

Secondary School DT Workshops



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Background

The State of Technical Education

Design and Technology *noun* [1]

| DT |

- 1 : **Design and Technology (DT)** is a practical school subject in which students design and manufacture products using materials, tools, mechanisms and electronics, researching users and developing, building and evaluating prototypes safely. [1]

? Why It Matters

Skills DT Develops:

Teamwork and communication
Tool and technology confidence

Problem solving
Idea generation

For *most* students, DT is their first experience of a workshop, offering supervised use of tools and materials while building early practical confidence in a controlled setting.

These skills are directly relevant beyond the classroom.

Currently the engineering industry is one of the largest employment sectors in the UK, yet skills shortages remain persistent.

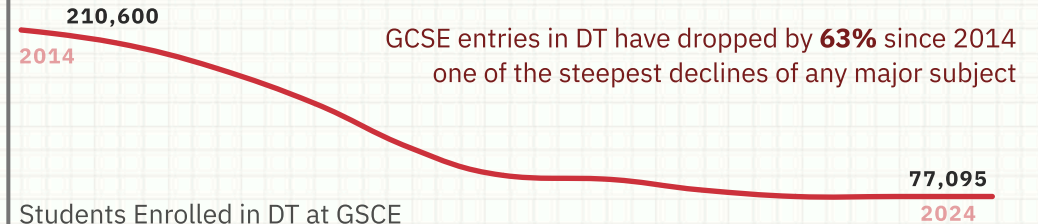
76% of engineering employers they struggle to find technical skills when recruiting. [2]

DT directly develops these capabilities through hands-on design, prototyping and material understanding.

Strengthening DT in schools is a clear and realistic way to build the technical confidence and applied skills that the industry demands.

? Why It Declining

Despite its practical and economic relevance, Design and Technology has experienced sustained decline. [3][4][5]

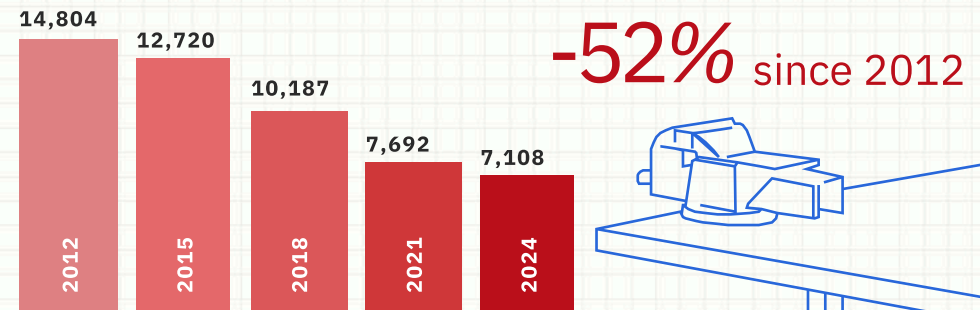


DT is hard to protect when budgets are tight, because it needs specialist rooms, tools, materials and technician time, so it costs more than classroom subjects. [6][7]



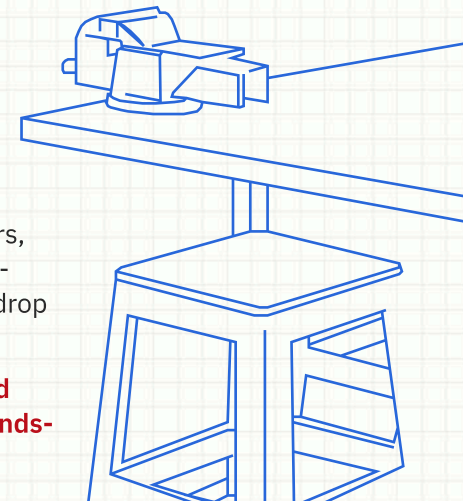
Government measures like the **English Baccalaureate** focus on a small set of academic subjects and leave DT out. This makes D&T look **low priority**, so schools feel less pressure to protect it when cutting timetables and budgets.

There is also a **serious shortage of specialist teachers**. The number of trained DT teachers has fallen to less than half of its 2012 level. [8]



Recruitment targets have been **missed** for years, leaving some schools unable to staff safe, high-quality workshop lessons and forcing them to drop the subject.

As a result, fewer students experience DT and many enter further education with limited hands-on confidence.



User Focus

DT Students and DT Teachers

The Users

Our focus will be on GCSE and A-Level Design and Technology students, who complete individual design-and-make coursework projects in school workshops. DT teachers are considered secondary users, as they supervise practical work and influence how tools are used.

GCSE & A-Level DT Students

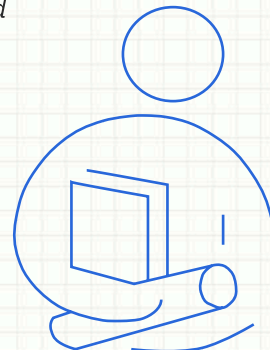
DT coursework projects typically follow this process, with all stages documented in a design portfolio.



We will research all stages of this process, with a focus on ideation, modelling and manufacturing, where students carry out most practical work.

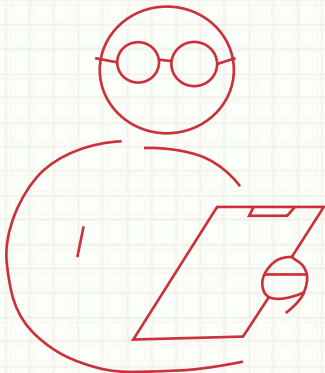
They have **some prior experience** in Years 7-9, however they are still **novice users**, developing skills and confidence with tools, materials and manufacturing processes.

Students must balance **learning** new **skills** with **completing coursework** within limited time, materials and teacher supervision.



DT Teachers

Teachers supervise all practical work in the workshop, ensuring that tools and machines are used safely and that activities comply with school safety regulations.



They support multiple students at once, helping with **design decisions**, **manufacturing processes** and **machine use**.

Teachers balance supervision, teaching and assessment while monitoring progress and ensuring coursework meets exam board requirements.

They have to **prepare materials**, **organise equipment** and **coordinate basic maintenance** alongside teaching.



The Workshop

The DT workshop is a practical space where students design and make products. Classes are typically 15 students, with multiple year groups sharing the workshop. Lessons last 50–90 minutes.

Typical Workshop

Workshops are usually large rooms with workbenches, shared hand tools and machinery requiring significant investment.

City of London School for Girls DT Workshop



Laser Cutters
Pillar Drills

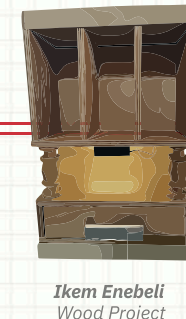
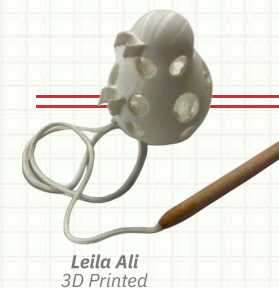
Centre Lathes
Vacuum Formers

Scroll Saws
3D Printers

Soldering Irons
Belt Sanders

Example Projects

Projects include furniture, storage, lighting, speakers, mechanical and electronic products, built as prototypes using timber, plastics, metals or cardboard.



Research Methods

Aims, Questions and Methodology

Primary Aim:

Understand the specific operational and behavioural challenges faced by DT students and teachers, and to identify recurring points of interruption, dependency and risk. The research focused on how workshops function in practice, not just how they are intended to function.

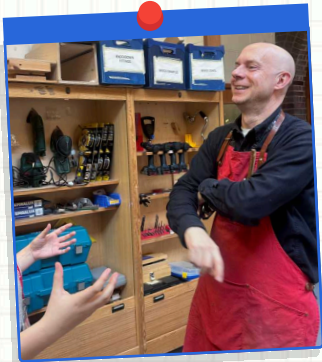


Interviews

To reduce single-site bias, research was carried out across two contrasting schools: Bro Edern, a state school in Wales, and City of London School for Girls (CLSG), an academic private school in London. Despite differences in budget and context, nearly all challenges were the same in both schools.

11 Interviews Conducted

- 4 GCSE DT Students
- 3 DT Teachers
- 3 A-level DT Students
- 1 DT Technician



Interviews were semi-structured.

A guided question framework ensured consistency, while a conversational approach encouraged deeper responses and unexpected insights.

Additional insights were noted when students collectively agreed on shared problems during informal group moments.



Observations

Some of the Interviews and workshop observation were conducted on the same day to directly compare stated behaviour with observed behaviour.

A full DT lesson was observed to capture:

- Student independence levels
- Teacher intervention frequency
- Tool and machine usage
- Waiting patterns
- Peer interaction
- Preparation and reset behaviours
- Bottlenecks in workflow

Observed for
180
Minutes



Observation allowed behavioural insights that students did not explicitly state in interviews. All notes were recorded live using typed notes. Photographs were taken to document layout, tool access and workflow and how the students behaved with the tools.



Survey

Following interviews and observation, a survey was created and distributed to students at both schools.

The survey combined multiple choice, Likert-scale confidence ratings and open responses.

The purpose of the survey was not exploratory, it was confirmatory, to test whether identified issues from interviews and observations were consistently experienced across cohorts and across both schools.

92
Survey
Responses

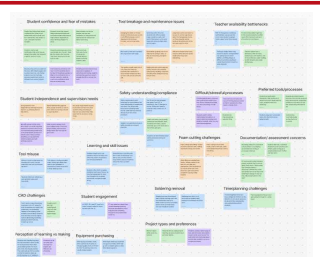


Data Synthesis

Interview notes, observations and survey results were extracted into individual statements.

