*A *.pptx version of this file, and several other associated resources, are available [here]*

Ben Mullan

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Candidate Number:	**6203**
Institution:	**John Hampden Grammar School**
Centre Number:	**52415**

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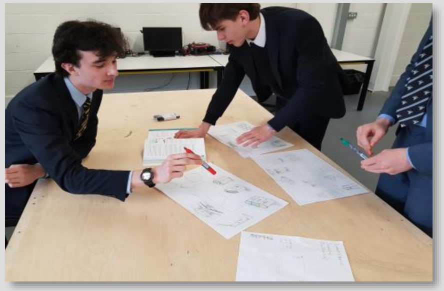


Exploring the Contexts (1)

Introduction

Here I explore different contexts, in an attempt to find a suitable area in which to solve a problem. To this end, I shall create a "Mind Map" for each of three "*contexts*"; {"At Home", "At School", "Local Community"}. In so doing, I will be able to see which places, people, and processes could benefit from having a product specifically designed for them, to solve an identified problem. I am also undertaking broader research related to the contexts, concerning topical and current issues in the wider community – this aids in the generation of ideas and provides an insight into the needs of a large number of different people (some of whom may even be stakeholders in the product).

Getting into a house
- Key box for people with arthritis

Residential security
- Alarm
- Camera

Market Potential

There are some competitors in the interactive instrument market, with Casio's light-up keyboard, so I would have to look elsewhere in this category.

Next Steps

Next I shall investigate the [At School] Context…

At Home

Playing, Learning, or teaching a Musical Instrument…

Music
- Playing the Piano
  - **Recording songs played**
- Musical Instruments
  - **Portable version of large instrument ?**
  - A thumb Piano
  - A wind instrument
  - Learning to play an instrument
    - Interactively?
      - Lights and sound
- **Listening to music**
  - in small spaces – electrostatic speakers
  - A keyboard-surmounting device to
  - …play a keyboard or other
  - …instrument automatically

Sitting at a Computer
- Ergonomics
  - Using a Keyboard more comfortably
  - Eye strain
- Cable "management"
  - Clip system for cables
- Adapting other rooms for office use
  - Drawer for keyboard which attaches to existing desk
  - Laptop dock for a Television
- **Charging electronics and computers**
  - Unified charging station

Server Rack cable management

Automating Network Administration Processes ?
- The movement of Servers in and out of a rack
  - Wheeled, server-bearing trolley?

Numerous household tasks could be made faster or easier with the right product. Everyday activities could be made more enjoyable by removing laborious or repetitive subprocesses and automating them…

In the Kitchen
- Washing up
  - Dispensing soap (automatically?)
- Eating
  - Food packaging is often plastic – **wasteful**
- Smaller versions of existing kitchen Utensils, for small kitchens
- Oven safety

8 Unusually Large Musical Instruments

Top 6 Problems With Cable Management For Your Desk

Greg Knighton

What a Waste: An Updated Look into the Future of Solid Waste Management

Article Reference Links on "Sources" slide at end

Wider Research

A current and topical issue both around the home and in wider society is that of recycling. In the UK alone, over 200,000,000,000 grams of plastic packaging waste is produced each year, whereof only ~67% is recycled. In the aftermath of several failed biochemical experiments to create an organic packaging material of my own, the possibility of mitigating this waste continues to intrigue me and provide opportunity for a designed solution.

Around the House…

In researching this context, I considered some of the activities performed frequently around my household. One such activity is that of ***playing the piano or other musical instruments***, wherefor there is a need to keep a log of what is played, because none of the Piano's players possess the ability to decipher or produce sheet music themselves. Also of interest, were the resident Server Racks and associated wriggling swarms of cables, which could certainly do with having some verity of cable management solution put in place. Because ***Rack-Mount Servers are also very heavy***, I considered the possibility of having a movable wheeled trolley, perhaps with the integrated ability to raise and lower a bed on which a Server could rest during transportation.

