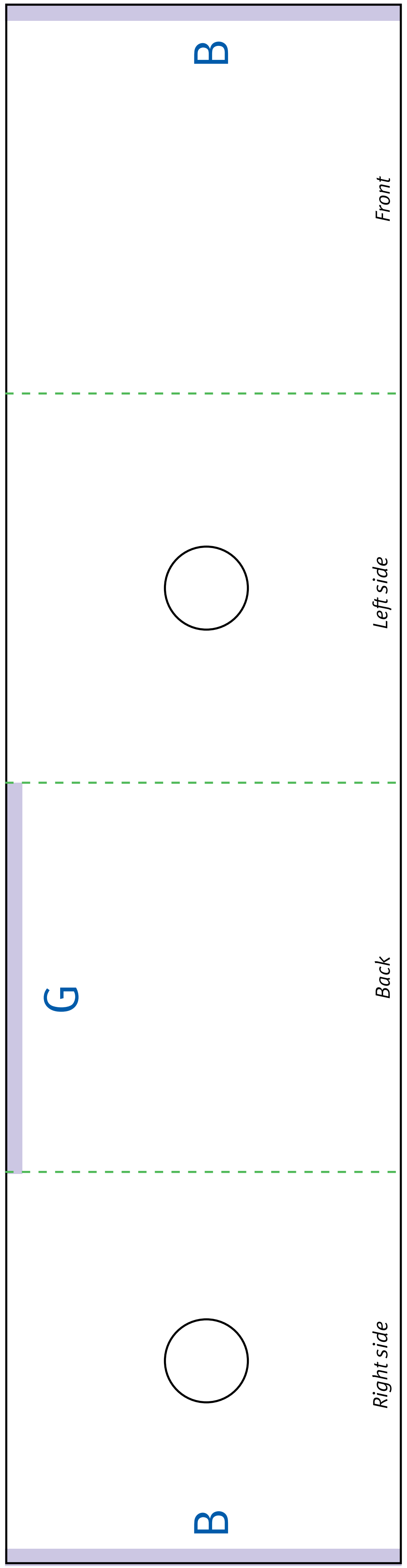
CAM follower



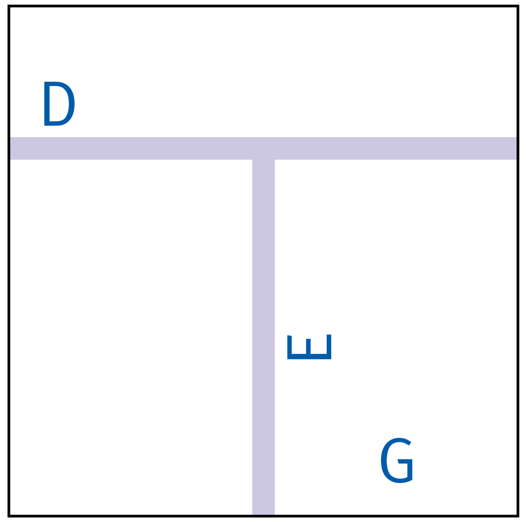
Vertical



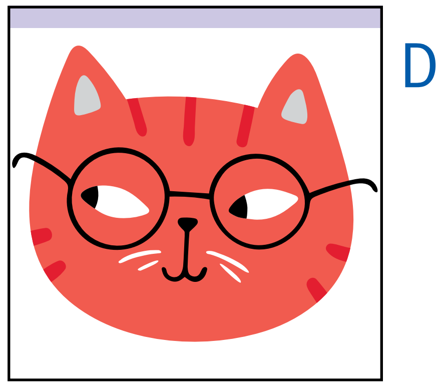
PIECE 2 • The box



Lid



Cat face



DEVELOPED BY
Monica

YOU CAN FABRICATE IT!

3D hologram projector

BEGINNER–INTERMEDIATE

40

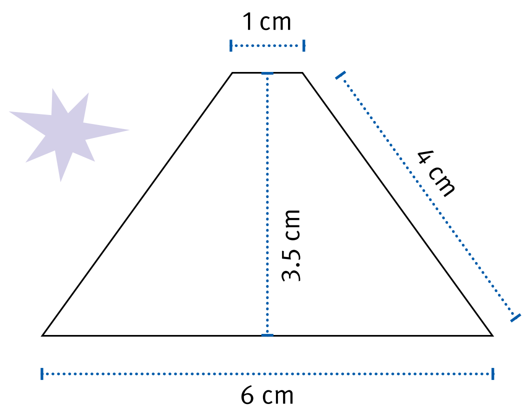
40 MINUTES

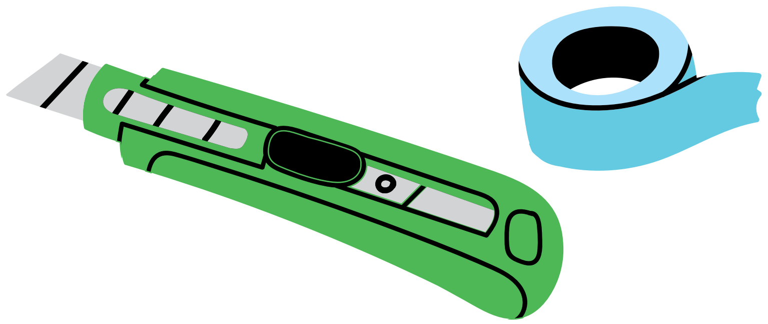
Supplies + tools

- Clear, thin, firm plastic – e.g. the plastic used in fizzy drinks bottles
- Pen (Sharpies work best)
- Ruler
- Safety goggles
- Cutting mat
- Blade cutter or glass cutter or Stanley utility knife
- Glue gun and hot glue
- Clear adhesive tape
- Mobile phone

→ By placing a reflective projector on top of your mobile phone, you can turn a 2D image into a 3D hologram. The technique used here is based on an old theatre illusion called ‘Pepper’s Ghost’. Places like Disney World still use it today to float ghosts in their Haunted Mansion ride. It’s also the technique that was used to project deceased rapper Tupac Shakur on stage at the Coachella music festival, shocking the audience with how real the hologram looked.

Holography, the practice of making holograms, records the light scattered from an object (in this case, your phone) through angled reflective surfaces. The technique gives an image a look of having full depth and surface properties.





01 Create 4 paper templates using the dimensions in the diagram to the left.

02 Copy the paper template onto the plastic, creating four identical segments. The dimensions will make a projector small enough to rest on your phone screen.

03 Wearing goggles and placing the plastic on the cutting mat, use the cutter or knife to score and then cut out each section.

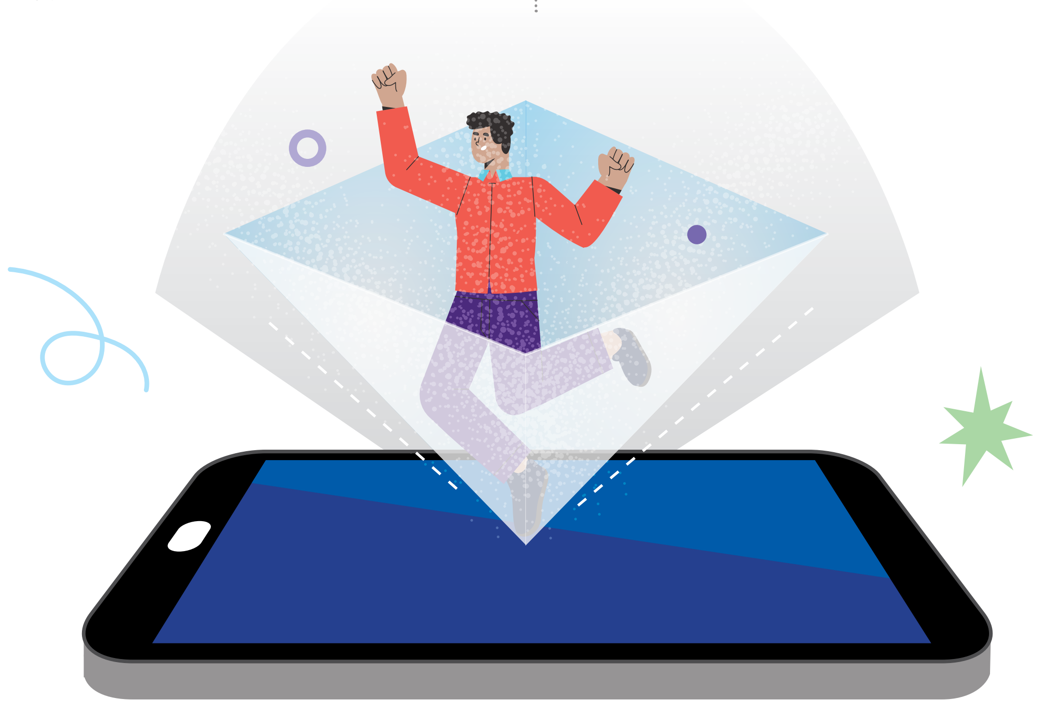
04 Combine the four sections into a square pyramid shape. The ‘top’ of the pyramid will be open. You can use clear tape to hold the shape together or use the hot glue gun to glue the sides together to form the pyramid.

05 Find a 3D holographic video on a streaming site such as YouTube to play on your mobile phone at full screen size.

06 Place the pyramid upside down on the centre of the mobile screen as the video plays, so that the open top is touching the screen.

07 Switch off the lights and enjoy your hologram projection!

Watch the online tutorial: **https://bit.ly/3oG6iru**



What’s next?

How could you adjust your projector to create a larger or smaller hologram?

If you could build a hologram projector out of a material other than plastic, what would you use? Why?

What kinds of objects would you rather see in 3D than in 2D?

DEVELOPED BY
Kate

YOU CAN WIRE IT!

Mini DJ lights

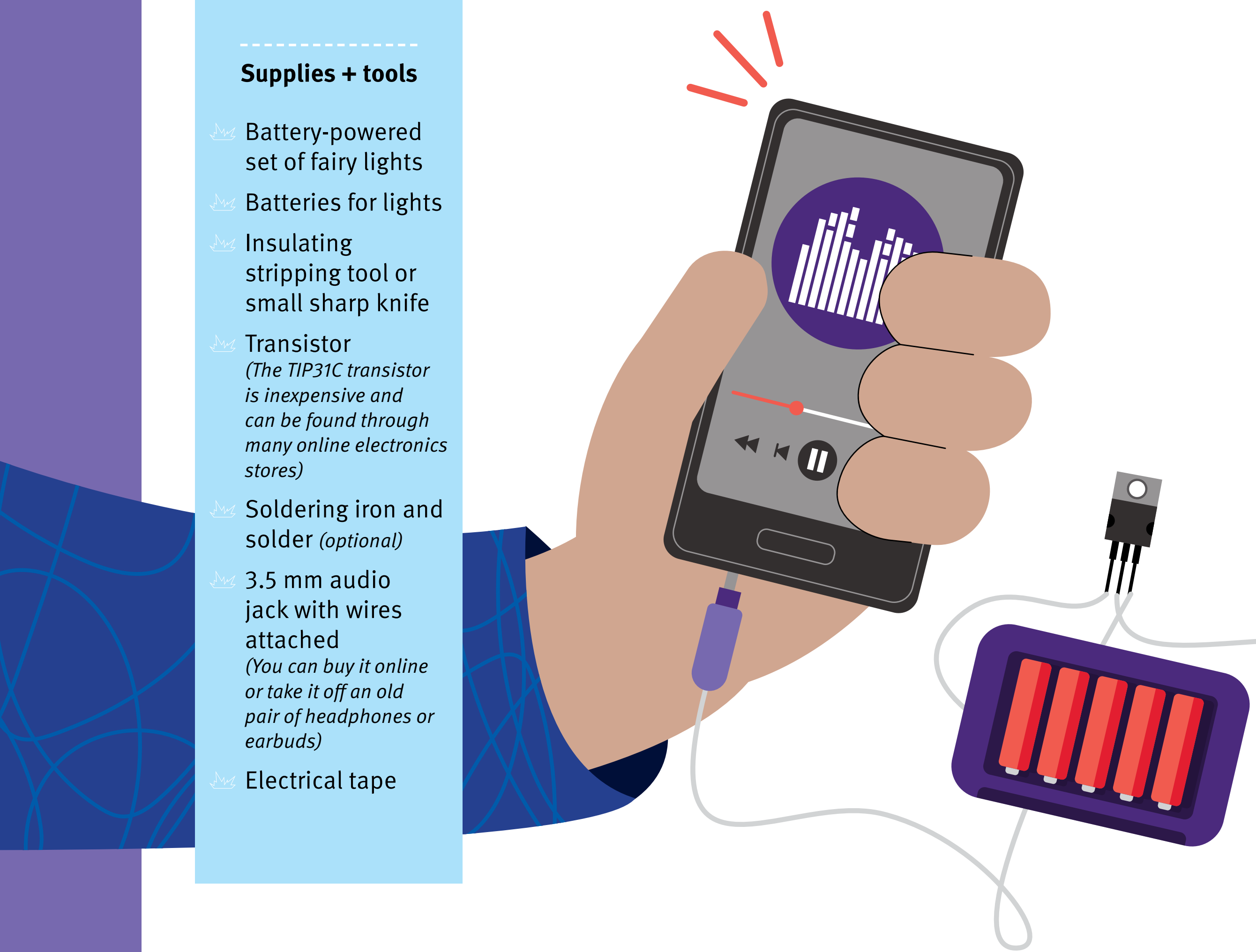
INTERMEDIATE

45 MINUTES TO AN HOUR

Supplies + tools

- Battery-powered set of fairy lights
- Batteries for lights
- Insulating stripping tool or small sharp knife
- Transistor *(The TIP31C transistor is inexpensive and can be found through many online electronics stores)*
- Soldering iron and solder *(optional)*
- 3.5 mm audio jack with wires attached *(You can buy it online or take it off an old pair of headphones or earbuds)*
- Electrical tape

→ Get your dance on with this simple electronics project which makes a set of fairy lights pulse in time to music. Its most important component is a transistor, a device that allows a small electrical signal to control a more powerful electrical circuit. In this case, the transistor makes it possible to use a small audio signal that would normally go to a speaker or headphones to control the light circuit.