These were grouped using affinity mapping. Clusters were formed based on repetition, behavioural patterns and system-level themes.

From these clusters, structured insights were developed, **forming the basis for identifying opportunities.**



Research Findings

Thematic Analysis of Research



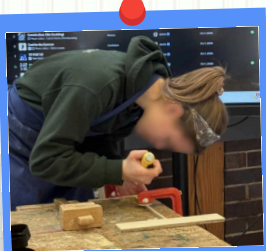
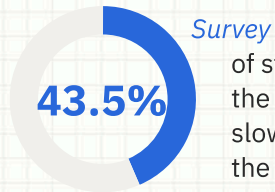
Students

"Only 1 teacher...very hard to get his attention" - Year 11 student

"...have to wait for 20 minutes to get his help" - Year 11 student



Students waiting to ask questions and get help from the teacher



Year 13 chiselling hinge recess on scrap wood

"I've been putting off the chiselling because it stresses me out... I have to do it now though...I'm practising on scrap first because any mistake on my project ... could ruin it"

- Year 13 student

Survey

47.8% of students state that they have avoided using a tool in fear of making a mistake.

Common tools mentioned are:

- Chisels
- Biscuit joiner
- Table router (for rebates)

"The belt sander is probably my favourite because it's just satisfying and easy to use, you turn it on and go."

- Year 12 student

Survey

78.2%

of students said they were more likely to **wait for teacher confirmation** even if they thought they knew what to do.



Technician helping Year 11 student set up machine



Teachers and Technicians

"Craft knives and chisels are the most dangerous tools in the workshop"

- Mr Barker (Head of DT at CLSG)

Survey

65.2%

While no students claimed to have been seriously hurt, 65.2% of students report minor cuts and burns within the workshop.



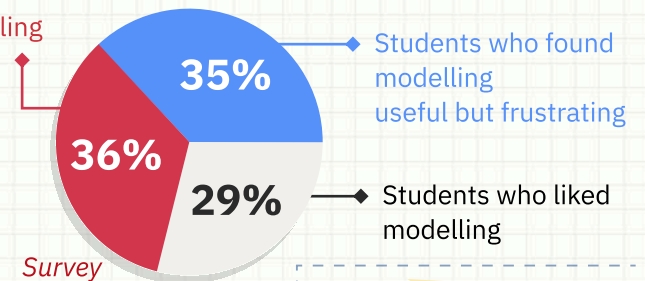
Ruaridh using ChompSaw at CLSG

"Curves and geometric shapes are really difficult for the students to cut accurately with craft knives" - Mr McDonald (CLSG DT teacher)

To try and improve cardboard modelling the department invested in a **ChompSaw** however teachers felt the it was more useful for younger year groups and was **not accurate enough** for GCSE and A-level work where finish and precision are important.

Students who disliked modelling and found it time consuming

41.2% of students find cutting curves and complex geometries especially difficult



"Cutting foam is one of those jobs that seems simple, but creates a lot of mess and dust... becomes a safety issue..."

- Mr Teacher (Head of DT at Bro Edern)

"We spend a lot of time doing preparation tasks for students like sizing foam... students take too long... there is never enough time"

- Mr Teacher (Head of DT at Bro Edern)



Technician cutting material to size for students

User Personas

Pain Points, Coursework journey map and Opportunities



Student ID



Year: 11
Name: GCSE George
Project Type: Woodwork
Skill Level:

Pain points:

- Seeks teacher **reassurance** before new steps
- Clumsy with handheld tools and gets minor injuries
- Worried about **setting up machines incorrectly**
- Spends a long time **waiting** for the teacher



Student ID



Year: 13
Name: A-Level Alysa
Project Type: Woodwork and 3D printing
Skill Level:

Pain points:

- Struggles to **turn sketches** into accurate **models**
- Precise final detailing feels **high-risk** and **stressful**
- Finds **models don't match** intended **purpose** so **evaluation** at the end **is tricky** to do properly



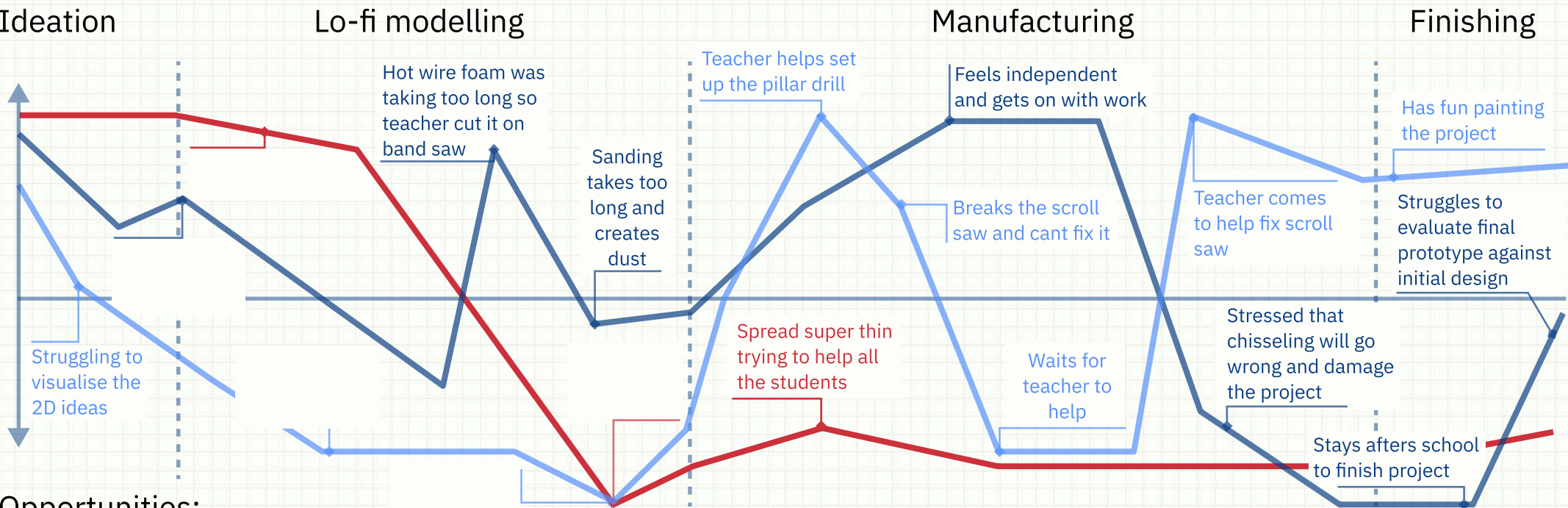
Staff ID



Role: DT Teacher
Name: Teacher Tim
Teaching Classes: Year 10-13
Skill Level:

Pain points:

- Lots of **students cut or burn themselves** during modelling so lots of **paperwork** needs to be done
- Students are always needing help and there are too many of them so **time** is always **spread thin**



Opportunities:

Make early **cardboard modelling safer** and **easier**, helping students produce **cleaner prototypes** with less reliance on hand skill and **less waiting** for teacher support when using and setting up tools.

Support **more accurate foam** prototypes, especially for **complex** or **organic forms**, with cleaner refinement, **less dust**, and stronger links between modelling, final manufacture, and evaluation.

Reduce repeated reassurance and setup help by making practical work **safer, cleaner, and easier** for students to carry out **independently** in busy classes so teachers can help the students who need it most.

Insights & Opportunities

Key Findings Translated into Design Opportunities



Insights

Research across interviews, workshop observations, and surveys revealed consistent patterns in how students approach practical work in school workshops.

001



With around 14–16 students per workshop, **teacher attention is spread thin**, students can wait up to half a lesson, slowing overall progress.

002



Students try to **avoid processes where one mistake could ruin the part or project**, treating tasks such as chiselling as high-risk steps that require supervision.

003



Foam modelling supports rapid form exploration but creates significant dust and debris, making it **messy and difficult to manage** in a classroom workshop.

004



Students often seek teacher help before major processes, even when they have the skills, showing **low confidence making independent decisions**.

005



Students **frequently pause work to ask for reassurance** rather than resolving uncertainty themselves, slowing workflow and increasing reliance on staff.

006



Cardboard and foam modelling often produces **rough or inaccurate results**, so some students treat it as a coursework requirement rather than a valuable design tool.

007



Students rely heavily on **craft knives** for modelling because they are accessible and flexible, but **achieving accurate cuts**, especially curves and geometric shapes, **is difficult**.

008



Students prefer predictable tools with minimal setup and **avoid tools that require precise control** when the perceived risk of mistakes is high.



Opportunities

Three opportunity areas were identified from the research insights, highlighting key directions for concept exploration.

High-Risk Processes

002 / 005 / 008

How might we help DT *GCSE/A-Level* students confidently complete material removal processes that carry high risk to the project without compromising their work?

Teacher Reliance

001 / 004 / 005

How might we encourage collaborative problem-solving among DT *GCSE/A-Level* students so they rely less on teacher validation and feel confident resolving uncertainties during practical work?

Prototyping Quality

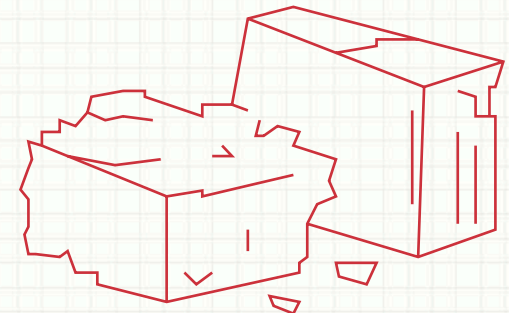
003 / 004 / 006 / 007

How might we enable DT *GCSE/A-level* students to work independently and cleanly to produce higher-quality results in line with their initial design in the lo-fi prototyping stage with materials such as carboard & foam?