Exploring the Contexts (2)

Introduction

The "At School" context presented a number of interesting physical settings to solve problems in. Most products designed for use in a school will be subject to somewhat harsh conditions, due to the care and attention typically delivered by groups of students of this age group, over several years. Therefore, it is important to consider that any product intended for use in such an environment ought not to be too delicate or fragile, or predisposed to becoming dysfunctional after a period of time. I shall explore these settings and derive from them any common themes, into which I shall undertake some further research to establish what is most important for this context.

Article Reference Links on "Sources" slide at end

The Benefits Of Automation In Today's Workforce

The Effect of Poor Organizational Skills

Small Business | Human Resources | Organizational Skills

Have you thought about your greenhouse watering strategy lately?

Wider Research

One reoccurring theme in the realm of the school as a design context, was the idea of ***automation***. This, it seems, is largely due to the many systematic and repetitive processes which occur around the site and within departments. Could, for instance, the Greenhouse be watered and temperature-controlled automatically? Might an automatic paper dispenser be of use in the 6th form centre? Perhaps an automated tool organiser or product documentation system would be beneficial for the Design Dept.?

Also of note for this context, is the effect of ***organisation*** on productivity and wellbeing. I have noticed that many students feel more *positive* and ready when entering and working in a *tidy* space, and therefore, this makes for another potential design brief. Research has shown that simply working in an organised environment can increase one's work output by 48%.

Product Documentation in the Design Dept.
- Recording progress in books whilst in a workshop
  - Clipboard
- Photography
  - Movable and flexible lighting solutions (automation?)
  - Animation?
  - Holder or stand or table

Doing schoolwork
- Writing
  - Ink smudges
    - Shirts to repel ink
  - Pencil sharpening
- Hand begins to ache when nearing the bottom of a page
- Typing
  - Wrist strain and RSI

At School

Recycling

A recent innovation within the Design Dept. has been enforcing the separation of materials to be recycled. With separate containers for metal, wood, and plastic scraps, recycling has been made *more* possible – but perhaps not enough of the students know about *how and what* they can actually recycle or reuse…

In the School Garden
- **Disposing of rubbish there**
- **Greenhouse**
  - Watering the plants (automatically?)
  - Keeping plants warm in winter
- Poor internet reception
  - Signal Booster? Passive?
- Storage for outdoor objects
  - Rain protection

Market Potential

A rising trend is the need to properly dispose of rubbish, so this would create many opportunities for a product in this area.

Spending large amounts of time in school has enabled me to analyse routines and problems around the site and classrooms…

In the workshops
- Keeping tools organised
- At the lathes there are often disorganised tools piled on top
- **Facilitating proper recycling and ordering of scrap materials**
- **Making students aware of recycling procedures (?)**
- Sandpaper dispenser

6th Form "Study" Rooms
- Paper dispenser
- SMB Printing Client for iPads
- Laptop usage
  - Sockets available under desks?
  - Docks for full KVM consoles

Next Steps

Next I shall investigate the [Local Community] Context…

Exploring the Contexts (3)

Introduction

This context arguably comprises the largest number of *different locations* to explore. In addition, a large number of *people* could be affected by any product designed herefor, so it is important to bear in mind the widespread effect such products could potentially induce.

Parks and Green Spaces

Since almost all communities and towns have a park or otherwise green space at their centre, this setting provides a heterogeneous variety of design possibilities. I was particularly drawn to the idea of a product which could in some way facilitate dynamic and inter-personal collaboration. A large, comically-round table for instance, might suffice to bring about the next generation of Arthurian knights, or a shelter from the rain or wind could incentivise people who would usually remain indoors, to come outside.

Article Reference Links on "Sources" slide at end

Coronavirus: How do I home-school my children and what does Bitesize offer?

School's Out, Learning's Not!

Covid-19: The challenges of home-schooling

All members of the public use facilities within the local area, so products designed for this context ought to have durability and longevity as an integral part of their design…

Local Community

- Parks
  - Sporting facilities
    - Outdoor storage for footballs, tennis rackets etc.
  - Playground
    - Non-degradable rubber flooring
    - Giant Musical Instruments
      - Different lengths of [metal | plastic] pipes
      - A [water or air]-powered wind instrument (organ?)