01 Remove the batteries from your set of lights. Identify the negative or ground wire on the lights. The easiest way to do this is to open the battery pack and follow the wire that goes to the negative (–) terminal.

02 Separate the negative wire from the other wires so that you have plenty of slack to position the transistor and audio jack.

03 Cut the negative wire so that there are two loose ends with sufficient slack to make connections. Strip 1 cm of insulation off both loose ends of the negative wire.

04 Connect the negative wire coming from the lights to the collector of the transistor. For the TIPC31C, the collector is the middle leg (the data sheet that comes with the transistor can help you find the middle leg). If you have a soldering iron, carefully solder the wire to the collector. If not, wrap the wire around the leg and tape in place.

05 Connect the ground wire coming from the battery pack to the emitter of the transistor. For the TIPC31C, this is the right-hand leg if the side with writing is facing you and the legs are pointing downward. You can wrap the wire around the leg but don't tape it yet.

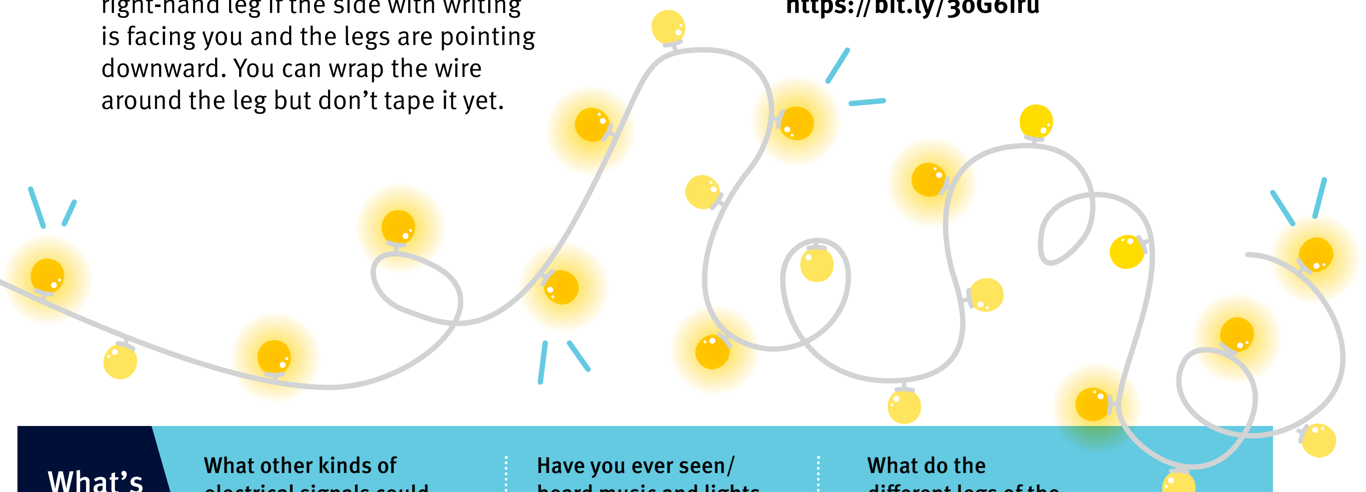
06 Connect the stripped ground wire of the audio jack to the transistor emitter (right-hand leg). If your audio jack is not wired, the ground for that wire is usually the section closest to the base. Now tape the audio jack ground wire and the battery pack ground wire to the transistor right-hand leg.

07 Connect the positive wire of the audio jack to the remaining (left) leg of the transistor and tape to hold in place. If you have a wired jack with more than two wires (for the left and right speakers), either wire works fine.

08 Insulate any remaining exposed wire by wrapping it with tape. Secure the transistor so the connections can't fall loose. Taping it to the battery pack works well.

09 Insert your light batteries. Plug in your audio jack to a music source and play some music to see your lights blink to the beat.

Watch the online tutorial: **https://bit.ly/3oG6iru**



What's next?

- What other kinds of electrical signals could you connect in this way?
- Have you ever seen/heard music and lights connected in this way? Where?
- What do the different legs of the transistor do?

DEVELOPED BY
Jacob

YOU CAN PROGRAMME IT!

Magic plant

INTERMEDIATE–ADVANCED

20

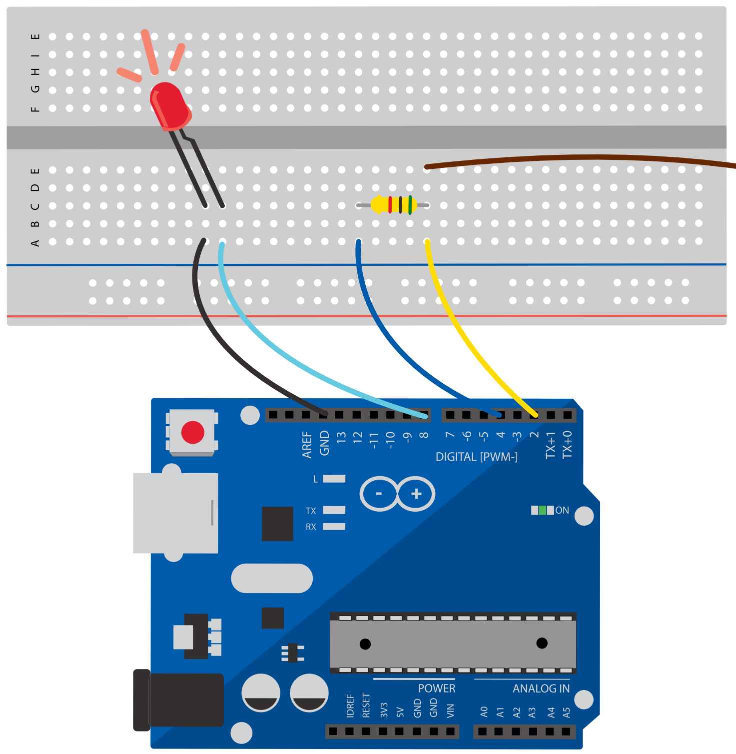
20 MINUTES

Supplies + tools

- LED bulb; common specifications would be 5 mm, 10 mA, 1.9 V
- Breadboard
- 4 short (approximately 15 cm) lengths of insulated wire or breadboard jumper wire
- Arduino microcontroller (Uno or Nano version)
- 1m Ohm (Mega) resistor
- Wire stripper or small pliers
- Strand of single core copper wire (30–50 cm long)
- Any size plant in non-metal pot
- Water

By wiring a living plant to a programmable Arduino microcontroller, you can turn an LED off and on by pinching one of the leaves of the plant or its pot. How do you get a leaf to act like one of the touch sensors on your mobile? It turns out that the water inside a plant is a good conductor of electricity.

The science behind this is the idea of capacitive sensing. The moisture in the soil and the plant body act as a conductor. When we touch the plant, the Arduino now measures the capacitance of the plant and the body together. It is this touch that is perceived by the circuit, which the Arduino can detect and output different commands. In our case, it is to turn the LED on and off.



01 Place the LED into your breadboard. Using one of the jumper wires, connect the longer leg (+) of the LED to pin 8 on the Arduino via the breadboard, the red wire in the diagram.

02 Using another jumper cable or wire, connect the shorter LED leg to GND (ground) on the Arduino via the breadboard, the black wire in the diagram.

03 Using the breadboard, connect one end of the resistor to pin 4 on the Arduino, then connect the other end of the resistor to pin 2.

04 Using the wire stripper, remove about 5 cm of insulation from the wire at both ends.

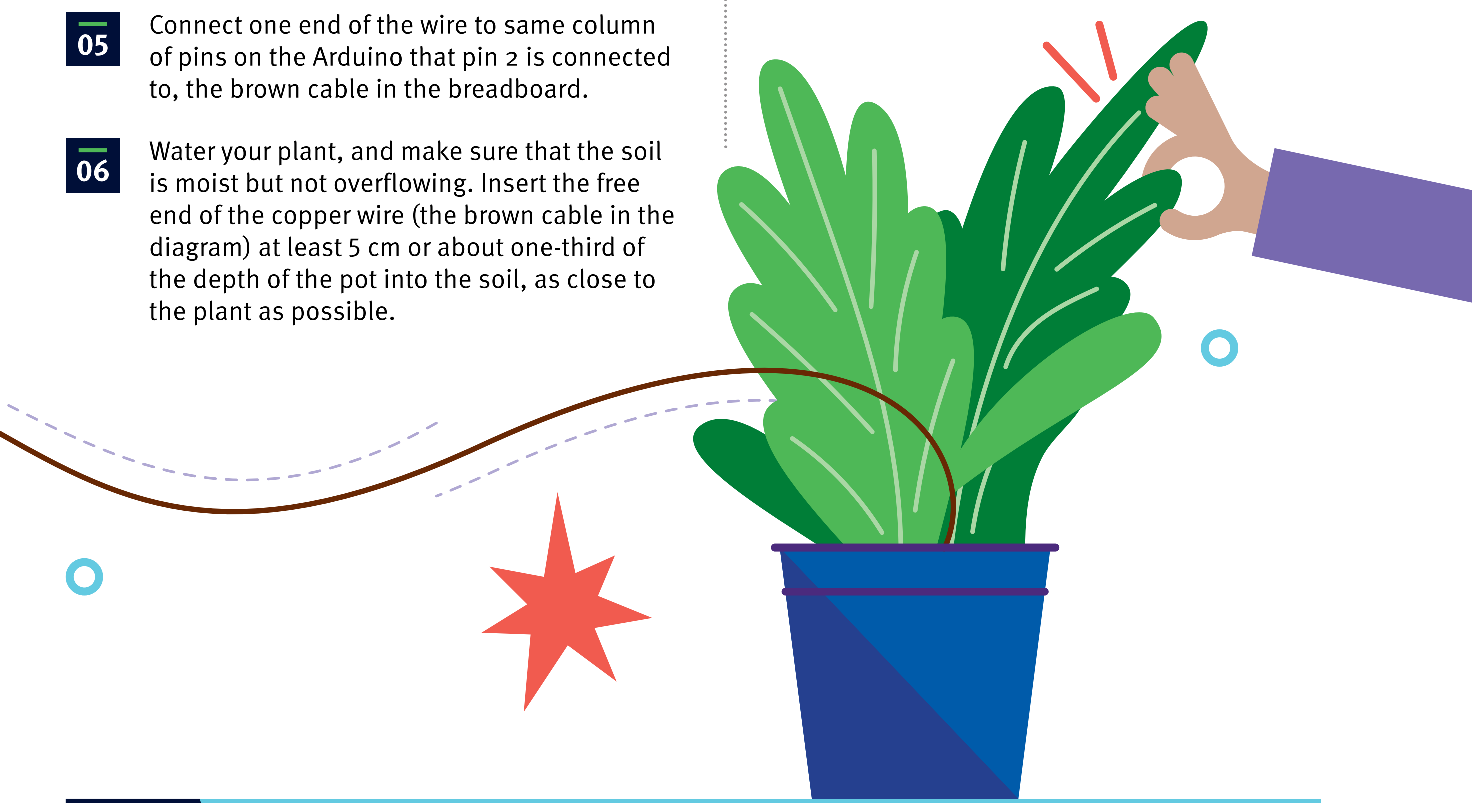
05 Connect one end of the wire to same column of pins on the Arduino that pin 2 is connected to, the brown cable in the breadboard.