This was selected following tutor discussion and evaluation against the project brief.

Cardboard and foam prototyping is widely used in early stages but it produces inaccurate results, mistakes, and messy conditions, making it difficult for students to represent ideas clearly.

Improving this stage would strengthen the design process and it presents strong potential for electro-mechanical solutions.



Market & Commercial Context

Market Structure, Funding and Regulatory Environment

Global Education Market
 **\$7 trillion** [19]

Secondary Education Market
 **\$2.3 trillion**
 **£71 billion** [20] [21]

Of the **£2.1 billion** allocated to English schools as capital funding (2025–26), a rough estimate of **£30–80 million** is **allocated to workshops** within schools in England. [22]

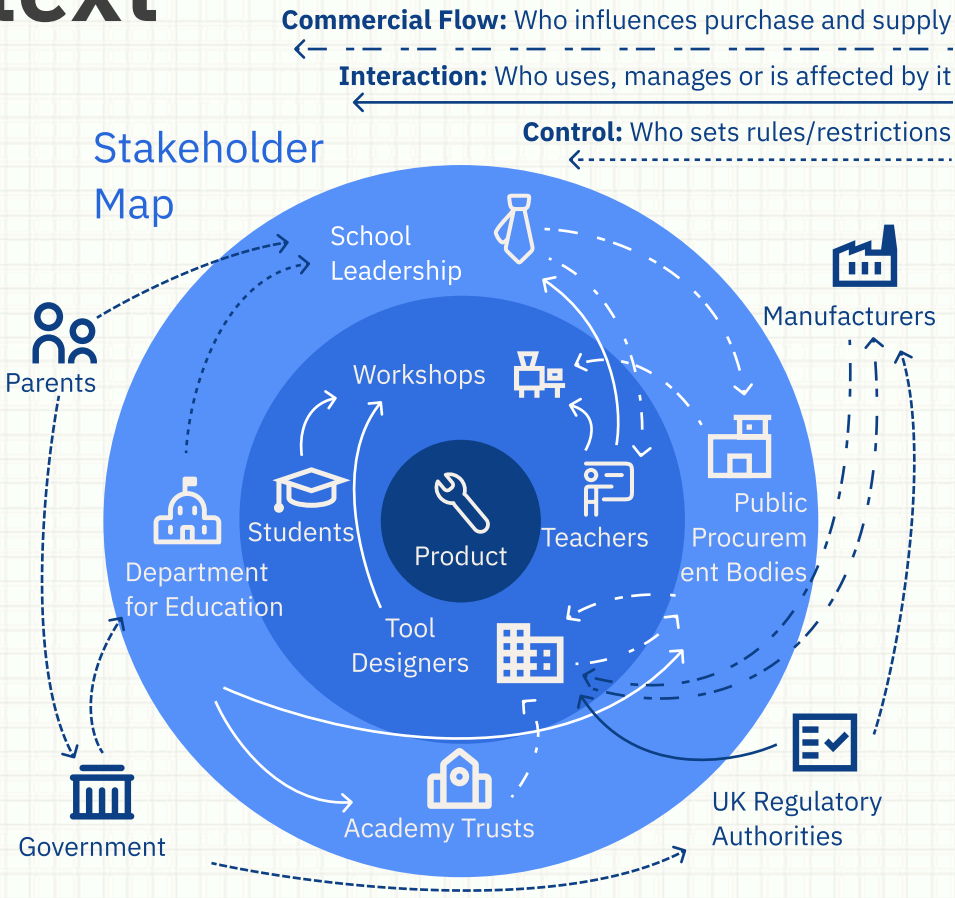
School purchasing is shaped by major procurement routes such as:

 **(50+ frameworks)** [23]

 **(£25bn public spend)** [24]

 **(12,000+ schools; 28,000+ products)** [25]

Opportunities	Political: DfE’s sustainability strategy pushes schools to give students more practical experience and real-world making. [10]	Economic: Reducing failed models and material waste could lower overall workshop cost . DT workshops depend on specialist spaces and equipment . Schools may resist products that add cost or require space.[12]	Social: DT rewards iterative development and modelling, so there is a clear need for tools that help students with this. [9] Teachers balance [11] multiple students at once, so tools need to be safe for students to use unsupervised.
	Challenges School equipment must fit workshop safety expectations and standards, slowing adoption of new tools.		
Opportunities	Technological: DT accepts a range of 2D/3D design methods. There is scope for hybrid CAD/CAM and hand prototyping . [9]	Legal: Products that reduce [13] dust, fumes or exposed heat would better align with workshop health and safety expectations . DT workshops operate within recognised safety standards , including BS 4163 for DT in schools. [14]	Environmental: [10] A solution that improves accuracy could reduce cardboard and foam waste during modelling. Schools are under growing pressure to reduce waste and make more sustainable procurement choices.
	Challenges Prototyping tools are too basic for precision and too complex and hazardous for students to use independently. [14]		



 **PESTLE Analysis**

PESTLE analysis highlighted that the opportunity is not just to make prototyping easier, but to make it **more viable** within the secondary school DT.

Solutions must balance modelling capability with **safety, cost, ease of use, waste reduction** and compatibility with busy workshop environments.

 **Analysis**

The stakeholder map showed that the main users are not the main decision-makers.

While students and teachers use the tools directly, the choice is **shaped** more **by procurement bodies** and **regulations**. This means the solution must meet user needs while also being **safe, compliant, affordable** and suitable for school purchasing.

Benchmarking & Analysis

As a group, products were selected for benchmarking based on how closely they related to our HMW and key research insights. This helped identify what current solutions already exist, how effectively they respond to the problem, and where important gaps or weaknesses remain.

Criteria

Each product was scored against criteria considered most relevant to the HMW and the intended school workshop context:

	Score
Capability	30
Safety	20
Intuitiveness	20
Independence	15
Longevity	10

These criteria assessed:

- How well the product supports modelling
- How safe it is for secondary school students
- Ease of use and setup without instruction
- Ability to use it safely without teacher support
- How durable or repairable it would be over time.

The **scoring is weighted**, with more important criteria given a higher value than others. The total is out of 100 for an overall score of the product.

GROWNEER Rotary Tool

[15]

- Versatile for shaping
- Designed for hobbyists, not school workshops
- Multiple attachments reduce ease of use
- Some prior knowledge needed for safe use
- Basic setup and fairly simple operation
- Replaceable heads improve lifespan
- Not ideal for repeated school use

20

9

12

11

6

This was our teardown product

A cordless multi-purpose rotary tool for sanding, polishing, drilling, engraving.

Total Score: 58

While students could use it independently it is not a safe tool and not designed for schools

Hilltop Foam Cutter

[17]

- Cuts good foam organic and curved shapes
- High temperature, burns
- Thin wire is hard to see, increasing burn risk
- Melting foam produces toxic fumes
- Multiple attachments reduces understanding
- Unlikely to be trusted for independent student use
- Replaceable heads improve longevity

24

6

13

5

9

Cordless design provides cleaner and more controlled shaping, especially for organic shapes.

Total Score: 57

The tool is very good at modelling organic shapes however is also extremely unsafe for students

HOTO Glue Gun

[16]

- Cordless, neat glue application and joining
- Fairly safe, but still a burn risk
- Anti-drip nozzle reduces mess
- Simple, one-button
- Suited to hobby use than heavy school use
- Not ideal for long-term repeated classroom use

25

12

18

14

2

Offers neater glue application with better control and safety features

Total Score: 71

Good for joining materials and fairly safe but not designed for school repeated use.

The Chomp Saw

[18]

- Good for modelling curves but bad for gematric shapes
- Leaves a jagged edge, bad quality cut
- Only cuts up to 3 mm
- Extremely safe, designed for children 3+
- Simple on/off use
- No replacement parts currently available
- Blade wear reduces long-term longevity

17

20

20

15

2

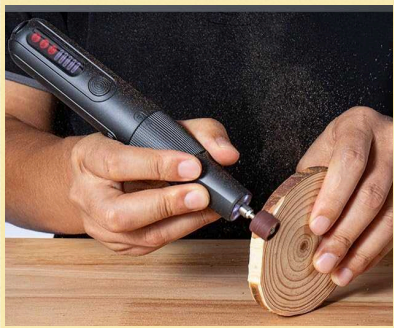
Enables safer and quicker cardboard cutting especially for curves.