- Remote "Learning"
  - Attention Spans
  - Distractions – prevention methods?
  - Sitting for too long; back aches
  - Methods for communicating with school
    - Stand for tablet, for good Webcam positioning
  - Timer for breaks and lessons

- Footpaths
  - Rotting wooden fences
- **Bus stops**
  - Dysfunctional digital timetables
  - Lack of shelter
  - Litter disposal

Bus Stops

Traveling on busses to school on a daily basis has enabled me to take a critical stance hither.

Travelling

I found that another context very closely-linked to the local community was that of travel.

Performing other tasks whilst in transit can be difficult and even dangerous – products could designed to help…

- To School
  - On a bus
    - **Having enough power for laptops**
    - Having your ticket ready
  - In the Car
    - Holding cups or phones

Eco-friendly Transport

As regulations increasingly enforce the use of non-polluting methods of transport, cycles and even electric scooters will become more common.

Market Potential

Because of the large number of commuters taking up public transport (↑08%) and bicycles (↑12%) in recent years, there would be a large customer base for traveling accessories.

- By scooter or bike
  - Mud splatter protection
  - E-Scooters run out of power
  - Holders for Cups or Phones
  - **Navigation**
  - Security
    - Lock
      - Ground-fixed
    - Alarm
      - Internet-connected

Wider Research: Remote Learning

This topical and current issue provides several possibilities. Namely, maintaining a suitable level of concentration, ergonomic and posture correction, and school communications relay methods. I recall - from my own time in Remote Learning - the difficulties associated with sustaining a concentration span, and the challenging task of having to manage and regulate one's own time. A time-keeping device to provide reminders and notifications of scheduled lessons could therefore be useful herefor.

Next Steps

The next step is to narrow this broad set of ideas down, and begin to sketch some existing products in these categories. This will allow me to see potential modifications which could be made to these products.

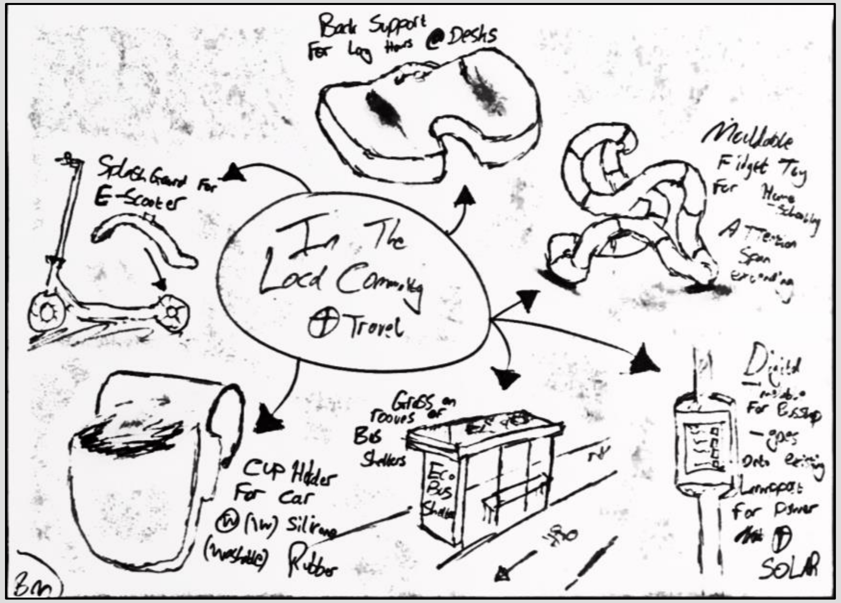
Exploring the Contexts (4)