06 Water your plant, and make sure that the soil is moist but not overflowing. Insert the free end of the copper wire (the brown cable in the diagram) at least 5 cm or about one-third of the depth of the pot into the soil, as close to the plant as possible.

07 Connect the Arduino to your computer and install the CapacitiveSensor library. Copy and upload the code to the Arduino.

Instructions and CapacitiveSensor code can be found online: **bit.ly/2Xg8fzR**

08 Touch the pot or a leaf on the plant. The LED should light up at your touch.



What's next?

What other types of technology could be operated using touch?

Could you wire a plant so that different leaves control different LEDs?

Do different types of plants or different types of pots work better than others to conduct electricity?

DEVELOPED BY
Oisin

YOU CAN CONCOCT IT!

LED fingertip gloves

Touch your thumb to any finger in these gloves and watch that finger glow by completing an electrical circuit! If the weave on the glove is thin enough, the LED sewn into the thumb can be hidden inside the glove. Then you can make the light look like it is jumping from one hand to the other, you can "pull" it from behind your friend's ear, and perform other classic close-up magic manoeuvres.

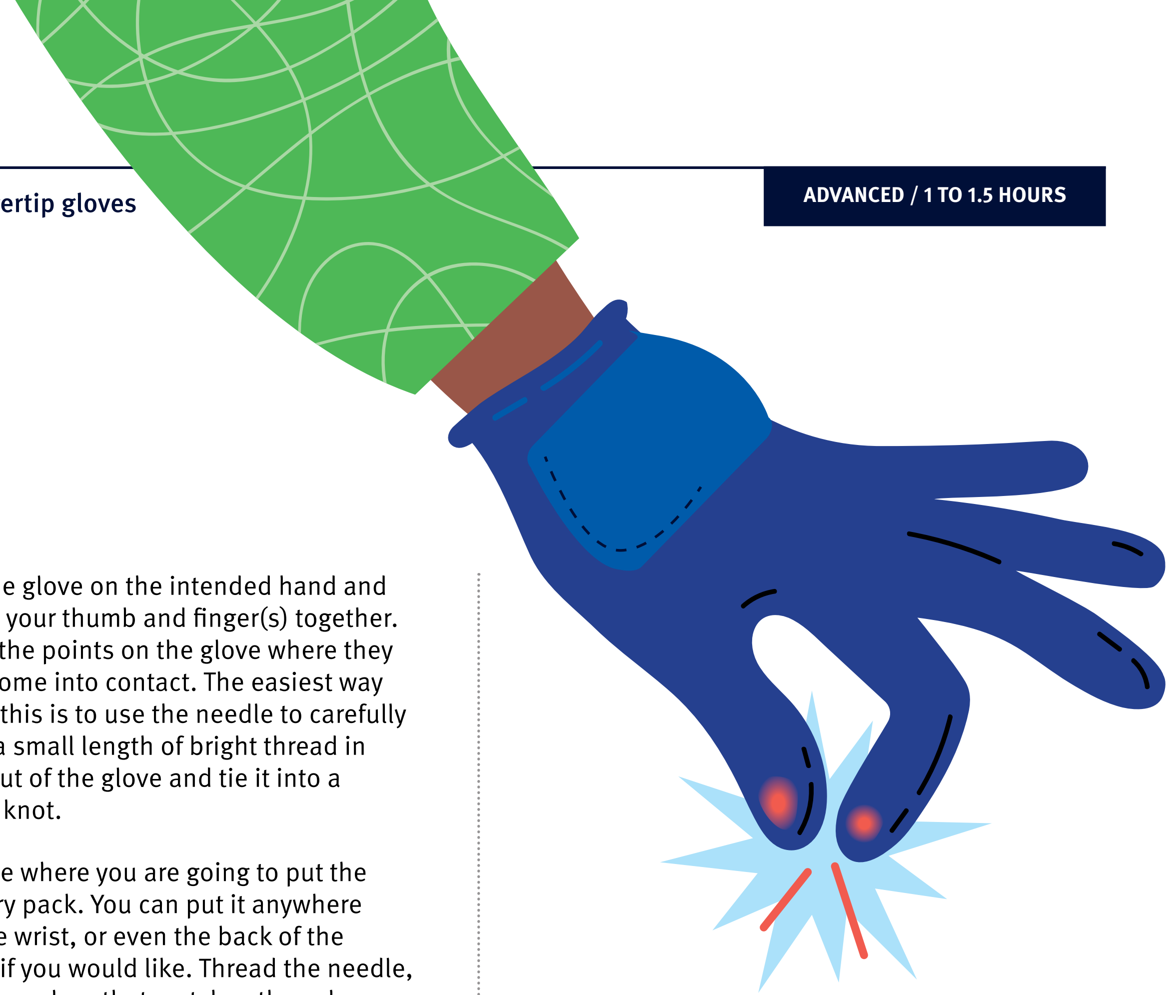
ADVANCED

90

1 TO 1.5 HOURS

Supplies + tools

- Textile glove
- Battery pack with 2 AAA batteries
- Needle, thread, pins
- Scrap of fabric (ideally the same colour as the glove, and at least twice the size of the battery pack)
- Chalk, marker or pen for marking the fabric scrap
- Fabric scissors
- 120 Ohm through-hole resistor
- Soldering iron and solder
- 50 cm of thin wire, preferably multi-core (multi-core wire will last longer in a wearable device like a glove, because it is less prone to break after repeated bending)
- Safety goggles
- Wire snips
- 1 to 4 bare brass domed tack pins (one for each finger you want to light up)
- 1 to 4 LEDs (one for each finger you want to light up)
- Wire stripper



01 Put the glove on the intended hand and touch your thumb and finger(s) together. Mark the points on the glove where they first come into contact. The easiest way to do this is to use the needle to carefully loop a small length of bright thread in and out of the glove and tie it into a small knot.

02 Decide where you are going to put the battery pack. You can put it anywhere on the wrist, or even the back of the hand if you would like. Thread the needle, using a colour that matches the colour of the glove.

03 Place the glove on your work surface, and the battery pack where you would like it on the glove. Lay your scrap of fabric over the battery pack and push it down tightly around all four edges of the pack. You will find that you get a fold of fabric in each corner.

04 Using a pen, marker or chalk, trace along the two long base sides of the battery pack, along the two shorter sides and then vertically up the fabric fold at each corner. You should end up with a rough cross shape if you were to lay the fabric flat.

05 Keep the fabric in place around the battery pack by placing pins at each corner to hold the fold of fabric in place. Carefully remove the battery pack.

06 Sew together the four corner edges you have pinned. These lines of stitches will turn your flat piece of fabric into a rectangular pouch shape.

07 Cut around the edge of the pouch shape you have formed, making sure to leave 10 to 15 mm extra fabric around the lines you have marked for seam allowance. You can also carefully trim off the extra fabric in folded corners that you have sewn, to avoid excess fabric in each corner.

08 Turn the fabric pouch inside out so that your markings and corner seams are on the inside. Place the pouch back on the glove where you would like it and pin in place on three sides. Leave one side open. If you want to create a more professional finish, you can fold a narrow edge of the fabric (10 to 15 mm) under and inside the pouch, so that you have a neat edge to sew along.

If your glove fabric is particularly stretchy, you may want to stretch it slightly before pinning so that it still fits over your hand.

09 Check that the battery pack fits in the pouch as it is pinned in the glove. You want it to be tight enough to be secure, but not so tight that it is too difficult to get it in. Adjust the pins if necessary. Once you are happy the battery pack fits correctly, sew along the three pinned edges of the pouch to attach it to the glove. Remove the pins.

010 Turn the glove inside out. Pinch the fabric around the mark you made on the thumb pad, and push the leg of the 120 Ohm resistor through both layers of fabric. The main body of the resistor should be on the inside of the glove, and a short section (around 5–10 mm) at the end of the leg should be poking out of the glove where you have marked.

11 Once you are happy with the placement of the leg, push it all the way through the glove so that the end is as far away from the fabric as possible. Place a small blob of solder on the end of the leg – make sure to not burn the fabric! Give the solder a few minutes to cool, then pull the leg back to its original position. The solder should help keep it in place, and stop it pulling out of the fabric. If you need to, you can also stitch a few loops of thread through the glove and around the soldered end of the resistor leg to make it more secure. The resistor should run along the inside of the thumb, towards the wrist.

12 Put the battery holder in its pouch, and poke its leads though the glove, so they are on the inside. Stretch the black lead towards the resistor. If it is long enough, you can strip the end (about 5 mm) and solder it directly to the free end of the resistor. If not, add some wire to the end of it to make the two meet. You want there to be plenty of slack, so that it doesn't inhibit normal hand movements or pull taut, but not so much that you have a big loop of wire that might poke out unnecessarily. Remember to hold everything away from any fabric when you are soldering so you don't burn it, and to let it cool before you touch it or let it relax back to the fabric.

13 Once you are happy with where the resistor should sit, and the connection to the battery pack, you can hold the components in place with a few loops of stitching around the wires to guide them where you want them to sit. Leave a little room around bulges in the wire (like the resistor body and the solder joint) so that they can move a little bit as the glove moves with your hand.

14 Solder as short a length as you can safely hold, as long as it's longer than 25 mm, of wire onto the base of a brass tack. Try to use as little solder as possible and solder down low against the tack, as you want this to sit comfortably against your finger. Snip off the spike on the tack so that you are left with a brass dome with a wire coming from its inside centre. Be sure to smooth down any sharp edges inside with the wire snips.

15 Turn the glove right side out. Push the wire coming from the tack through a marking you have made on any flat, fingertip surface on the glove that you would like to light up (except the thumb, where the resistor is located) The brass tack dome should be on the outside of the glove, and the wire should be on the inside.

16 Push both legs of an LED through the very end of the glove's finger where you have placed the tack, so that the LED points in the same direction as the finger when straight. Bend the legs slightly, so that the LED doesn't fall out. Turn the glove inside out.

17 Pull the LED legs all the way through the glove material. Bend the negative LED leg (the shorter of the two legs) down toward the brass dome. Bend the positive leg up toward the fingernail. This will hold it in place against the glove fingertip.

18 Pull the wire from the brass dome as far as possible through the glove material. Cut this wire to be about 25 mm and strip approximately 5 mm of the end with the wire snips. Carefully solder this stripped end to the negative LED leg, about 10 mm from the glove. Snip off the excess LED leg. Be careful not to burn the glove, and let everything cool before you touch it!

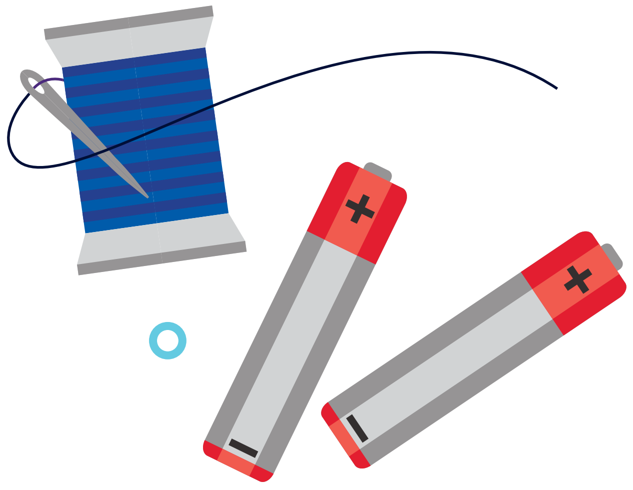
19 Use a piece of wire that is long enough to run comfortably from the LED to the battery pack on the wrist. Solder this wire onto the positive LED leg, around 10 mm from the glove. Snip off the remaining LED leg.

20 Once everything is cool, carefully put on the glove to test how everything sits. Bend the LED legs as you need to for it to sit well. Run the long wire soldered to the LED positive leg back to the battery pack. You can sew small loops around the wires and LED legs where necessary to hold them in place. They should be free to move so that they aren't pulled tight when you move your hand inside the glove, but held tight enough against the fabric so that the glove can be pulled on and off without snagging the wires and legs.

21 Repeat Steps 12–18 for all other fingers on the glove that you would like to light up. Just be sure that all the wires from the positive LED legs can meet the positive wire of the battery pack in the same place. Once you have mounted all the LED fingers, solder all of the wires coming from the positive LED legs to the positive wire (the red wire) of the battery pack.

22 Put two AAA batteries into the battery pack. Touch any LED-equipped finger to your thumb. The LED should light up!

Watch the online tutorial:
https://bit.ly/30G6iru



What's next?