Total Score: 74

Extremely safe and all students can use it easily, but not designed for school modelling

Product Teardown

Rotary Tool Teardown and Evaluation

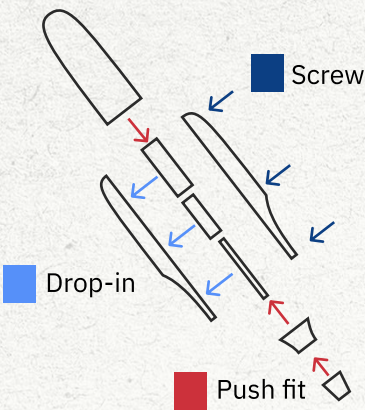


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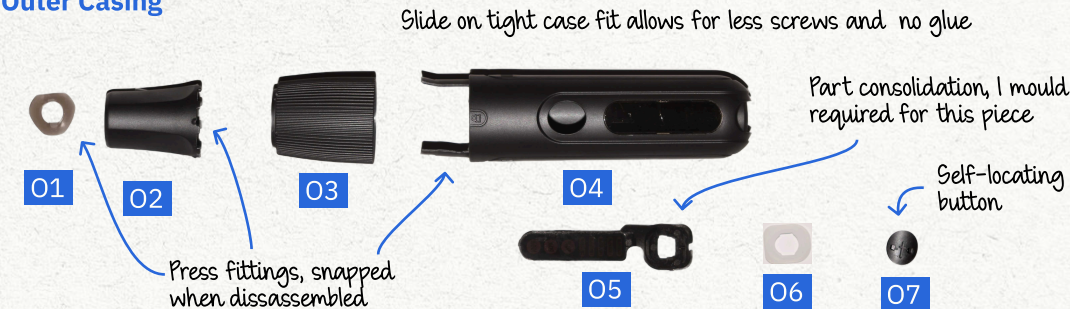
Specification

Size	205 x 33 x 33mm
Power	8V
Speed	6000-23000 rpm
Weight	480g
Price	Power
Attachments	117Pcs

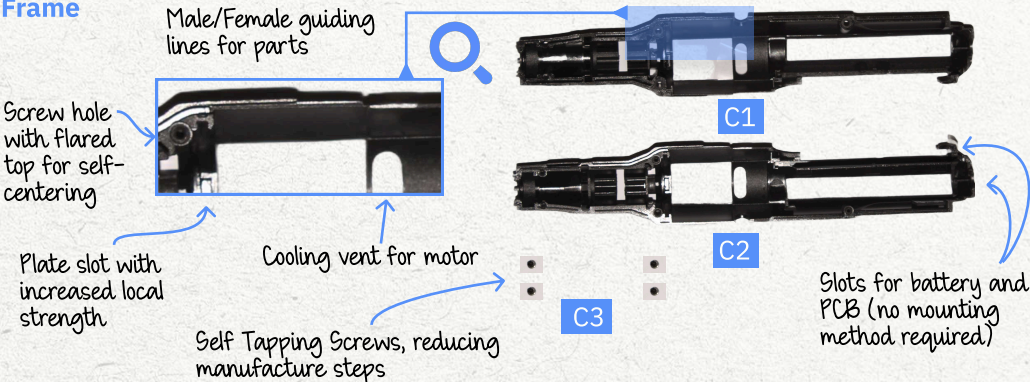
Assembly Overview



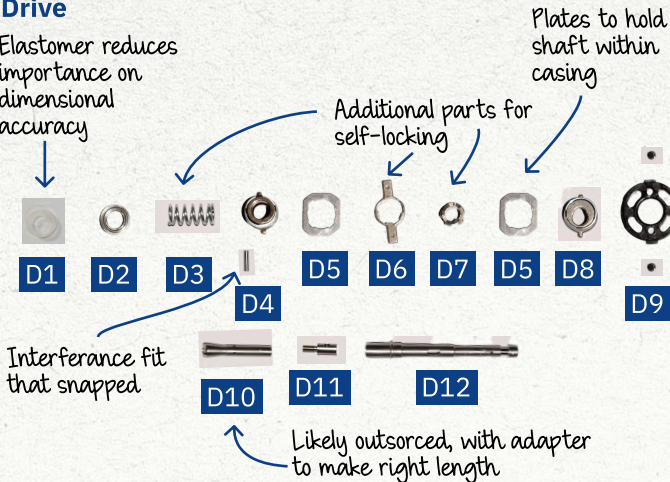
Outer Casing



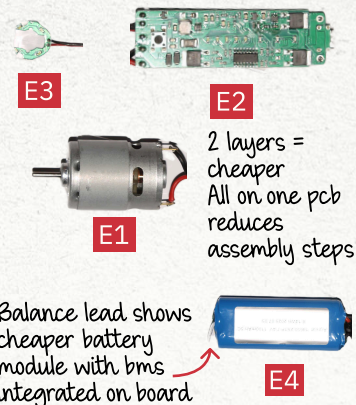
Frame



Drive



Electronics



Bill of Materials

Part	Material	Manufacturing
O1, O5	Polycarbonate	
O2, O3, O4, O5, O7	TPE	Injection Moulded
O6	Silicone	
C1, C2, D9	ABS	
C3	Hardened carbon steel	Cold Forging
D5	Mild Steel	Stamped
D6, D7, D8	Zinc Alloy	Cast
D11, D12	Steel	Lathe, cross drilled
E2, E3	PCB	Pick & Place



DFM / DFA

Design For Manufacture

- Many key components are likely outsourced, while in-house manufactured parts are kept relatively simple apart from the frame.
- Both metal and plastic parts appear to rely on established, traditional, and highly scalable manufacturing processes.

Design For Assembly

- Components fit into the two-part internal frame using slots and guide pins for alignment.
- Minimal screws and no glue are used, with the outer casing providing rigidity and push-fit sealing.
- This simplifies assembly, but reopening the case would likely damage some fittings.

Product Teardown

Rotary Tool Teardown and Evaluation

Key

Feature

Part Number

Feature description and reason for inclusion

Compromises to afford the feature

Product Objective

Light

01, E3



LED to create presentable modern feature

More parts (pcb, plastic housing, LEDs), assembly steps (pcb connection, parts)

Aesthetics

Technical

Button

06, 07

Multi-function push-button and extra membrane & cover to create a quality tactile feel.

Additional component | new material | further assembly step

Aesthetics

Display

05, E2



LED display to show speed and battery shown on component holding both display and button).

Large RPM numbers to emphasise power and feature count.

Further components and process to print writing | added assembly steps to place screen | mould complexity to include mounting pins.

Ease of Use

Technical

Aesthetics

Battery

E4

Inbuilt, outsourced 2s1p li-ion typical of a consumer device, reduces size and customer knowledge

Non-replaceable | lower power output (5C discharge) limits motor power | battery degradation

Ease of Use

Locking Mechanism

D3, D6, D7, O3



[15]

Fast and simple locking mechanism to switch attachments without tools

Significantly increased part count | further manufacture steps | more outsourcing | weaker clamping force

Technical

Ease of Use

Magnet

04



Magnetic swivel cover to provide tactile clicking feel

Component mould cost | magnet cost | Assembly step to place cap in body

Aesthetics

Casing Choice

02, 03, 04, 07



A-bodies are made from soft touch, glistening plastic sitting above structural frame. Seams minimised with no bolts and creases only where different parts rotate relative to each other.

Costly material | Reduced serviceability due to unopenable body | Reduced cooling of motor therefore limit on prolonged usage

Aesthetics

Summary

Feature Selection

The main driving factor behind features is to increase online sales, therefore features that stand out are likely to be more impactful than directly improving the quality of the tool

Decision Trade-offs

Most common tradeoffs were made in increasing assembly operation and casing materials, as all major key components are likely sourced and these operations are heavily automated and scale well

Target User

This product is aimed at the casual hobbyist, therefore it lacks many features required for our user group such as; intuitiveness, repairability and safety to the user and of the device.

Project Aim

Encourage students to utilise lo-fi prototyping stage to iterate, explore and evaluate ideas better, providing better practical hand-on technical skills

HMW enable **DT GCSE/A-level** students to work **independently** and **cleanly** to produce **higher-quality results** in line with their initial design in the **lo-fi prototyping stage** with materials such as carboard & foam?

Design Considerations:

Independence

Safety

Maintanable

Intuitiveness

Workshop-fit

Solution Areas



Marking



Cutting



Joining



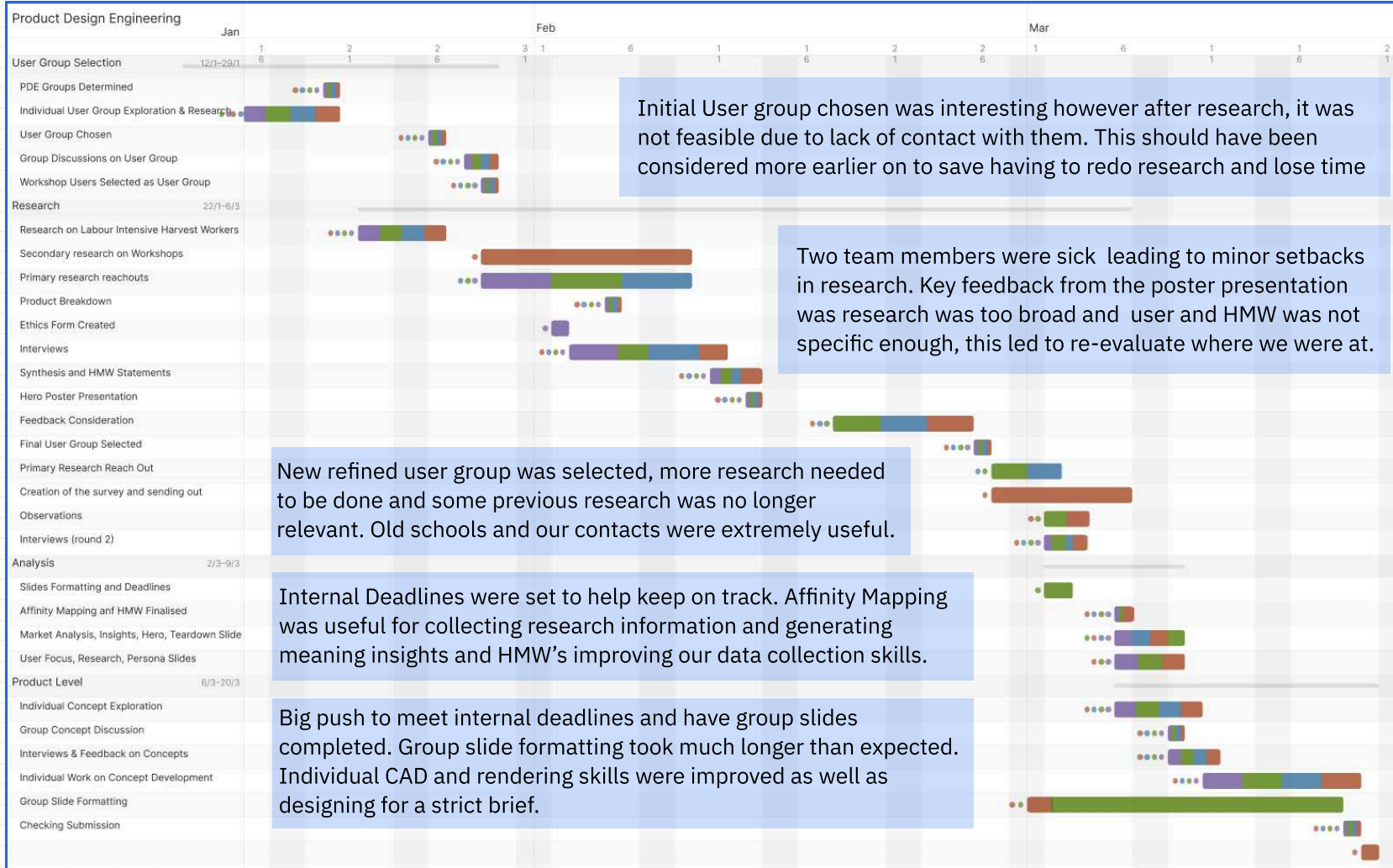
Shaping

Problems

1. Prototyping stage of design process is overlooked due to impracticality
2. Current methods' difficulty in idea representation
3. Foam cutting methods, unclean and potentially hazardous
4. Cardboard cutting methods are inaccurate and time consuming

Project Management

Contributions



Mayli Jones

CCO

- Primary User reach out
- Interviews and Observations
- Research Methods, Research Findings, User Personas, Project Management, User Questionnaire, Title and References Slides
- Gantt Chart and Contributions
- Formatting Market Research, Benchmarking, Product Teardown and Project Aim Slides
- Organising internal deadlines

Ruaridh Murdoch

CIO

- Secondary Research
- Interviews and Observations
- Background, User Focus, Research Methods, Insights and Opportunity slides
- Page Formatting for slides
- Collecting and Organising data and meeting notes
- Formatted and worded Insights and HMW's and Affinity Mapping
- Made Survey and Organised Responses

Arda Kancal

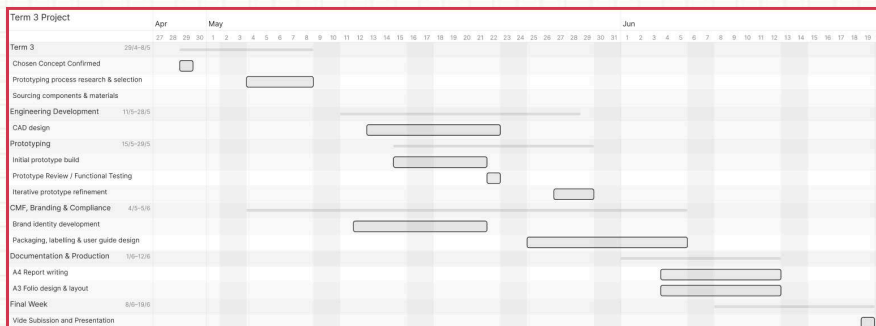
COO

- Conducted Interviews
- Market and Product Research
- Market Commercial context and Benchmarking Slides
- Made Personas for the journey map
- Made an initial Gantt chart
- Completed Teardown

Rhys Wijeratne

CTO

- Primary User reach out
- Conducted Interviews
- Both Project Teardown and Project Aim Slides
- In charge of teardown research and analysis during teardown



Term 3 Gantt Chart was roughly planned using the module handbook however tasks haven't been assigned yet.

Questionnaire

User Evaluation Survey

Student (primary user) Questionnaire

Name: _____

School/Institution: _____

Circle:
Year 10 Year 11
Year 12 Year 13

Do you consent for this data to be used for research and published?
Yes No
_____ signature

Rate each statement from 1–5.
1 being strongly disagree 5 being strongly agree

I would feel intimidated when using this product. 1 2 3 4 5

If this product were available in my school, I would be more likely to use lo-fi prototyping. 1 2 3 4 5

I would feel safe using this product by myself. 1 2 3 4 5

I would feel comfortable using this product without teacher help or setup. 1 2 3 4 5

I would need training or significant experience to use this product effectively. 1 2 3 4 5

This product would help me turn design ideas into lo-fi prototypes. 1 2 3 4 5

I would feel stressed about damaging my prototype while using this product. 1 2 3 4 5

This product would help me create both geometric and organic shapes more effectively. 1 2 3 4 5

Fri Form

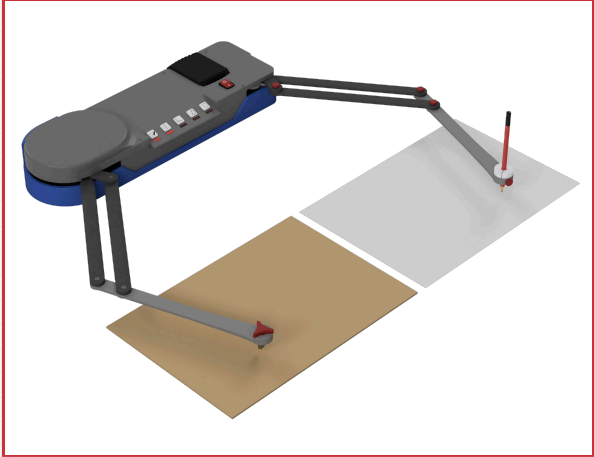


Trace Cut

Mayli has mitigating circumstances and an extension on Individual so CAD and Final Sketches have not been completed yet. Idea is based around cutting curved and geometric shapes in cardboard cleanly and easily.

This will be updated once she has handed in her individual slides.

Perfect Pantograph



Teacher (secondary user) Questionnaire

Do you think this product is safe to use?

Would you trust a student to use this product independently?

Do you think this product would reduce minor injuries such as cuts or burns from craft knives or glue guns?

Do you think this product would create a messy workshop environment?

Do you think this product could be used effectively in a secondary school workshop?

Do you think this product would be an affordable long-term investment?

Does the upkeep of this product seem difficult to manage?

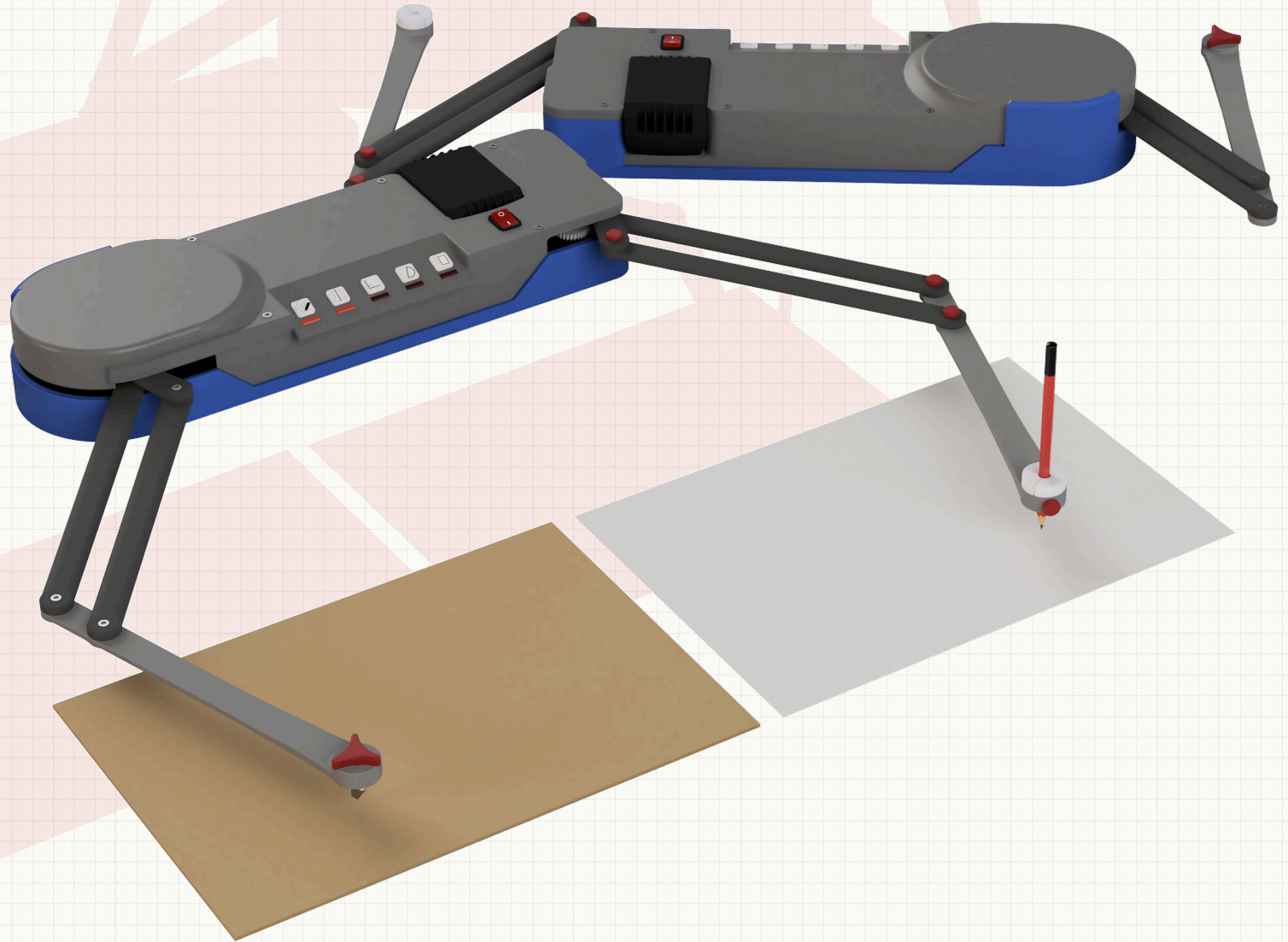
Circle:
YES / NO
YES / NO
YES / NO
YES / NO
YES / NO
YES / NO
YES / NO

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Perfect Pantograph



Ruaridh Murdoch
Individual

Individual Focus

Ruaridh Murdoch

Further Development of Opportunity

Goal and Direction

Primary Goal

Group Aim

Encourage students to utilise lo-fi prototyping stage to iterate, explore and evaluate ideas better, providing better practical hand-on technical skills

Students often struggle to turn sketches into accurate physical models. Cutting cardboard or foam with craft knives requires a lot of manual control, and small mistakes can ruin parts. This often discourages experimentation and iteration.