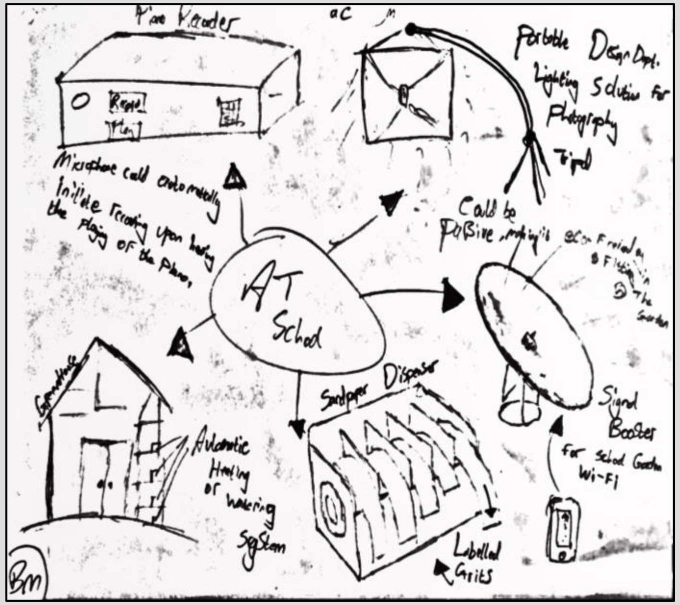
Introduction

From the initial MindMaps on the previous slides, I will now produce some sketches and drawn ideas, in order to further my understanding of the requirements of the most promising contexts.

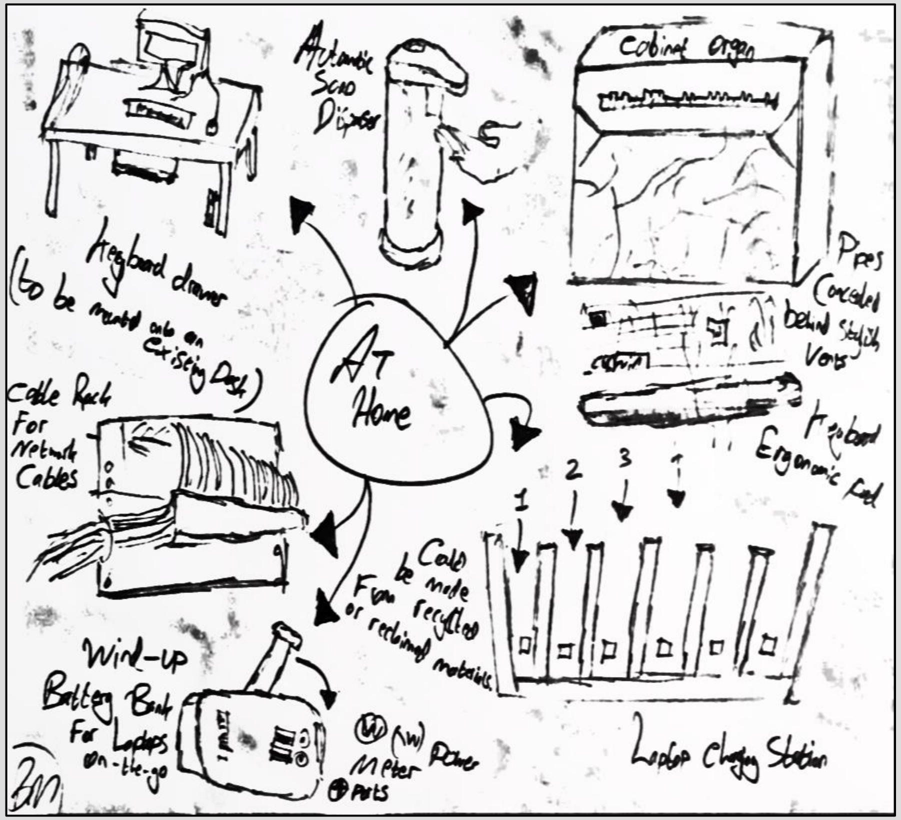
During the sketching process here, I came to the following conclusions:

- The [Local Community & Travel] context seems to inspire products which would be either very small and insubstantial, or very large, and on that basis potentially needlessly-cumbersome to facilitate the fabrication of.
- The [At Home] context has allowed me to explore the widest *range* of design possibilities.
- The [At School] context reveals several exciting areas for further exploration, around several different areas indoors and outdoors.