- Could you build a lamp that lights up when you touch it, using these materials?
- How would you change this project to make a glove with fingertips that buzz or chime when touched?
- Could you use these same materials to create an alarm or flashing light that turns off when you break the circuit?

DEVELOPED BY
Alex

YOU CAN BUILD IT!

Skateboard from a pallet

→ This project is a good introduction to ramping up your woodworking tools and skills. If you have a well-equipped makerspace, building your skateboard this way can be inexpensive, and you'll have an awesome personal final product that's actually useful.

ADVANCED

120

2+ HOURS

Time will vary depending on time needed for glue to dry.

Supplies + tools

- Crowbar or claw hammer
- Pallet wood
- Paper and pencil
- Tape measure or ruler
- Sanding sponges or right-angled sanding block
- Wood glue
- At least 2–3 quick grip trigger clamps
- Hand saw, coping saw, circular saw or jigsaw (all saws should be used with caution, but circular saws and jigsaws require special instruction and/or supervision to operate)
- Wood rasp
- Spray paint
- Outdoor water-based wood varnish
- Paintbrush for varnish
- Grip tape or anti-slip deck spray
- Electric drill and ¼ inch or 7 mm drill bit
- Countersink drill bit; standard 45-degree countersink will work well
- 2 trucks and wheel sets from old skateboard

01 Using the crowbar or claw hammer, pry apart the pallet into separate wood planks and remove any nails from the planks. How many planks you'll need depends on the size of your board. For instance, I built one using two planks. Be sure to choose planks that are free of rot and cracks.

02 Draw or print out a stencil on paper that is the length, width and shape that you want for your skateboard deck. You can find some standard stencil designs online or draw a stencil with your own ideal shape and style.

The longer the distance between each pair of wheels, the more flexible and unstable your skateboard will be.

03 Measure your pallet planks to see if your stencil will fit entirely on one plank. If not, you will need to glue more than one plank together. This is called a blank.

04 Choose the planks you will be joining, and make sure that the edges you will be gluing together are as straight and smooth as possible. You can do this by sanding the edges with sanding sponges or a right-angled sanding block.

05 Apply wood glue to both sanded plank edges. Hold the glued edges together by clamping the planks with quick grip trigger clamps, making sure to keep them aligned. Place the clamps regularly along the length of the planks to evenly distribute pressure. The more clamps the better, but 2–3 will be fine! The glue bottle should tell you its drying time, but overnight is usually a good time to leave it.

06 Using your stencil as a guide, trace the outline of your skateboard deck on the blank. Your stencil may have marks to show where the holes needed to attach the trucks will go. If possible, the trucks should be screwed in on both sides of a join line, which will make the joint between the planks stronger.

07 Clamp your blank to a table or other board to hold it securely. Using one of the saws listed above, roughly cut out your skateboard deck. Don't worry about being too precise here. The aim is to hack off most of the wood to save yourself work later.

08 Use a wood rasp to shave away wood around the edges of the deck until it is the desired shape. You may also want to use the rasp to shave away some wood on the bottom of the board along its outside edges. This can prevent the wheels from hitting wood when turning sharply. Be sure to keep the wood flat where the trucks will attach.

09 A kicktail is an angled part of the skateboard at the rear of the deck that makes it easier to pivot and do tricks on the board. If you would like a kicktail on your board, you can hand saw a small block (the same width as the board and roughly 1/5 the length) at an angle of roughly 20 degrees. Then glue it on top of the tail end of the deck. (After the glue has dried, use the rasp to refine the kicktail shape on the bottom of the board.

10 Use spray paint to decorate your deck in any way you like. After the paint has dried, brush on two layers of wood varnish to protect the design and the wood from water.

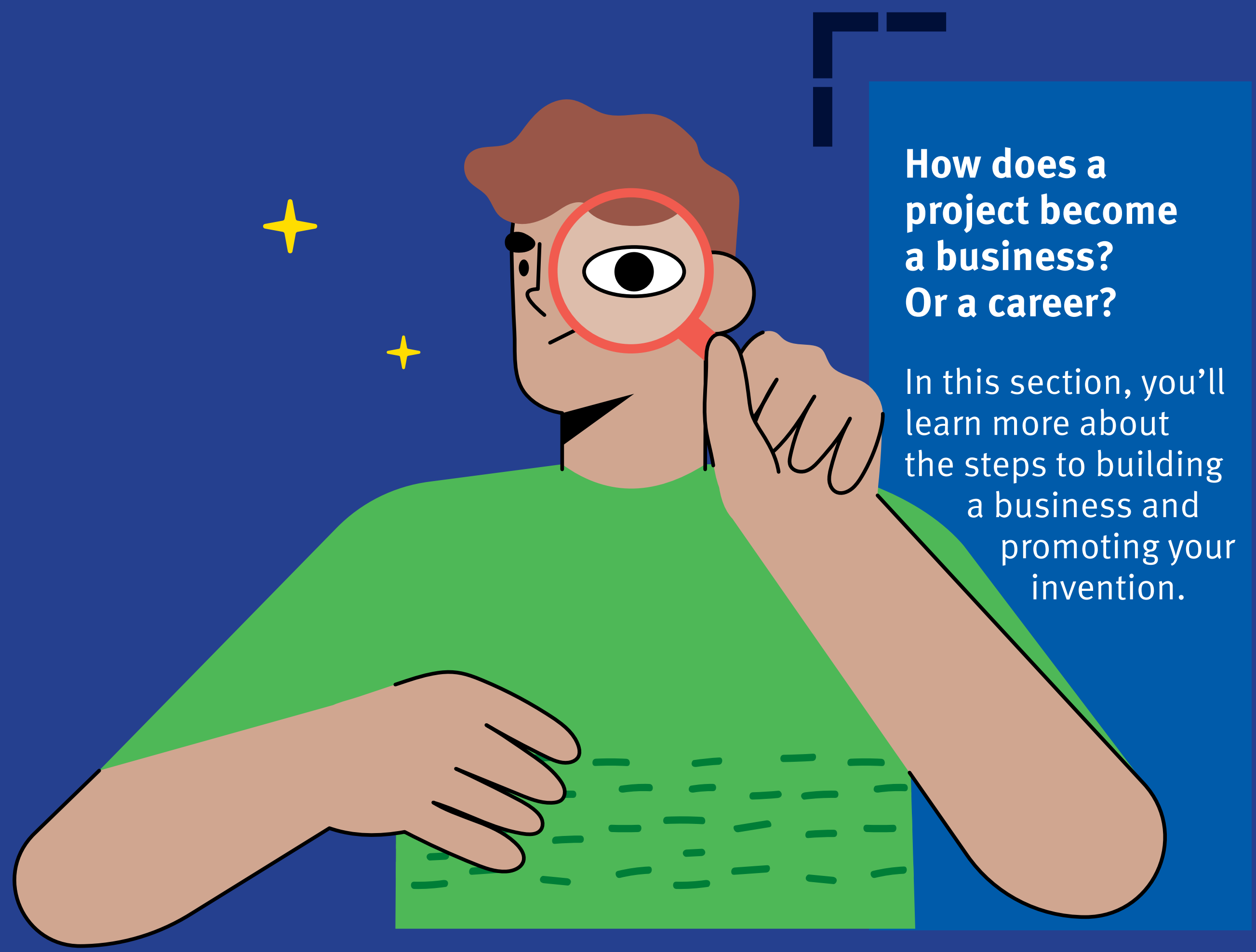
11 Apply strips of grip tape to the top of the deck to make it less slippery for riding. If you don't want to cover your design with tape, you can spray on a coat of anti-slip deck spray instead, but you will have to reapply spray as it wears away.

12 Using a countersink drill bit, drill holes into the bottom of the deck in the places indicated by your stencil. Use the bolts that came with your trucks to attach them to the deck.

What's next?

- Is wood really the best material for a skateboard deck? What other kinds of materials could you use?
- Can you do different tricks on a long skateboard deck compared to a short deck? If so, why?
- How much does the shape of a skateboard affect its speed?

Constructing your future

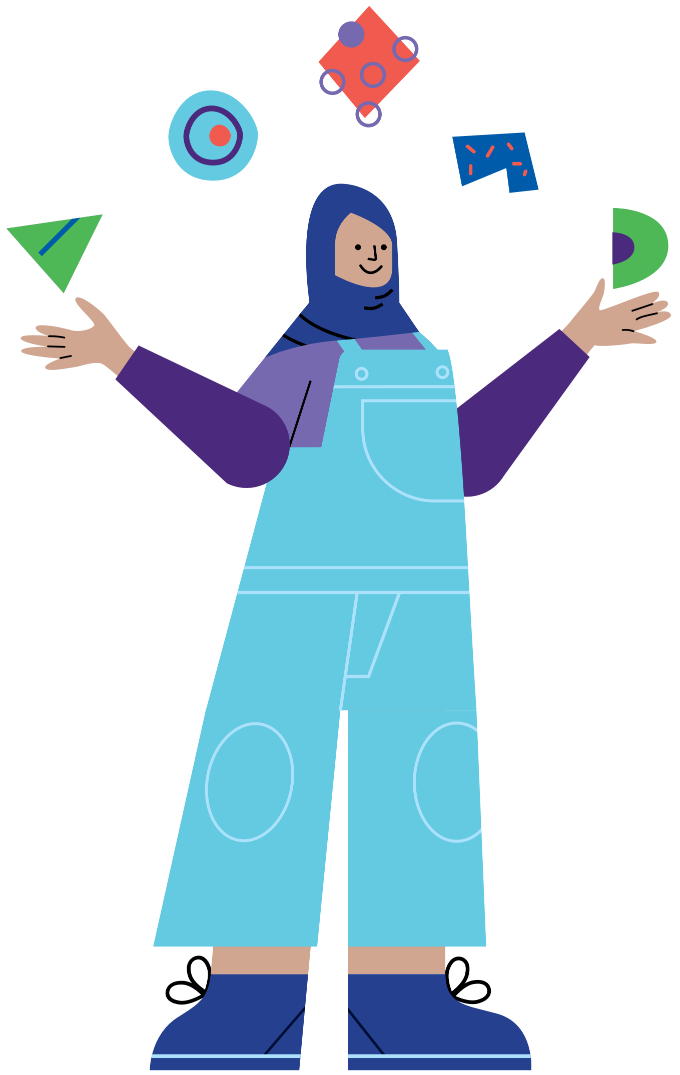


How does a project become a business? Or a career?

In this section, you'll learn more about the steps to building a business and promoting your invention.

Cultivating creativity

→ You're either born creative or not, right? Wrong. Creativity is a skill that can be cultivated and improved just like playing the piano or speaking French. What does it mean to be creative? If something is creative, it must be both novel and useful. Using a paper clip to secure paper may be appropriate but it's unoriginal. However, using a paper clip to de-stone cherries is both novel and useful.



Creativity is not static. Taking a walk through nature, sleeping on an idea, practising mindfulness, and being happy all boost your creativity. Diversity – not just in race, gender, or age, but also in personalities, beliefs, and cultures – improves creative thinking and novel idea generation. Working together can enhance creative flow; 'stacking' or 'snowballing' ideas leads to a creative burst of new innovative ideas. Satirical comedy shows like *Rick and Morty* rely on such creative bursts in the writer's room. No idea is shut down – instead, the next person adds to or builds off the previous comment. Disney similarly favours the "yes and…" or "yes if…" approach to fuel such creative thinking.

Psychologists have found that creative people are great at cognitive disinhibition. This essentially means the mental filters we all have that screen the stream of data our brains receive daily are suppressed. Just like an umbrella stops the rain from getting you wet, cognitive filters stop irrelevant or superfluous information from our environment from overloading your brain.

However, creative thinkers have access to huge amounts of disconnected information. Their lack of a filter means they can connect divergent ideas, and thoughts flow more freely without limitations. It's why creative thinkers like Einstein or Newton are often viewed as the eccentric creative genius type – all that information can result in slightly odd behaviours. For instance, Charles Dickens used to fend off imaginary urchins with his umbrella while walking down London's streets.

You may not naturally have cognitive disinhibition like Dickens or Einstein, but you can actively turn off your inner self-critic. Embracing any and all ideas generated with positivity and acceptance will undoubtedly lead to more fruitful and creative outcomes. Creativity can be cultivated by embracing new experiences, harnessing the power of play, tapping into your curious self, and questioning the status quo.

Working creative thinking into daily life boosts mood and mental health and improves brain function. Something as simple as a mindfulness colouring exercise can ward off stress and anxiety and spark new neural pathways critical for learning.

The power of play

Play is an easy way to foster creativity and boost creative problem-solving. Educational psychologists have long known that young children learn essential skills in the playground. In childhood, play is everywhere. But in adolescence and adulthood, the playtime stops. We no longer engage in imaginative play and instead favour a systematic approach to work. We stop playing games and instead write essays.