Design Direction

Individual Aim

My focus is improving the transition from sketch to prototype, concentrating on cutting and forming processes that reduce user error while still allowing students to control the shape they create.

Design Considerations

Safe for Classroom Use

Workshop tools already cause many minor injuries. Survey results showed 65.2% of students reported cuts or burns. Any solution should reduce exposed blades, slipping, and burn risks so it can be safely used by students aged 14–18.

Enable Student Independence

Teachers cannot assist every student immediately during lessons. Tools should work without teacher setup so students can continue modelling without waiting.

Quick and Simple to Use

DT lessons are short. Tools with long setup times reduce making time. The solution should be quick to start, easy to learn, and easy to reset between users.

Reduce Manual Skill Required

Accurate cutting currently depends on manual knife control. This makes curves and complex shapes difficult. The design should reduce the level of precision required from the user.

Clean and Manageable in Workshops

Foam modelling produces dust and debris which teachers identified as messy and a potential safety issue. A solution should contain or reduce waste during use.



Cardboard Model - Bro Edern



Cardboard Model - CLSG



Foam Model - Bro Edern

Technical Considerations

Foam Fume Management

Heated foam cutting produces harmful fumes. Most systems vent outside, which limits where the tool can be used. Adding built-in filtration allows safe indoor use in classrooms.

Battery Compatibility

Use standard cordless drill batteries (~12–20V) that schools already have. This allows quick swaps and no separate power unit. The device can sit directly on the battery or have it slot in, with voltage stepped down for electronics and motors.



Concept Exploration

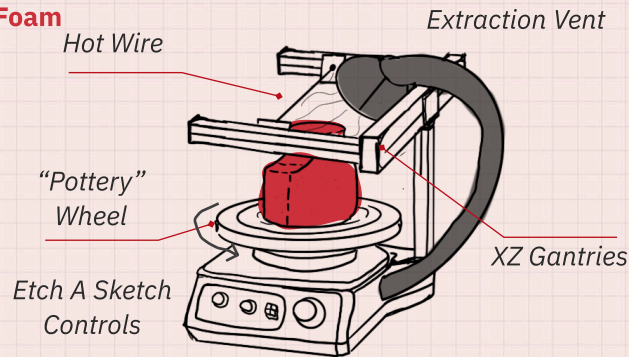
Ruaridh Murdoch

Creative Ideation from Insights

■ Cardboard ■ Foam

Vase Former

Foam

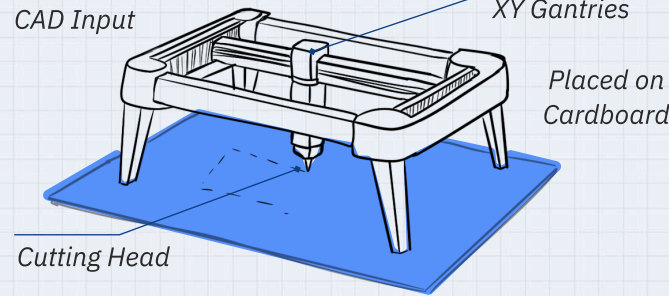


A foam shaping machine inspired by a pottery wheel.

The student mounts a foam block and adjusts the hot-wire cutter while the platform rotates. The platform can also rotate in steps to create geometric forms. An extraction vent removes fumes during cutting.

CAD Cutter

Cardboard

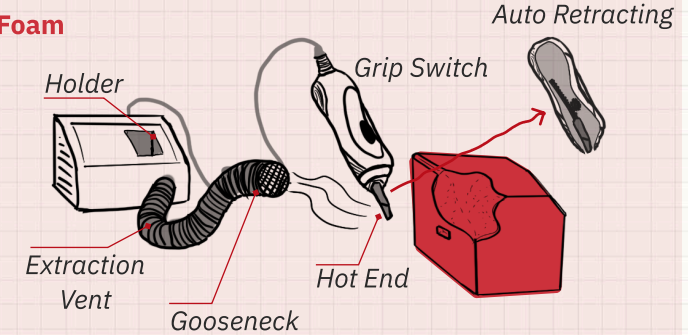


A lightweight CNC cutter designed for quick classroom use.

Students place the device on top of cardboard and send a simple design file to cut or score parts automatically. This allows accurate model components to be produced without manual knife work.

Safe Hot-End

Foam

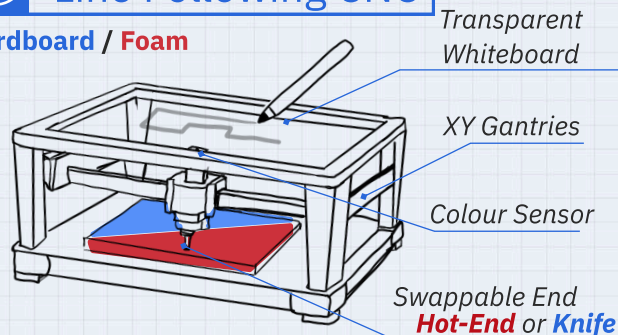


A handheld foam carving tool designed to make detailed shaping safer and easier.

The heated tip only extends while the grip is held, retracting when released. An extraction unit removes fumes and provides a safe place to store the tool when not in use.

Line Following CNC

Cardboard / Foam

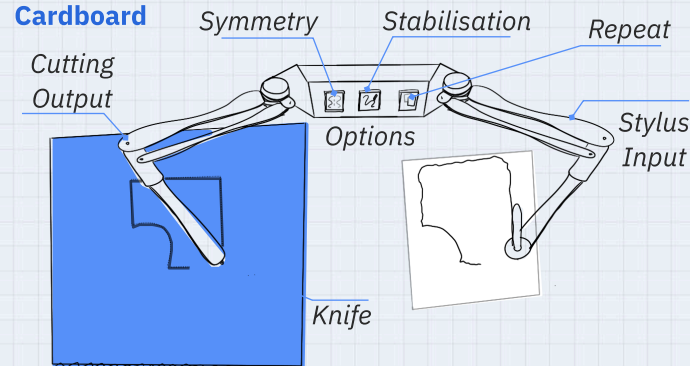


A drawing-guided cutting machine that follows lines sketched by the student.

Students draw their path on the whiteboard. A colour sensor follows the line and guides a motorised cutter to reproduce the shape in foam or cardboard below. No CAD or precise knife work required.

Perfect Pantograph

Cardboard

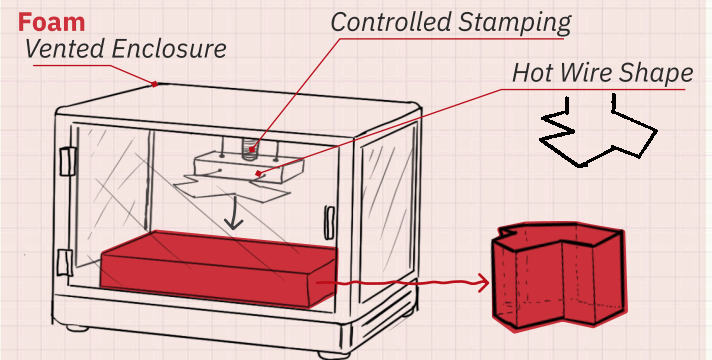


Portable system that turns drawings into precise cuts.

The student moves a stylus to sketch the shape they want, while a mirrored arm performs the cut in cardboard. Stabilisation, symmetry and repeat options help produce cleaner and more consistent parts.

Cookie Cutter

Foam



Cutting press that uses custom bent heated wire.

Students create their own wire outline and insert it into the machine before pressing it through the foam. This produces clean, repeatable shapes while containing fumes inside the enclosure.

Concept Selection

Feedback & Selection

Scoring Matrix

Analysed all six concepts using four criteria derived from the research and project constraints. Each concept was scored from 1-5 for each criteria, scores were then weighted and summed to produce a final ranking.