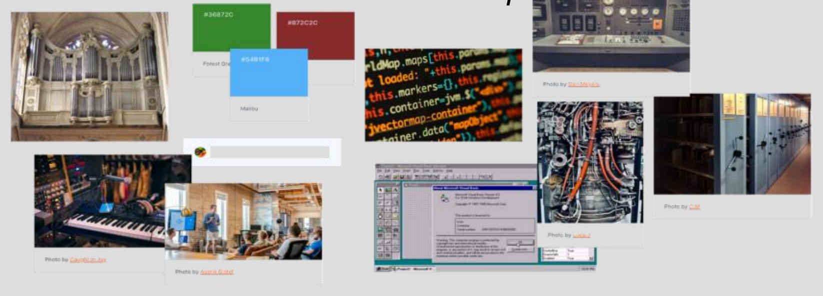




Context	Potential Briefs
At Home	• Design a product to facilitate the adaptation of a desk into an office, or otherwise computer-integrated workspace • Design a product to aid in the organisation of a Server Rack and equipment held therein • Design a smaller version of a conventionally large musical instrument
At School	• Design a product to automate some of the processes required to keep plants alive in the School Greenhouse • Design a product which makes it easier to take photos of a product in the design dept. • Design a product to make it students more inclined to replace a tool after it's use.
In the Local Community & Travel	• Design a product to improve the educational experience of a child who is home-learning during a lockdown



MilaNote Mindmap



Next Steps

A number of the of the ideas on these MindMaps show great potential for further exploration. My next step, therefore, is to settle on the most promising contextual design area, and with this information, identify a suitable primary user.

Design Brief & Identification of Stakeholders

Introduction

From the brainstorming and Sketching process, I have chosen to take forward the [At School] context, due to it having inspired the largest number of worthwhile and exciting concepts. In addition, this context allows me to create both outdoor and indoor products, and even implements the possibility of electronics, or by other means, the automation of processes. Events are beginning to occur around school at a greater frequency, and as such, there is a great and broad window of opportunity within this selected context.

Stakeholders

As a means of identifying stakeholders, I have produced the following list of people for whom such a product may be *of importance*:

- **End users** – current and future Students of the design dept.
- The Design **Teachers and Technicians** at the school
- Skilled and **unskilled workers** who might be involved in the manufacture of this product
- Tool and **Hardware retailers** such as Axminster or ScrewFix or Ikea
- Other environments wherein products are fabricated and|or photos need to be taken of those products E.g. **Studios**

Primary User

I asked Pete Grover if he would be my primary user.
Mr. Grover is a Design Technician, involved with the development of almost all products within the Department, and so is familiar with the problems experienced by students during the processes of the manufacturing and documentation of products. He often oversees younger students documenting their product development, and understands the difficulties involved.

Marketability

The scope for marketing products created within this context is substantial because of the many stakeholders (and thereby customers) who are involved with schools, both directly and indirectly. The product is amenable to being sold both directly to a scholarly institution, and also to associated departments or individuals. The growing importance of digitalisation in schools means that camera-assistive technology has a growing role, and is thus **profitable**.

Having chosen to proceed with the [At School] context, I was most drawn to the concept of producing a product to **aid in the process of the design department's users making or taking pictures of products**. I also discovered several sources suggesting that this is a current and topical area.

Whilst building products, one is often tempted to splay tools and materials around oneself, **disregarding their organisation** and thereby ease of access. I shall herefor explore solutions to this problem of keeping tools organised and yet instantly available.

Mental Health Benefits of Decluttering
Medically Reviewed by Dan Brennan, MD on October 25, 2021

6 Tips on Keeping a Neat & Tidy Workshop
29 Oct 2019

Overlapping this exploratory realm, a product could be designed to assist in the latter stages of a workpiece's development, whereby photographs of the workpiece are required. Such a product could be involved at any one of the numerous stages of the photographic process, from the positioning of the target object or camera, to the lighting or backdrop.