This is a huge oversight. There are tangible and lasting benefits of using play as we get older. When we play, our stress levels are lowered, our bodies flood with feel-good endorphins, our brain function improves and we feel more connected socially. Cognitive function and memory recall improve, and social connectedness is enriched.

Tech giants like Google and Microsoft have mastered the power of play in the workplace: art and yoga classes, game rooms, a Lego play station, indoor ladders and slides resembling a snakes and ladders game come to life, secret reading rooms are hidden behind bookcases, and jungle-themed conference rooms are all commonplace. But these are not just fun quirks of the office. Playful workplace layouts have been shown to boost productivity and creativity.

The explosion of the maker movement also shows that play is making a comeback in a big way. With the emergence of makerspaces and Fab Labs all over the world, tinkering is finally being considered a serious form of play. Makerspaces offer a space for open exploration where failure and mistakes are encouraged. This is good news, since even a short amount of play is shown to have lasting cognitive and creative benefits.

Staying curious

The average four-year-old asks between 100 and 300 questions a day. Children are boundless and persistent in their curiosity, naturally investigating and exploring their environment through discovery learning. Channelling this explorer mindset and staying curious goes hand in hand with creativity. When we're more curious, we gather more information and can link disparate ideas together, all of which lead to unique and creative ideas.

As adults, we can become preoccupied with our fear of failure or embarrassment at getting something wrong, and this stunts our creativity. A four-year-old will throw themselves into new experiences but adults tend to shy away from unknown challenges.

> "Staying curious means embracing the inventor mindset."

So how can we stay curious? Question, question, question! Ask "Why?", "What if…?", "When?", and "How?". Use disruptive thinking to challenge the status quo, like Netflix ("What if people didn't have to go to the cinema to watch movies?") or Airbnb ("What if people didn't stay in hotels on holiday?").

Staying curious means embracing the inventor mindset; so throw yourself into new experiences and challenges, be inquisitive, tinker and test solutions, and most importantly, fail fast and fail early. When in doubt, think like a four-year-old!

REBECCA SWEENEY *is the Reach Out Makerspace Assistant for Schools Outreach who enjoys helping others find creative ways to tap into their inner maker.*

Kick-start creative thinking

Dictionary story

Pick four random words from the dictionary. Use the words to create an interesting, cohesive story. This will improve your ability to make connections and combine ideas that don't necessarily relate.

Improve a product

List as many ways as you can to change a product to make it more useful or desirable. For instance, change a toy to make it more fun for children to play with.

30 circles challenge

On a sheet with thirty blank circles, using a pencil turn as many circles as you can into recognisable objects in 3 minutes. How many did you complete? Were your ideas unoriginal (like a football) or unique (like an igloo)? Did you combine circles or did you stick to the assumed rules?

Flip the challenge

Reword a problem to reverse the question it asks, then brain-storm solutions to that instead. For instance, "How can I be more creative?" will be "How do I stop being creative?"

Alternative uses task

Think of as many uses as you can for a chair, brick, paper clip, ping pong ball, or shoe.

Get visual

Use building blocks or modelling clay to create a visual model of a topic, case study, or problem at hand. For instance, map the body or brain using construction blocks.

Get random

Design challenge generators provide endless randomised prompts to practise honing creativity skills. Here are some of our favourites to get you started:

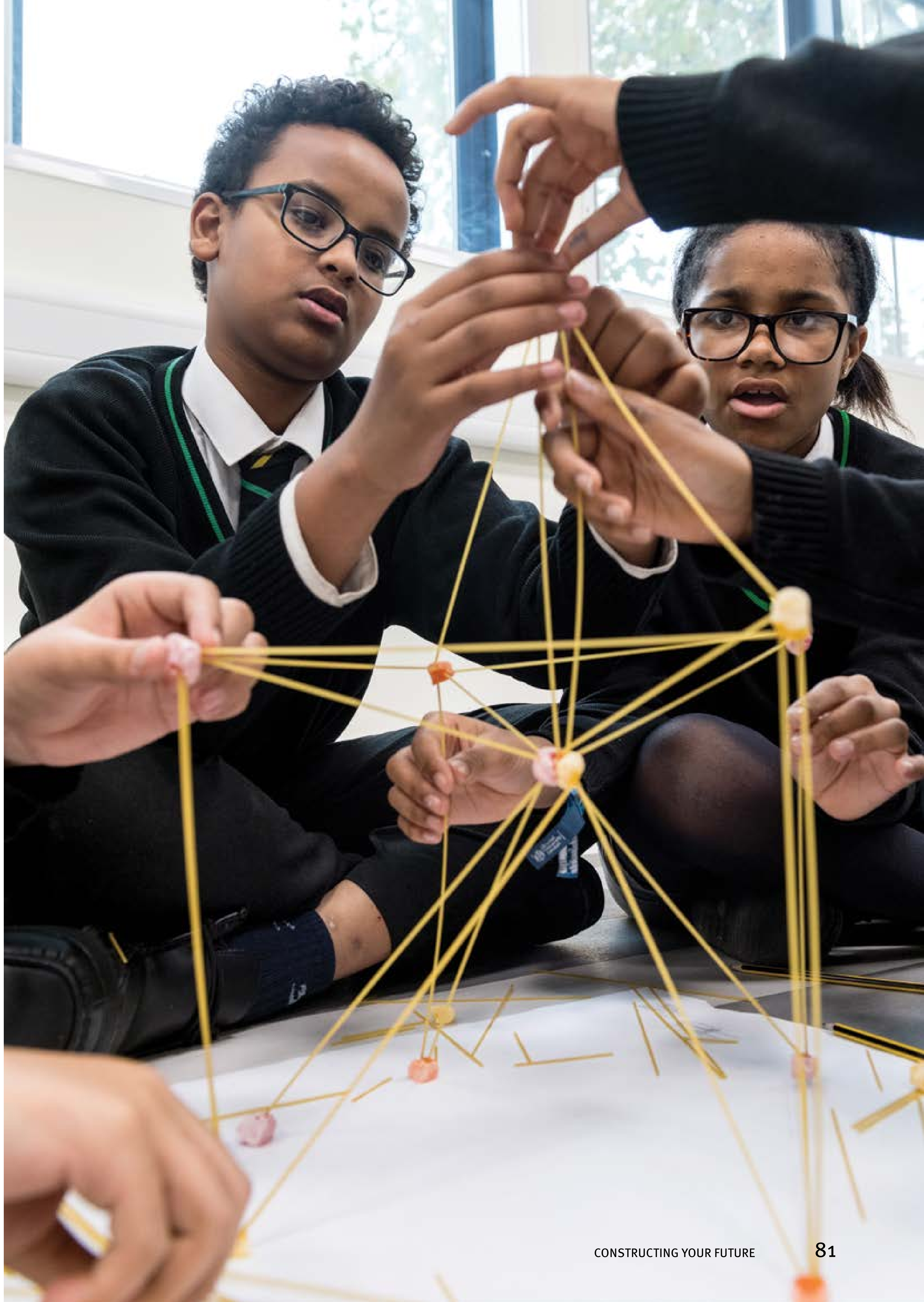
www.sharpen.design

whatshouldidesign.com

briefz.biz

Do nothing!

Scheduling time to simply do nothing and daydream is a sure-fire way to get your creative juices flowing. Letting the mind wander while doing something relaxing creates the mental space needed for ideas to surface.



Starting your own business

→ Growing up in London, I've always wanted to start my own business, but didn't know how or where to start. If you're reading this guide you might relate to that. Maybe it's something you created in a workshop like the Makerspace, or perhaps you have a skill you want to share. This will show you how you can turn your next great idea into a business.

I made a few mistakes starting a business, but I also learnt a few tips and tricks along the way – which is what this guide is all about. I'll show you how to design a company logo, how to think about costs, and how to build a website.

Calculating costs

You have a great idea and you want to launch a business. Imagine you went straight ahead and took out a business loan, rented an office, hired staff, and jumped straight in. Do you think your business would be a success? Probably not.

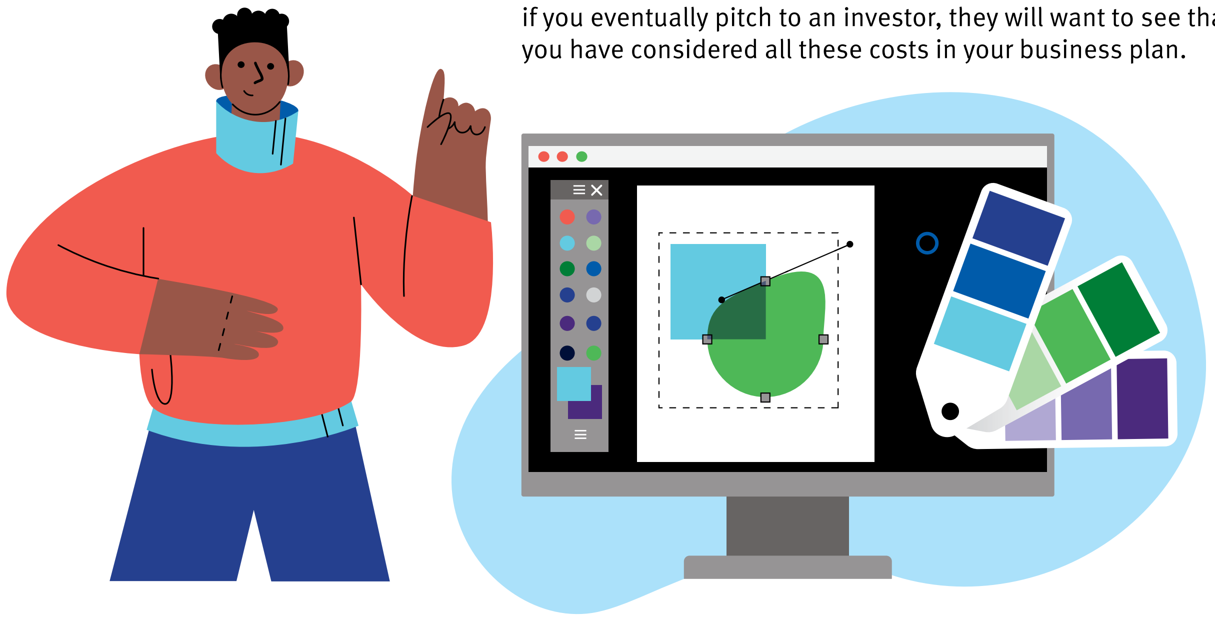
One of the key factors in creating a successful business is making sure that your business is making money. The money you earn should be more than the money you spend on materials, staff time, premises, and branding. Calculating the cost of producing your product is important if you want to see how viable your new idea might be.

When you are calculating how much to charge for a product you have made, there are lots of hidden costs. You need to calculate how much it costs to produce the item, to make sure that you are charging consumers the correct amount. You might find that you need to charge more than people are willing to pay and therefore that your idea might need adjusting.

A basic way to calculate product costs looks a little like this:

1. List all materials
2. Estimate amount of material per product
3. Find prices for these materials from reputable sources
4. Calculate the price per material (cost × quantity)
5. Calculate total price

When you establish your business plan, consider costs such as renting an office, paying insurance, paying staff, transportation, and promotion costs. If you need to apply for a business loan or if you eventually pitch to an investor, they will want to see that you have considered all these costs in your business plan.



Defining your brand

In business, branding is extremely important. Think of how you can almost taste the Cadbury's logo or smell the Subway logo. Consider the iconic giant M of the McDonald's 'golden arches'.

Branding plays a key role in attracting customers to your product. You want it to convey the qualities you are offering with your product as well as attracting new consumers. Companies like Coca-Cola, Apple and Nike spend a lot of time and money perfecting their brands, considering colours and fonts. Our brains associate colours with emotions and memories to the point of familiarity. For example, we often associate the colour green with health or the environment, red with importance, and black with elegance. When you are creating a logo for your business think carefully about the colours and symbols you choose. You need to make sure that these correctly convey the image of your brand.

Logos are important when branding your business, but today more than ever brands are also built on name and reputation. This is where your personal brand comes in. A personal brand is how you promote yourself, as the founder of a product. It's made up of your skills, experiences, and personality. A good personal brand captures what makes you different to help you build a reputation. Many businesses use social media platforms such as YouTube or Instagram to promote their brand. This can also include the personal brand of the creator or founder. This is particularly true of new start-ups. Olajide Olatunji, Elon Musk, and Billie Eilish have all used their personal brand to sell a product or service.