Criteria		Weighting
Impact	How much the concept improves students' ability to create accurate prototypes.	35%
Feasibility	How realistic the concept is to engineer and prototype.	30%
Safety	How safe the concept is for use in a DT workshop.	20%
Control	Whether the student still controls the design outcome.	15%

Concept	Impact	Feasibility	Safety	Control	Score
Vase Former	4	3	3	4	3.45
CAD Cutter	3	4	4	2	3.35
Safe Hot End	4	5	4	4	4.35
Line CNC	3	3	4	3	3.20
P. Pantograph	5	4	4	5	4.50
Cookie Cutter	3	3	3	2	2.84

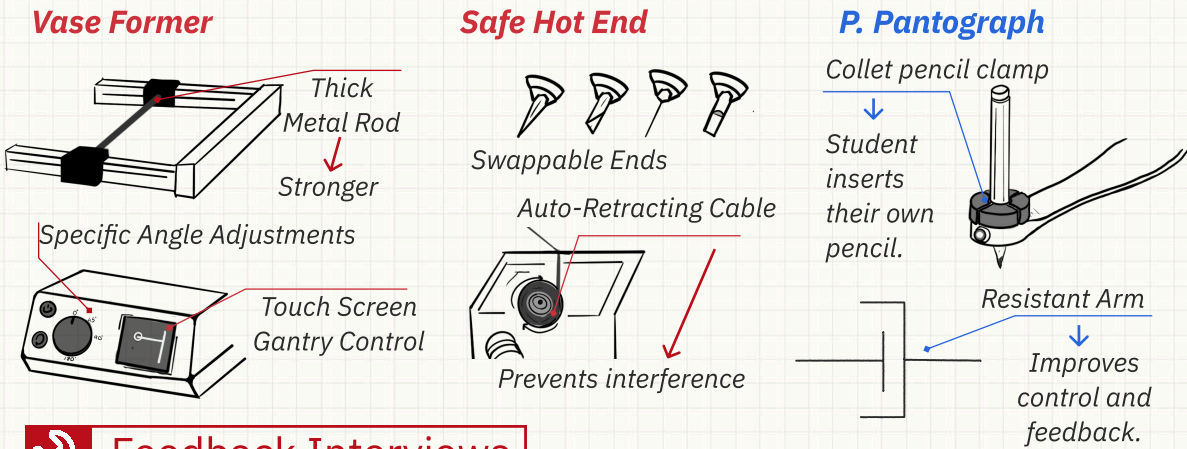
The three best-scoring concepts were selected for further development:

Vase Former **Safe Hot End** **P. Pantograph**

These showed the strongest overall balance and were taken forward for further development.

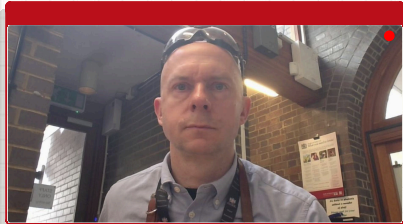
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Further Development



Feedback Interviews

Short interviews were conducted with **Luke Barker** (Head of DT, City of London School for Girls) and two DT students from different schools to gather reactions to the three concepts.



Vase Former

Seen as useful but less exciting. Angle guidance (45° / 90°) could help students cut more accurately.

Safe Hot End

Students liked the idea of carving foam freely. Safety features were seen as helpful for preventing burns.

Concerns about fumes from melting foam. Foam modelling is also less common in schools due to cost, with cardboard used more often.

Perfect Pantograph

Most positive response. Drawing interaction felt intuitive and similar to tools students already use. Helpful for students who can sketch but struggle to cut accurately.

Based on the feedback and scoring matrix, the Perfect Pantograph was selected as the concept to take forward for further development.

Concept Development

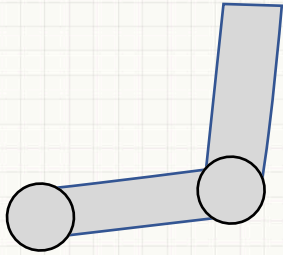
Ruaridh Murdoch

Perfect Pantograph Exploration

Arm

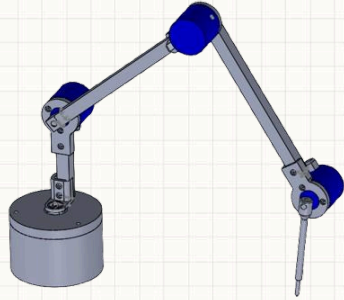
The input arm needs to track 2D position. Three approaches considered:

Planar Arm



Rotary potentiometers at joints. Simple and efficient.

CMM Digitiser Arm



Allows pen angle but adds joints, cost, and fragility

Camera Tracking



No arm needed, but lighting could make it unreliable

Planar arm with rotary potentiometers is preferred as it is sufficient accuracy for cardboard. The cutting arm mirrors the processed input in near real-time, both servos sat at the shoulder to reduce inertia and student tampering, moving the arm with linkages.



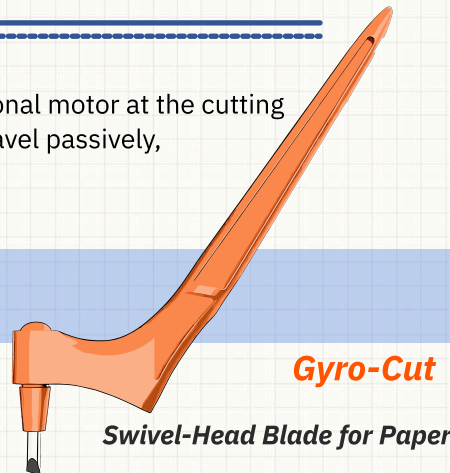
For blade lift, a third servo is needed for pressure control, allowing the device to both score and cut.

For curves, a fixed razor blade requires an additional motor at the cutting head. A swivel blade self-aligns to direction of travel passively, significantly simplifying the head.

Cutting footprint should cover:

A3
AREA

for versatile modelling

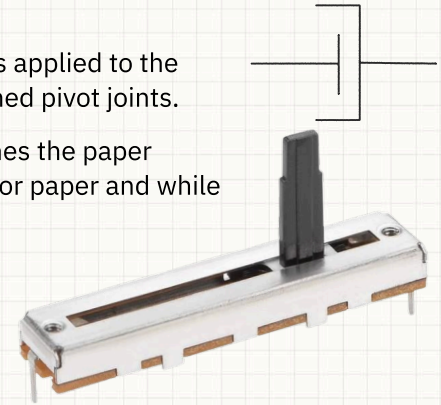


Inputs

To make movement feel deliberate, resistance is applied to the stylus arm via controlled friction through tightened pivot joints.

The system needs to detect when the pen touches the paper without adding weight or electronics to the pen or paper and while allowing different pen heights.

This could be done by measuring vertical movement using a linear potentiometer near the shoulder.



Functional modes, inspired by **Procreate's** input processing:

- **Stabilisation** — weighted moving average smooths input jitter before sending to cutting arm
- **Symmetry** — mirrors path across a defined axis
- **Axis-only** — constrains output to horizontal/vertical for straight cuts
- **Repeat** — stores and replays a path with defined spacing for batch cutting
- **Perfect Circle** — fits a circle to the input gesture

Materials & Manufacture

The housing should be **ABS**. It is impact resistant and easy to mould. The arms would need to be stiffer, flex could introduce path error. Thick aluminium sheet resists this while staying lightweight.

Design for Manufacture:

One fastener size throughout. Consistent wall thickness to avoid moulding problems and snap fit internals to reduce assembly (seen in the teardown).

Design for Assembly:

The interviews showed that students could not confidently change blades on machines like scroll saws, this created an urgent need for a teacher, slowing down workflow.

- *The blade should be easy to swap when it gets dull, having a locking mechanism that students understand.*
- *Electronics access should require a different tool so teachers can get in but students cannot.*

Technical Design

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3D Model, Features and Rationale