Why Everyone does Lighting Wrong in Photography
And tips on how you can apply them to your photography.
BY DAN RICHARDS | PUBLISHED JAN 29, 2013 1:00 AM

Hold it steady!
Why getting stable shots is so hard

Encompassing both of the above, is the theme of speeding up product development:

Slowing down to speed up
Speeding up isn't the answer. In fact, we find that if top teams slow down, they eventually achieve their obj

How can engineers speed up production?
12 Sep 2019
Professional Engineering

Top 7 Reasons We Accumulate Garage Clutter & How to Eliminate It

Previous Possible Design Briefs

My potential briefs from the last slide – for my chosen context:

- Design a product to automate some of the processes required to keep plants alive in the School Greenhouse
- Design a product which makes it easier to take photos of a product in the design dept.
- Design a product to make it students more inclined to replace a tool after it's use.

Initial Design Brief

Due to the evidence surrounding the topic of making the development of products in a workshop more time-efficient (whilst, at the same time, desiring ever-higher output quality), my brief is to design a product which makes (at least) one stage of the product documentation process more efficient.

The final product should not obstruct any of the existing departmental processes within the workshops, and should be aesthetically tolerable, following the ***[function over form]*** principle. The design ought to also be produced at a similar or lower cost, than that of any existing solutions, because if the school's budget.

Ideas back from Initial Brainstorming:

In the workshops
Keeping tools organised
At the lathes there are often disorganised tools piled on top
Facilitating proper recycling and ordering of scrap materials
Sandpaper dispenser

Photography in the Design Department
Movable and flexible lighting solutions
Product jigs or holders – animation?
Backdrop holder or stand or table

The referenced potential retail Stakeholders:

AXMINSTER Tools & Machinery
SCREWFIX
IKEA

Next Steps

The next step is to converse with the primary user and establish the specific issues they have within the workshops at school. As well as this, I will be doing some research into existing products and therefrom enumerate any "gaps in the market".

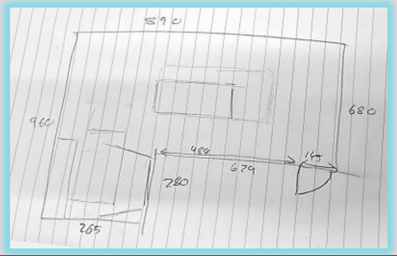
Investigating PU Needs & Wants

Introduction

With a general context chosen, and a PU identified and recruited, I can now ask the PU about the current problems that actually exist within the Design Dept. This shall be done by means of an Interview.

Evaluating the Product Location

The availability of the "6-th Form Room" in design was acknowledged by the PU to be a suitable place for such a photographic setup, not least because of it's close proximity to the rest of the department (including the workshops, whence products to be photographed come). I therefore produced a dimensioned diagram of the room, only to confirm that there is indeed enough space for a product in this particular area.



PU Interview

With the [At School] \ [Design Dept. Processes] context selected, I asked Mr. Grover these **initial open-ended questions**:

- What problems are encountered on a regular basis when students are developing products in the Design Dept.?
- What issues are there with any existing solutions to those problems?
- What basic needs and wants might you have for a designed solution to one of these problems?

PU Need
Ease of use for Students
Size
Aesthetically Pleasing
Relatively Simple
Adaptable and Multipurpose
Ergonomic and Comfortable
Security, Longevity, Sustainability
Weight
PU Score

← I discussed some of these potential needs with the PU…

↑ Click here to Listen ↑

Summary of Responses

During the interview, the Primary User drew attention to the fact that the Design Dept.'s current ***photography setup in particular*** leaves much to be desired, and lots of room for opportunity.

There were two major points concerning photographing products, that Mr. Grover raised:

1. The ***Backdrop system*** is at present inadequate; a system whereby multiple colours of paper could be pulled down, was a suggested solution which the PU mentioned.
2. The camera operator (a student attempting to photograph his work) generally lacks the ability to concurrently hold both a product, and a camera. For this reason, ***shots are not always steady***, and some sort of jig or stand to hold the product or camera was suggested by Mr. Grover to be a potential product too.