To establish a brand, you will need:

- **Business name:** Business names sometimes indicate the type of products or services you are selling.
- **Business slogan:** *Just Do It. Eat Fresh. Taste the Rainbow.* All great slogans – can you come up with something greater? Your slogan should convey the spirit of your business.
- **Product names:** These should differentiate between products and are different from the business name. For example, the business name is Apple while the product name is iPhone.
- **Brand colours:** Think of what kind of image you are trying to achieve with your colours. Are you looking to be cool and hip or perhaps more professional? It all depends on your brand image and your target audience.
- **Company logo:** You can use a free online resource like Wix Logo Creator to make your logo or create one yourself.

Building a website

Here's the fun bit that will get your creative juices flowing – website making! At sites such as www.wix.com, you can select a business type and let them create a website for you. Remember to keep any phone numbers, addresses, or full names private until you decide to publish any of this information on your business website.

You will need the following pages, but feel free to cut or add any further pages you think need to be included:

- **Home:** This is the first page your website visitors will see and should be set up as a launchpad into the site. On it, provide brief information about what you do so that visitors know they are in the right place, but don't feel like you have to include every detail about your company.
- **About us:** Information about you and your team, who are you, what motivates you, and why your customers should invest their money into your product and you. It's a real chance to sell yourself. The key to this section is to be authentic.
- **Products:** Tell your customers everything they need to know about prices, specifications, materials, colours, and availability.
- **Sustainability:** Discusses the impact of your company and products on the environment, its impact on the local community, and whether you use local labour and materials.

KYRILLOS SIDAROUS *works in the nuclear engineering field and is passionate about all things STEM and business related.*

How to pitch a start-up idea

→ What do you think when you hear the term 'start-up'? Silicon Valley, tech companies, Steve Jobs, and Google may be a few words that pop into your head. A start-up is just another name for a newly established business. Building a start-up is difficult to say the least, requiring careful research into product market fit, problem-solving, and business structure. Learning how to do that properly is a lifelong journey.

The story behind a pitch

One important element of creating a start-up is pitching or formally presenting your idea to future clients, customers, or investors. Grasping the philosophy of a start-up pitch is a great introduction to the type of strategic thinking required in entrepreneurship. In other words, a good pitch is a crucial step in convincing investors, potential customers, and the market that your start-up is a worthy idea.

After working with Apple, IDEO, and various early-stage start-ups, I've adopted a way of thinking about pitching projects and start-ups that helps me tell a compelling story. Essentially, a good pitch tells a story that incites action.

Getting started

Let's say you are telling the story of 'Bobbette', who needs to climb a mountain. There is a long and difficult journey up the mountain, on top of which she will see this amazing life-changing view. In typical school projects, we're used to walking through the story of how we made the project step by step. First, we have Bobbette (you). Then she goes on the difficult journey (the work you did on your project so far). Finally, she got to the top of the mountain (final result of the project). And that's where Bobbette saw the amazing view (the potential significance and impact of your project).

Using these steps, your pitch for the design of electric toothbrush might look like this: I'm a design engineer. I began building toothbrush prototypes with regular toothbrushes that vibrated. I tested them to see which worked best. Finally, I made an electric toothbrush that cleaned off most of the plaque. This electric toothbrush can clean plaque better than regular toothbrushes, saving trips to the dentist.

Quick story fix

See how that step-by-step flow can feel stagnant? There's no build-up of anticipation. As the listener, you're not necessarily inspired to action by that narrative. After all, it seems like a lot of work and the significance of it wasn't clear from the beginning.

The crazily simple fix to that flow is to start at the very last part – the view (significance and impact) of your start-up or project – then circle back. For example, Bobbette hears of this amazing view on top of the mountain (final result and significance/importance of this work). That's why she began this journey (the work/progress on the project). The journey led her to the top of the mountain, where she finally saw the view (tie back to original significance.)

Let's put this new narrative in terms of the electric toothbrush: I'm a design engineer. I had an idea to create an amazing vibrating electric toothbrush that can keep your teeth cleaner, saving trips to the dentist. I began building toothbrush prototypes with regular toothbrushes that vibrated. I tested them to see which worked best. Finally, I found an electric toothbrush that cleaned off most of the plaque. This electric toothbrush can clean plaque better than regular toothbrushes, keeping your teeth cleaner than ever.

> "A good pitch is a crucial step in convincing investors, potential customers, and the market that your start-up is a worthy idea."

Of course, this formula needs to be adjusted based on who you're speaking to and the contents of your project. Has there been a start-up or product idea you've been thinking of or working on? Next time you pitch it to your teacher, friends, or potential investors, try out this way of presenting your idea.

JOY ZHANG *is designer, engineer, and entrepreneur who is excited about bridging the technical and the creative in critical design and social entrepreneurship.*

Delivering a presentation

→ Delivering presentations is something you will probably have to do many times during your education and working life. While for most people this can be a scary and unpleasant task, with a little practice it's something everyone can enjoy. Whether you have an argument you want to state, an idea that you want to pitch, or a story you want to explain, presenting is basically just speaking to someone. This simple act is something we do hundreds of times a day, every day, easily and confidently. So why then is it more stressful when we're asked to do it in front of strangers at an interview or in front of judges at a competition or in front of the class at school?

Focus on the action, not the context

Think of a football player lining up to kick a penalty in the World Cup final, or Roger Federer standing at the back of the tennis court at Wimbledon. They each need to hit a ball in a very specific and accurate way while being watched by millions of sets of eyes. How is it that athletes such as Federer don't fall apart when they are weighed down with such pressure?

They sometimes do, and many of them take advantage of sport psychologists to help them cope with this pressure. One of the things psychologists work on with athletes is context.

Let's go back to Federer standing on the baseline at Wimbledon. One way of looking at what he needs to do is to strip it back to a simple act. What Federer needs to do is to hit a ball perfectly while millions of people watch. But fundamentally, all that Federer really needs to do is hit a ball. If he was in his back garden playing tennis with his friend and he really wanted to win, the action of hitting the ball would be identical. He still needs to move his arms in the same way, he needs to move his body in the same way.

The only difference is what is going on around him – the context. If he can focus on the actions he needs to do, then the action itself becomes simple. He focuses on hitting the ball – something he knows how to do – instead of focusing on not failing in front of all those people on such a big stage.

When giving your presentation, the key is to focus on this specific act: *my job is to tell someone something*. If you start getting stressed, focus again on the simple action you need to do. Don't focus on the potential outcomes or what this may mean for you.

You can try out this idea on exams. During exams it is easy for 'what-ifs' to start creeping into your brain, distracting you and causing stress. Writing answers in an exam is not that different from completing an assignment in class or doing your homework. The only difference is context. The next time you find your mind wandering in an exam, focus on the action you need to do, which is writing the answers.

Plan and practice

Thinking back to Federer at Wimbledon, he is not trying to hit a ball in front of people for the first time. He is doing something that he has practised many times. To stay calm and ignore the context, you need an action that is simple for you. You need to be confident about what it is you are going to say. The best way to do this is to plan the content of your presentation and practise it.

Make sure what you are saying is clear and simple. You can use notes, cue cards, or slides, but don't write out word for word what you're going to say. Write a few key words or prompts to remind yourself of the main points. That way if you go off-topic, you can still make sure to make your most important points.

> "The more presentations you give, the less scary they become."

The best way to become less anxious about giving presentations is to give more presentations. The more presentations you give, the less scary they become. Soon you will find that there isn't much difference between presenting to a group of ten people or a group of 200 people. It all goes back to that simple action – saying something to somebody.

KATE MULCAHY *is the Makerspace Programmes Manager as well as a maker, tinkerer, science presenter, and passionate believer in the power of creativity who is always looking to inspire new makers.*

Be a speaking superhero

One of the easiest ways to tell that someone is nervous while presenting is by looking at their stance. Humans can understand a huge amount about each other without speaking, just by reading each other's body language. If a speaker is uncomfortable or nervous, their body language could make their audience members nervous too.

We know that mood and emotion can affect body language, but did you know it can also work the other way around? Scientists recently discovered that people practising the 'superhero stance' in front of a mirror – chest out, hand on hips, head up – could improve their confidence and mood. Before a big interview, presentation, or exam, find somewhere where no one will see you and try practising some silly superhero poses.

When you're giving your presentation, try four tips:

1. Stand with strong with your feet approximately hip width apart. This will help you avoid shifting your weight.
2. Keep your shoulders back and head up.
3. Uncross your arms. This makes you look more welcoming and inviting.
4. If you're worried about fiddling with your hands, try holding your hands behind your back or holding them together in front of you.

Discovering opportunities

For most people, the first time you really think about your future is when you choose your GCSE subjects. For those who have already chosen their career path, this may be an easy decision. For those who are unsure, this unsteadiness intensifies until it's time to make this life-changing step in what feels like just a matter of weeks.

While facing pressure from teachers, family and peers, there are two questions you should ask yourself: what, right now, is the best route for me to take for the next step in my journey? And secondly, have I done enough to get to where I need to be?

Work experience, internships, and apprenticeships are all opportunities that present themselves both before and during university. They can help you to understand workplace environments and the kind of work you could be doing, and help you gain soft skills which are transferable to these settings in the future.

Work experience

In most cases, work experience is essential for getting a job and desirable for your applications into higher education. It shows institutions you have carefully researched and explored what jobs are like. It also allows you to work alongside professionals in a career you may want. There might be the chance to shadow other workers to understand their work and day-to-day responsibilities. This is a great opportunity to ask them real questions about the roles and the company ethos.

Work experience also helps you discover your motivators for work. For some it's money, for others it's creating lasting and meaningful impact in your role. You'll soon realise there's more to job satisfaction than just having the dream role.

Internships

Internships may last anything from a couple of weeks through to a year. If you're still at school, it's best to have a look for summer internships which take place over the holiday and allow you to follow a real work routine for a couple of weeks. Some may have set courses for development and training, and you're likely to find other peers partaking in the opportunity. Internships are great for networking within specific fields and finding other professionals to stay in contact with. This will let you discuss and share experiences of how to make the most of your environment and to build healthy working habits.

Many internships are based internationally and cover all travel fees. These internships are a great way to travel the world while gaining highly sought-after skills in today's global workforce.

Apprenticeships

Going straight into university doesn't work for everyone. For those seeking job experience immediately after school, an apprenticeship is a great next step. Under an apprenticeship, you will be considered employed from day one. Apprenticeships usually combine practical elements with study. This allows for job-specific training rather than focusing on transferable skills, a phrase usually associated with higher education institutions. Apprenticeships mean you'll earn a regular wage, one that will increase as you finish training. In addition, the practical hands-on element will mean that you will be trained directly in the skills that employers seek.

Degree apprenticeships form a compromise between a university degree and an apprenticeship. By undertaking a degree apprenticeship, you will gain several years of work experience and the qualifications from a university. The company you work for will pay your tuition, so you won't have to take out student loans. Degree apprenticeships aren't just limited to practical degrees – they are available for many different subjects from accountancy to childcare to laboratory work. While they may take more time to complete and are highly competitive, you're likely to come out ready for a job with the experience you have attained.

Placements

Placements are usually part of an academic program. Some degrees will include a placement year. These allow a cohort of students, usually studying the same or similar degrees, into industry placements for the most realistic experience of work life after university. They can also be just a few months long, usually making up the same number of credits as a university module. Often these are assessed, with the work completed contributing towards a final project. Placements are a great insight into the industry attached to your subject field. They increase your employability, which is hugely beneficial when entering the graduate job market.

> “Stepping out of your comfort zone and trying new things is the best way to grow.”

Highlight your experiences and skills

You don't have to have travelled the world or completed numerous internships to succeed. Identifying relevant experiences and signposting your skills in the right way can highlight your strengths to employers and higher education admission teams.

If you speak more than one language, that should be included. This shows your ability to communicate with people from different backgrounds.

Highlight your outside activities. For example, you may have played centre position in netball. You can frame this to show you gained skills in team leadership, motivation, and discipline. If you spent time volunteering at a local shelter or food bank, or started a book club or after-school STEM club, these activities shows initiative, passion, and organizational skills.

Overcoming obstacles

Many universities and employers have diversity and inclusion schemes for people from minority or low-income backgrounds. If you fall into these categories, remember to disclose this information and use these schemes to your advantage.

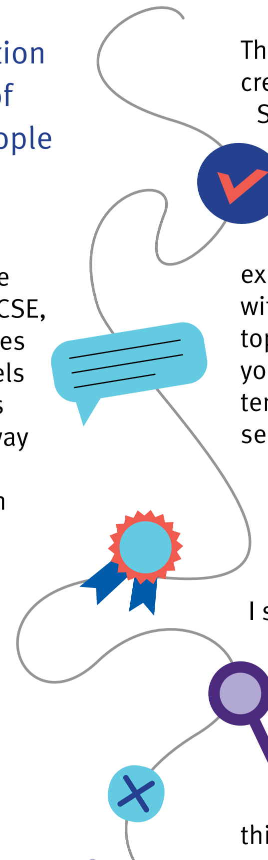
KYRILLOS SIDAROUS *works in the nuclear engineering field and is passionate about all things STEM and business related.*

Managing expectations

→ Throughout the transition into adulthood, a lot of pressure is put on young people to get their lives together.