Perfect Pantograph

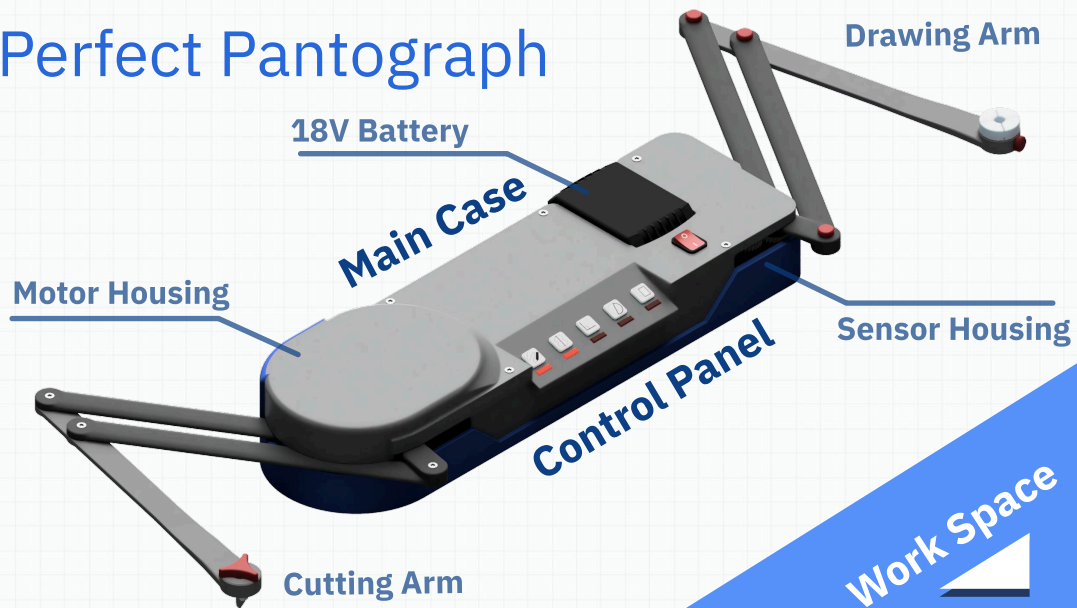


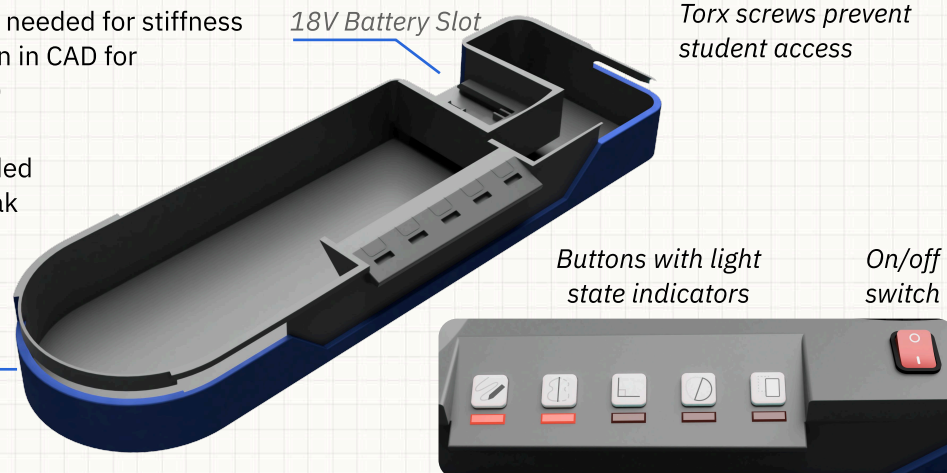
Image of Design is in the Packed State

Case Design

ABS, 3 mm wall thickness for injection moulding

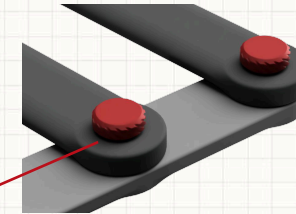
Ribs likely needed for stiffness (not shown in CAD for simplicity)

Overmoulded ABS in weak areas for strength + colour separation

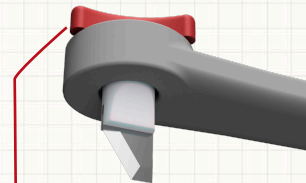
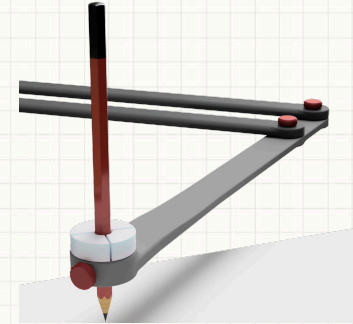


Arm Design

Knurled tighteners for adjustable resistance for control



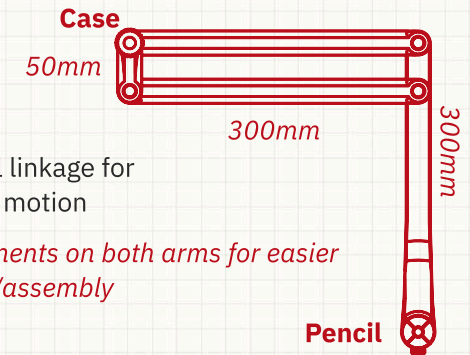
Collet clamp, student inserts own pencil



Swivel blade on bearing, screw top to remove blade system.

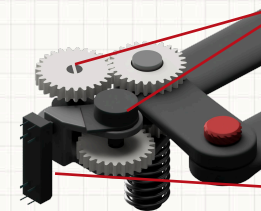
4-bar parallel linkage for stable planar motion

Same components on both arms for easier manufacture/assembly



Mechanisms

Drawing Arm Sensors



10kΩ Rotary Potentiometers
Offset pots using 1:1 gear linkage

Spring so natural arm position is up

250k Linear Slider Potentiometer

Cased together so it can be moved vertically

20mm vertical travel

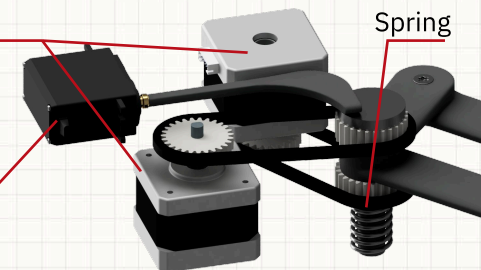
Cutting Arm Actuators

NEMA 17 Stepper Motors

For accurate and strong measurement
Linked using belts to allow vertical movement

MG996R Servo Motor

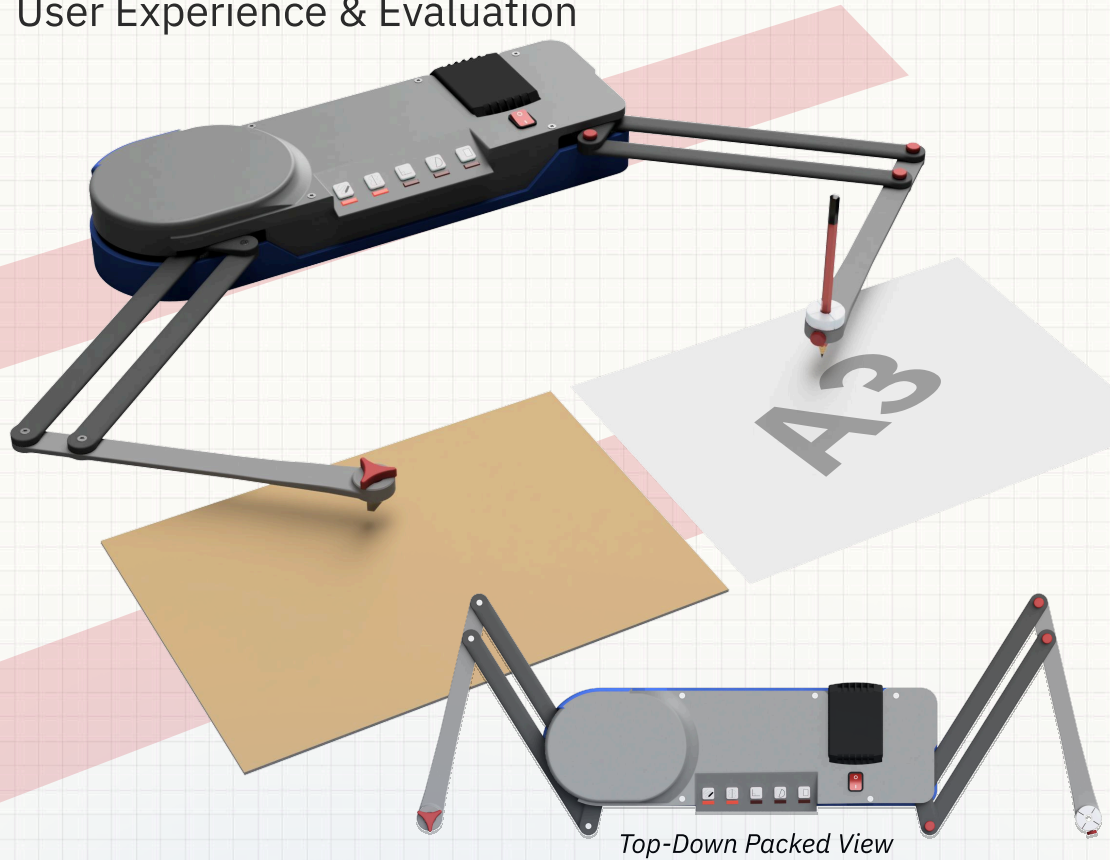
High torque metal geared servo for accurate blade pressure



Hard stops to prevent arm collision

Final Design

User Experience & Evaluation



Instructions for Use

1. Retrieve the tool from storage in its packed state.
2. Place it on the desk and insert the battery.
3. Insert a pencil, tighten the collet, and press it to the paper while turning the tool on (calibrates height).
4. The cutting arm now mirrors your actions. Pressing the pencil down engages the cut.
5. Trace an existing design or draw a new one.
6. Press any of the option buttons to perfect and refine. Press stabilise + repeat to score for folds.
7. When finished, remove the battery and pencil, then return the tool to storage.

You now have clean, accurate cardboard parts ready for modelling.

Ruaridh Murdoch

Product Description

The **Perfect Pantograph** is a desktop cutting tool that lets **DT students translate hand-drawn shapes into precise cardboard cuts**. The student sketches a path with the drawing arm while the cutting arm mirrors the movement in real time, moving a blade through cardboard with **consistent pressure and accuracy**. On-board processing **perfects the input before cutting**, so the output is always cleaner than the hand that drew it. Designed for shared school workshops, it requires **no CAD knowledge, no teacher setup or supervision, and no manual knife control**.

Stabilisation



Smooths shaky input so lines cut cleanly.

Symmetry



Mirrors your path across a central axis as you draw.

Axis Only



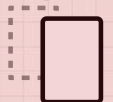
Locks movement to axis for straight cuts.

Perfect Circle



Fits your drawing to a clean circle automatically.

Repeat



Stores and replays the path again for batch cuts.

Evaluation

Students avoid modelling because cuts are inaccurate and take too long. When students trust that a cut will come out accurately, modelling becomes a better part of the design process rather than an obstacle to it.

Safe

No handheld blade reduces the risk of cuts and slips. The blade remains exposed during cutting however, so a blade guard is identified as a development priority.

Independant

No teacher setup or supervision required. Students can work continuously without waiting.

Quick and Simple

Fast setup, no CAD needed. Maximises making time in short lessons.

Reduce Manual Skill

Accuracy comes from the mechanism, not the user's hand.

Clean

A sharp blade cutting cardboard produces minimal debris, making workspace tidy.