The PU added that although there are some solutions out there already, they tend towards being:

- Too expensive,
- Too cumbersome for use in a school environment, or
- Needlessly feature-rich, making the product potentially confusing.

Refined Design Brief

Having collected some data about the desires of the Primary User, I am able to further refine and add the following, to the on-going Brief.

I now know that the final product should not consume an excessive amount of space, and should specifically focus on improving the usability of the *photography* area of the Design Dept.

In addition, the PU mentioned that the product could be multifunctional, and that because "the things being made range from being very small to very large", the product ought to account for varying sizes of products too.

Critical Thinking

Mr. Grover said that a backdrop system could be implemented simply with coloured rolls of paper. It may, however, be the case that such sheets wouldn't be long-lasting, as paper tears easily. Therefore, an improvement on this concept could be to use thick and cotton-reinforced sheets of a more matt-coated material, which may behave more desirably under the photographic lighting conditions in question.

Next Steps

The next step is to establish the requirements of other stakeholders of the product. I shall do this with a Questionnaire.

Existing Products

Introduction

Here I investigate products already on the market, which may meet the Design Brief for Mr. Grover. It is important to do this before producing any ideas of my own, because I need to identify *gaps* in the market, as well as what works well.

This is a standard fashion of Tripod. It works well, and is able to be put away for storage, but, might consume rather a lot of floor space when in use, and even be a trip hazard.

This more sophisticated broadcast Camera Jig is able to be maneuvered by the operator to pan and focus onto different parts of a scene or object.

Perhaps the idea of *moving the camera instead of the product* could be useful.

In doing this research, I also discovered the existence of so-called "bounce cards" and reflectors, which are positioned around the product being photographed, and used for directing the light of a flash onto the target.

A "Turntable" to rotate the target object

This product is a prime example of what the PU may have meant by "expensive" and "more than we actually need". In addition, the setup consumes a large amount of space, the likes of which are unavailable in the 6th Form Room for which I produced the scaled drawing.

Backdrops can come separately in several different colours, but might there be a way to combine all of these into one product?

A Protective enclosure for camera, making it safer in a school environment:

A simple light such as this one could make for a somewhat effective solution to the "inconsistent brightness" problem.

A light of increased complexity resembling the model depicted below has a greater ability to articulate and move to different angles, which would more effectively align with the PU's comment of needing to accommodate different sizes of product.

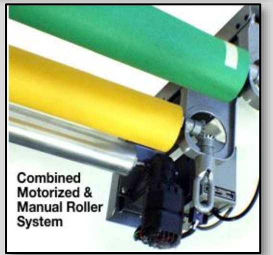
Perhaps the idea of *a light or camera being able to articulate* would be useful.

A1 Paper draws would be suitable for containing backdrop sheets:

A "GreenScreen" can allow any background to be superimposed onto the same physical material, with special, but widely-available, software…

A monitor mounted on a pole would be useful for seeing what the camera sees, and would be out of the way because it is suspended from the ceiling, or by other means, above.

Here is a system for accommodating several different rolls of backdrop for the backgrounds of products. There appears to be a series of black cords which could be used for retracting one sheet of backdrop and releasing another.

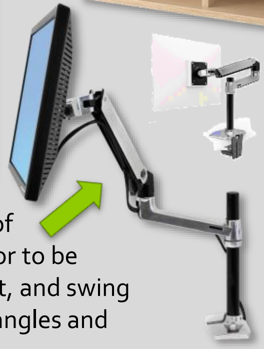


This appears to be an improvement on the cord and pulley system; one or more electric motors automatically deploy and retract the sheets on-demand.

Perhaps the idea of *automating the backdrops* could be useful.

Even just a very simple storage solution like this could be of great benefit to the organisation of cameras and [objects to be photographed] etc…

Camera Cranes such as this one have a counter balance to enable them to remain stationary at any given height and angle, avoiding the tendency to droop back down towards the ground under the influence of gravity.



An articulating arm allows a piece of equipment such as a display monitor to be highly-adjustable, and to swivel, tilt, and swing around to a multitude of different angles and positions.