It starts earlier than we expect. Early Key Stage 3 exams determine which subjects you can take for GCSE, the grades and subjects themselves deciding what you study for A-levels – if you even decide to do A-levels or follow a vocational route. Halfway through your A-levels you choose your university degree path, which you're told shapes your career, should you get the grades.

All of this is before your 18th birthday – the legal age you can buy fireworks. Serious stuff, right?

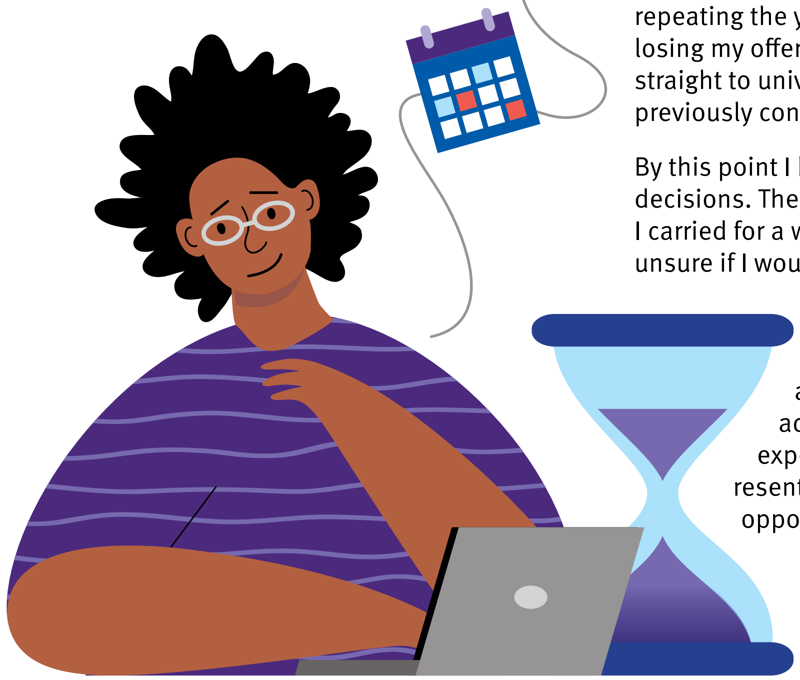


This stressful timeline normalised by society creates an overwhelming pressure for many students. Some have an idea of where they want to be by a certain age. Others, like me, were just trying to make it through term to the summer holidays. Having to plan so much so early is no easy feat. Writing personal statements and completing work experience, all while trying to keep up academically with deadlines and targets makes it difficult to stay on top of work. It can mean targets are not achieved and you lose self-belief. This loss of momentum could be temporary, but it could have a lasting effect on your self-confidence.

Second-guessing

I know this from personal experience. It wasn't until I started my PhD in Medical Physics and Computational Modelling that I finally began feeling a sense of academic achievement. After studying biology, chemistry, maths and psychology for two years, I had failed to reach my academic goals at A-level and therefore failed to get into my firm UCAS choice. At the time this felt like the worst thing that could happen. I was faced with a choice of repeating the year to retake some modules, risking losing my offers or getting worse grades, or going straight to university to study a subject I'd never previously considered.

By this point I began second guessing all my decisions. The loss of confidence was something I carried for a while. Even starting my degree, I was unsure if I would keep up as I still had this negative mental perspective. With time this changed. I immersed myself in university culture and my studies and very quickly I was back excelling academically. I realised that this experience was not something I should resent but instead was a valuable learning opportunity for me.



New career paths

I had always wanted to be a doctor and right now that's exactly what I am working towards. It's just not the kind of doctor I had planned. I'm hoping to be a PhD, not a medical doctor. I never even considered that I would follow this route. When you're younger, things are very black and white. If I want to work with oil and fuels, chemical engineering is the route to take. If I want to work in medicine, I should go straight to medical school. What we're often not told is that the subject you study at university is not the ultimate decider of your career path. While STEM degrees can have straightforward career paths, the skills you develop along the way open doors in many other subject fields. Problem-solving and lateral thinking will provide options in project management, consulting, and finance – options you may not have considered at 18. Should you wish to, you can even do further study to specialise in these disciplines.

For this reason, it's incredibly important to make the most of every opportunity available to you from school through to university or apprenticeships. Further study is the perfect place for professional and personal development. Careers fairs, work experience, industry placements, and even the flexibility of course modules all provide invaluable experience, especially within workplace environments. By exposing yourself to these settings, you'll discover what you like, what you don't, and what you prefer.

For myself, I stumbled into a number of opportunities which have led me to where I am now. Careful selection of modules such as science communication introduced me to outreach, and work experience in a radiology department is where I first considered medical physics as a career path. These experiences taught me the importance of having flexible plans and being able to adapt as your environment changes.

Striving for the best

As someone who has not stuck to the path they thought they would take, I've learnt more about myself than I ever thought I would. I no longer turn down opportunities I don't think I'm qualified for, nor do I fear the rejection I experienced back on results day. I trust that every decision I make is the best decision made at the time, and often encourage myself to leave my comfort zone as this is the only real path for growth. Managing expectations is not about expecting the worst. It's striving for the best while realising that things may not always go to plan. It's about picking yourself back up if they don't and always looking forward.

“There's more than one way to get to where you want to be.”

Some of my friends, of course, ended up doing exactly what they had planned to do when they were 18, but I can comfortably speak on behalf of those who didn't when I say: there's more than one way to get to where you want to be. And if you find yourself somewhere you didn't expect, enjoy the journey, because the resilience it takes to get over these hurdles will show you that you can do anything.

MONICA SIDAROUS *works at IBM as a healthcare and life sciences consultant who loves to inspire pupils to tinker, worldbuild, and problem-solve during their journey of self-discovery.*

Resources + contributors

Who inspires and ignites learning?

Discover some of the doers, tinkerers, crafters, builders, supporters and donors who help engage students creatively in STEM at the Dangoor Reach Out Makerspace.

Resources for makers

Making websites

DIY.org
→ **www.diy.org**
Learn new skills, complete challenges, and build a portfolio of fun projects. Choose from a variety of STEAM topics like drawing and engineering. DIY has a brilliant range of educational tutorials for projects which generally only require everyday materials commonly found around the house.

Hackaday
→ **www.hackaday.io**
For engineers and engineering enthusiasts. Hackaday is a blog which publishes several articles each day about hardware and software hacks. Hackaday is more suited to age groups 16+ as the projects and content are advanced.

Instructables
→ **www.instructables.com**
Instructables is a community for people who like to make things. If there is something you've always been dying to make, chances are someone has made an Instructable for it.

Makezine
→ **www.makezine.com**
Celebrates your right to tweak, hack, and bend any technology to your will. Makezine is based in the US and is the same organisation behind the Maker Faire brand. Most of their projects are clearly explained, photographed, and curated.

Thingiverse
→ **www.thingiverse.com**
Dedicated to the sharing of user-created digital design files. Providing primarily free, open-source hardware designs. A note of caution: the quality of designs varies. Check out user reviews if you're considering using one of the design files.

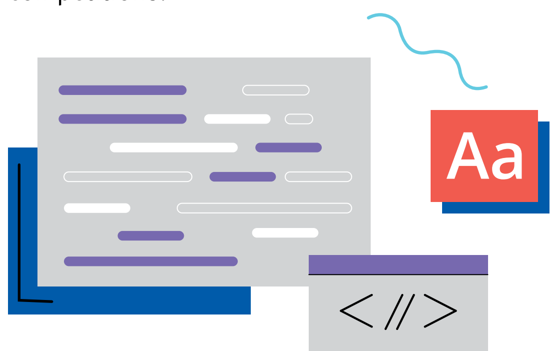
Free coding and programming games

CheckIO and Empire of Code
→ **checkio.org**
Strategy games that can teach you JavaScript or Python. Empire of Code uses a space setting and you learn by defending your own base and attacking others, while CheckIO lets you improve your skills by using others' solutions.

CodeCombat
→ **codecombat.com**
Aimed at teachers and students, but anyone can play. Learn Python, JavaScript, CoffeeScript, or the Lua game scripting language. On the beginner Dungeon level, you'll move your Hero through the game using some basic commands according to the tutorial alongside the game.

Code Monkey
→ **www.codemonkey.com**
Teaches coding using CoffeeScript, a real programming language, to teach you to build your own games in HTML5.

CodinGame
→ **www.codingame.com/start**
Offers up fun free games to help learn more than 25 programming languages, including JavaScript, Ruby, and PHP. One of the great things about CodinGame is that you can play with friends or colleagues, and also enter international coding competitions.



Inspiring podcasts

Clever
Amy Devers and Jaime Derringer
Candid and revealing conversations with the visionaries, culture-makers, and creative forces who shape our world and inform our society. Clever peels back the layers to unearth the gritty, authentic and sometimes surprising details of their creative paths.

Design Matters
Debbie Millman
The first ever podcast about design and an inquiry into the broader world of creative culture. The show is about how incredibly creative people design the arc of their lives.

Face to Face
Dezeen
Hosted by Marcus Fairs, the editor-in-chief of *Dezeen* magazine, the series features conversations with the biggest names in architecture and design about how they got to where they are today.

Material Matters
Grant Gibson
In-depth interviews with a variety of designers, makers, and artists about their relationship with a material or technique.

99% Invisible
Roman Mars
The best design is often invisible. Users don't see the design elements; they just know that the design works. Weekly exploration of the process and power of design and architecture.

Makerspace books

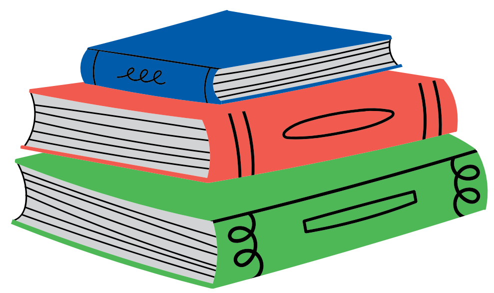
The Art of Curiosity
Exploratorium
Fifty of the world's most creative people share their stories, their inspirations, and their unique takes on science and education.

The Art of Tinkering
Karen Wilkinson and Mike Petrich, Exploratorium
Join 150+ makers as they share the stories behind their beautiful and bold works – and learn a few lessons in tinkering yourself.

Inventor Lab: Awesome Builds for Smart Makers
D.K. Publishing
Brimming with exciting educational activities and projects that focus on electronics and technology.

The Maker's Field Guide: The Art & Science of Making Anything Imaginable
Christopher Armstrong
Combines almost every single technique on making and building prototypes/models for design, engineering, and product development.

Woodwork: The Complete Step-by-Step Manual
D.K. Publishing
Woodwork is the ultimate visual guide to every essential woodworking technique.



London makerspaces

Blackhorse Road Workshops
Open-access community workshop in East London, which specialises in wood and metal processes, with affordable access to tools and space. Runs sessions specifically for young people and offers subsidised access.

Fab Lab London
London's first purpose-built digital fabrication and rapid prototyping workspace.

Hub Workshop
Traditional and digital do-it-yourself workshop located in Peckham.

London Hackspace
Non-profit hackerspace in Wembley. A community-run workshop for people to come to share tools and knowledge.

London Music Hackspace
Community for innovators and hobbyists passionate about music technology and sound art. Organises regular DIY workshops and events.

Machines Room
East London makerspace open to the public and businesses to come and fabricate their ideas.

Makerversity
Co-making space in Somerset House with work space for making and manufacturing start-up businesses, and applied learning opportunities.

Richmond MakerLabs
All-inclusive space for people with an interest in DIY and craft in Richmond.

South London Makerspace
Social community workshop in Herne Hill. Owned, run, and maintained by the members.

Places to visit for inspiration

LONDON-BASED

Design Museum
Devoted to contemporary design in every form from furniture to graphics, and architecture to industrial design.

Faraday Museum
Science and electromagnetic discoveries located in the basement of the Royal Institution.

London Museum of Water & Steam
Contains the largest collection of pumping engines in the world.

Royal Observatory
Greenwich
Home to the Greenwich meridian, a planetarium, and telescopes.

Science Museum
Exhibitions include developments in contemporary science, medicine, and technology.

Victoria and Albert Museum (V&A)
The world's largest museum of applied arts, decorative arts, and design, housing a permanent collection of over 2.27 million objects.

Wellcome Collection
Central London museum examining the links between medicine, life, and art through contemporary and historic exhibitions.

OUTSIDE LONDON

Discovery Museum
Newcastle upon Tyne
Tells the rich history of the area's maritime industry and technological development.

Jodrell Bank Discovery Centre
Cheshire
One of the world's largest fully steerable radio telescopes. Part of the Jodrell Bank Centre for Astrophysics at the University of Manchester.

We The Curious
Bristol
Science and arts centre and educational charity.

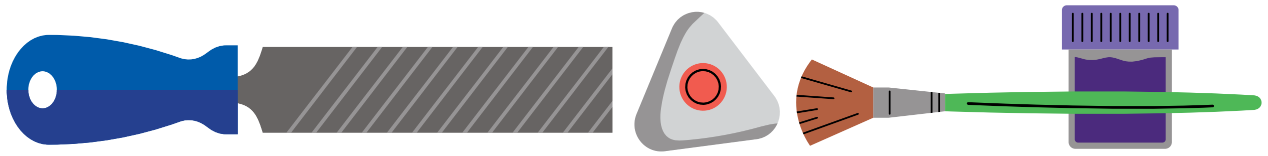
Cambridge Museum of Technology
Cambridge
Industrial heritage museum

History of Science Museum
Oxford
Holds a leading collection of scientific instruments from the Middle Ages to the 19th century.

National Museum of Computing
Bletchley Park, Milton Keynes
Home to the world's largest collection of working historic computers.

Science and Industry Museum
Manchester
Manchester, the world's first industrial city, is home to a museum full of amazing objects and revolutionary ideas that changed the world forever.

Contributors



The development of this book was brainstormed by a fantastic team of individuals who have a passion for making and want to share that love of tinkering with others.

Chloe Allen-Greeves
Makerspace Technical Assistant

Chloe supports young people at the Makerspace to use a wide range of different equipment, including 3D printers, laser cutters, woodworking machinery, electronics and crafting tools, ensuring the supply of materials and components are available to make ideas a reality. She enjoys making and repairing objects and in her spare time can be found restoring antiques.

Richard Brown
Makerspace Technician

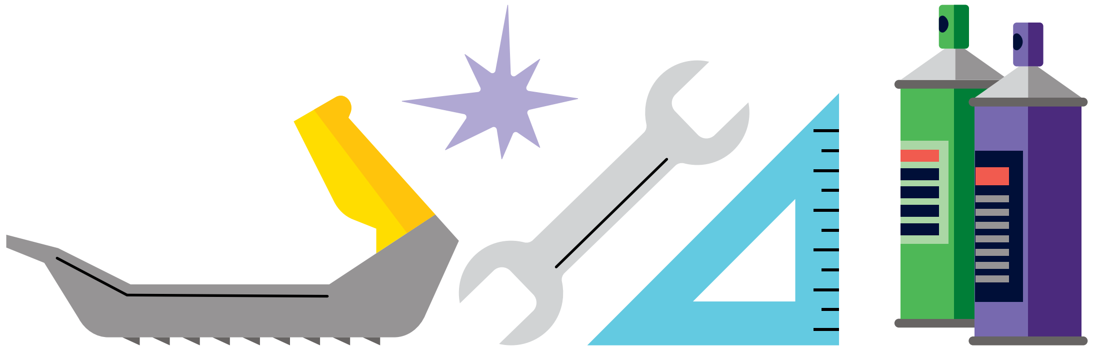
After finishing school and doing a range of jobs from shop assistant to warehouse worker, Richard studied 3D design then modelmaking. He spent around six years as a freelance modelmaker working mainly on prototypes and did some film and animation work. He then worked at the architectural practice of Foster + Partners managing the Sketch Modelshop, in which building design prototype models were made. He worked there for 18 years before becoming the Makerspace Technician at Imperial College London in 2017.

Tiffany Baptiste
Outreach Ambassador

Tiffany studied Bioengineering, earning a Bachelor's from the University of Sheffield and a Master's from Imperial. She is from Trinidad and Tobago. Her passion about giving students exposure to the world of STEM is what led her to working at the Makerspace. She has enjoyed learning new skills such as woodworking and 3D printing alongside Makerspace participants. In her spare time she likes to draw and do DIY crafting.

Alex Dallman-Porter
Outreach Academic Leader

Alex has balanced a love of science and art for many years. After studying biology, maths, chemistry and art at A-level, he pursued biomedical sciences at undergraduate level at the University of Oxford. After finishing, he made a switch to study Innovation Design Engineering at Imperial College London, where he met the founders of the healthcare startup he now works at.



Beren Kayali
Outreach Academic Leader

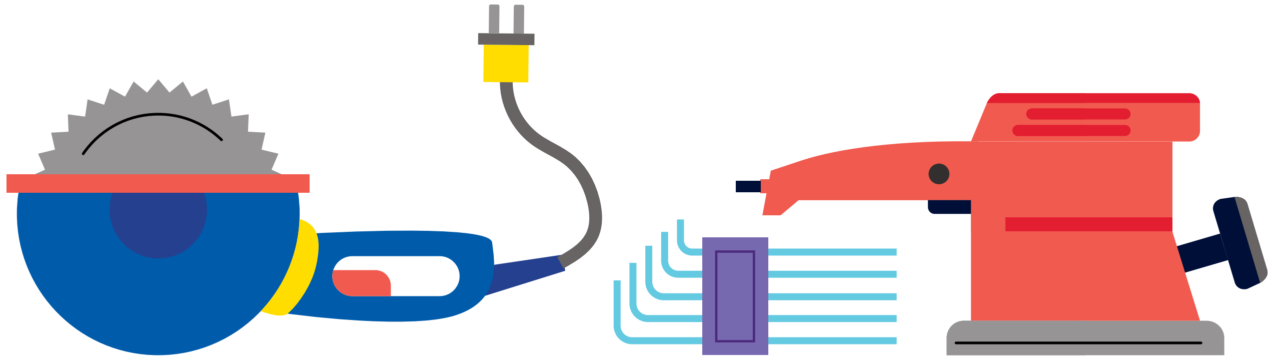
Beren is co-founder and acting CTO of Deploy Tech. Beren completed a BSc in Mechanical Engineering in 2017 from Bogaziçi University and a Joint Master's in Innovation Design Engineering at Imperial College London and the Royal College of Art in 2020. She was awarded the Royal Commission 1851 scholarship. During high school she competed in various robotics competitions, and she mentored her former robotics club while studying as an undergrad. Beren previously worked in human–machine interface design for Roketsan, a division of the Turkish Army, and a similar position for Turkish Airlines. In 2020 she worked on a future concept for flight for British Airways, and her design won the Future Flight Experience Design Award.

Ela Kemp
Outreach Academic Leader

Ela is a multi-disciplinary designer, working across all disciplines of design: product, packaging, brand and graphic. Whether it's making a website flow, tomato ketchup pour, or getting a child to scoot, she loves the challenge of designing products that bring a smile to everyday tasks, making them simple and easy to use.

Ahreum Jung
Makerspace Community Programmes and Design Coordinator

Ahreum creates and teaches design content, hands-on workshops, and developing community programmes. She has several years of experience in innovative product development, design research, and concept development. She has worked as lead designer for various ventures within industries that range from femtech and women's healthcare to foodtech, consultancies and packaging design. She is a technophile and is passionate about humanising technology and bringing impactful designs to market. In her free time, she loves making things and enjoys working with clay. She has a Master's degree in Innovation Design Engineering from Imperial College London and a Bachelor's degree in Graphic Design in Advertising from Michigan State University.



Kate Mulcahy

Makerspace Programmes Manager

Kate was instrumental in helping set up the makerspace workshop in 2017 and continues to manage the day-to-day operations and activities. Before working at Imperial College London she worked on many exciting projects including helping make the Royal Institution Christmas Lectures, working on the television show *Impossible Engineering*, and working for the Science Museum. She is a passionate maker and loves learning new techniques. Whether building robots or learning to carve stamps, above all she loves to share her love of making and to help inspire future creators.

Oisin Shaw

Outreach Academic Leader

Oisin is a PhD student in Mechanical Engineering at Imperial, working on batteries and hydrogen fuel cells for electric vehicles. He did his undergraduate degree in Mechanical Engineering at Imperial, during which time he became a technician for the Imperial College London Advanced Hackspace and was a founding member of a race team entering an ultra-efficiency race. He enjoys all kinds of making, including knitting, sewing, metal fabrication, woodwork, prototyping, electronics and more!

Kyrillos Sidarous

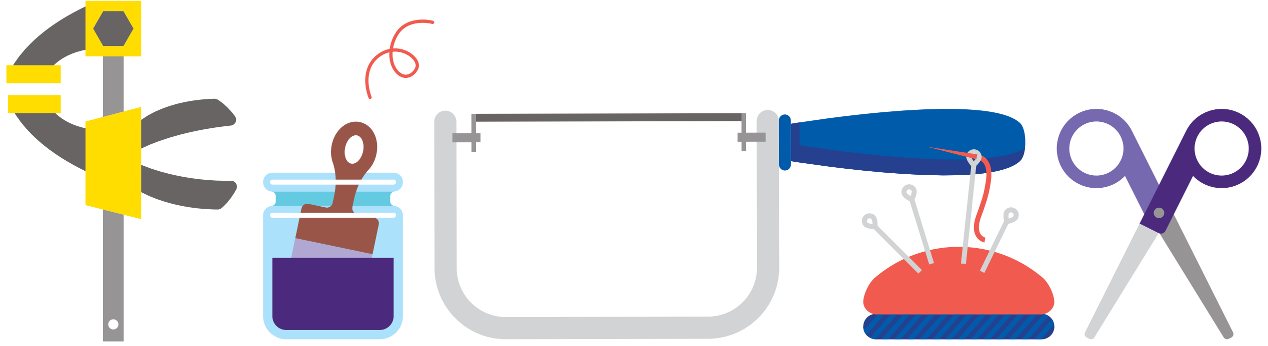
Outreach Academic Leader

Kyrillos is passionate about all things STEM and business related and was a student on an Imperial College London Summer School 15 years ago. He went on to study Engineering at Swansea University and then returned to Imperial to finish his Master's in International Health Management. Kyrillos currently works in the nuclear engineering field and often contributes to Outreach activities.

Monica Sidarous

Makerspace Academic Leader

Monica studied for her undergraduate degree in Chemistry at the University of Brighton. She took a year out for business experience and travel, and then went on to study a Master's in Advanced Biomedical Imaging at UCL. She undertook two years of a PhD in computational modelling for cancer before deciding she no longer wanted to pursue this. She now works at IBM as a healthcare and life sciences consultant.



Rebecca Sweeney

Makerspace Assistant

Following her interest in the social sciences, Rebecca earned her Master's degree in Psychology at the University of Edinburgh and later worked overseas on various education and community engagement projects in Japan, China and Uganda. Having benefited from Outreach initiatives herself, she is passionate about ensuring education is accessible for everyone. Rebecca now helps coordinate the daily running of Makerspace programmes as well as building relationships with local young people, community groups and teachers.

Jacob Tan

Makerspace Leader/ Mentor

Jacob has been a mentor and leader at the Makerspace for several years. He earned his integrated Master's degree (MEng) in Engineering Design at Imperial College London. He was a research assistant at Imperial working on 3D printing face masks, and now works for Brevan Howard as a data analyst. He likes playing video games, reading manga, and watching anime. He has a small workshop at home where he makes cosplay costumes. Some of his projects include a modified scooter with multi-colour LEDs, a modified Ender3 V2 3D printer, and Shigaraki Tomura costume.

Naomi Tan

Outreach Ambassador

With an interest in geography and the science behind it, Naomi studied for a BSc in Geophysics at Imperial, followed by an MSc in Environmental Technology, also from the College. This helped Naomi understand the science behind the Earth's environment, as well as policies to preserve the Earth's beauty. In her spare time, Naomi enjoys playing the piano and diving.

Joy Zhang

Outreach Ambassador

Joy is a designer, engineer, and entrepreneur who recently received her Master's in Innovation Design Engineering from Imperial College London and the Royal College of Art. She believes in the goodness of humanity and can't wait to see what we can create together. More about her and her work can be found at joyqzhang.com.

Thanks to our supporters

Our corporate and foundation partners are essential to enable us to provide programmes that nurture the talent and creativity of children, young people and their families.

Imperial College London is grateful to all those who have made the Makerspace and its programmes possible.

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Berkeley Group

Berkeley Foundation

➜ **www.imperial.ac.uk/reach-out-makerspace**

The Makerspace Manual: A Guide to Bringing Ideas to Life

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Further copies of this book are available from the Makerspace website or upon request though emailing makerspace@imperial.ac.uk

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