Ideas to take forward

There are several interesting concepts which I came across by doing this research, and they may be helpful in further developing my product idea:

- Moving the camera instead of the product
- Automating the backdrop positioning
- A light or camera or monitor being able to articulate to different angles and positions, E.g. via an arm.
- Protection or add-ons for an existing camera

PU comments

I asked Mr. Grover about the products on this page - this summarises his comments:

- GreenScreens too large and process of getting background superimposed would be needlessly indirect.
- Needs to store away but still be easily accessible. E.g. Could fold.
- A Backdrop system would need to work with multiple colours of fabric for flexibility.
- Ceiling-mounted could work
- Use light from LightTable – mirrors?
- Articulating arms good for positioning and holding bounce cards or reflectors

Next Steps

The next step is to thoroughly analyse several of these products in order to establish some potential specification points. I will also be getting more of the PU's comments herefor.

Closer Research (1 & 2)

Introduction

Here I review some of the products from the previous slide in more detail in order to establish precise specification points which could contribute to *my* design.

GreenScreen Backdrop Set

(Link on "Sources" Slide)

£25

2 * 3 Meters
Can be packed away

This product is specifically designed to be multi-purpose, as with the correct associated software, *any* background can be superimposed onto the green fabric.

What are the interesting features?

The canvas is very large, and would allow even very large products to be photographed with a consistent background. The PU mentioned that the photographic needs of the Department do vary, so this system could be suitable.

What does the Target Market think?

The PU raised the concern that because of the additional software required to replace the *green* with *a background of choice*, the process of simply photographing a product is made unjustifiably complicated for the majority of scenarios. Moreover, the vibrant shade of green is not by itself a suitable colour for a photo's backdrop without any post processing – so use of the potentially confusing software would be mandatory. Could end up being ripped, or might fall down. The software requires that the screen is setup in a specific, consistent manner. Software ought to demonstrate itself, and may have a rather steep learning curve.

Which Materials have been used in the products Construction?

The canvas itself is of a manmade polyester construction, and is reported to be "tear-resistant". The framing and stands are painted mild steel, so ought to be sufficiently strong. The product is somewhat cumbersome due to the size and weight of these materials, and the green on black is not the most aesthetically-pleasing combination.

What do the reviews say?

The reviews mention the "nice solid frame" and "quick delivery", but also comment on the poor overall quality of the metal components. This may be due to this specific set being on the lower end of the market. Even despite the low cost, this product is not praised for its value.

Overall Conclusion

This product appears to meet the PU's request of having a multipurpose solution, but might take up too much space when in use and be difficult to disassemble for storage. Requiring specialist software is also a concern when it comes to students using the system.

Specification Points & Ideas to take forward

- Being able to **fold** the frame away – space-saving design.
- Potentially: A tear-resistant greenscreen material (for background superimposition)

Electric Photography "Turntable"

(Link on "Sources" Slide)

£40

30 CM Diameter
Adjustable speed

With the aid of this product, the camera operator needn't worry about capturing all the required angles of the target object; the automatic turntable slowly rotates its upper plate to show multiple sides of the product in question.

What are the interesting features?

Quickly and efficiently capturing several different sides and angles of a product is made possible in this instance by placing the product onto a rotating surface.

What does the Target Market think?

The PU commented that one limiting factor of this product may be the size of the upper plate onto which the product can be placed.

Which Materials have been used in the products Construction?

Due in part to the plastic injection-moulded construction, the turntable is rated to hold no more than 25 KG. This would in fact be perfectly adequate for the majority of scenarios in the department.

What do the reviews say?

65% of the reviews award the product 5 stars, describing it as "easy to use" and "sturdy". Other reviews however, mention that it is "flimsy", "defective", and in one instance "broke after 20 revolutions with some magic smoke". Therefore, the quality of inexpensive photography products, such as this one, raises several questions concerning how safe they might be to use in a school, and how long they might last.

Overall Conclusion

This product is aesthetically fitting for the room in question, would – judging by the price – not be too expensive to manufacture, and is not too large, so could be easily stored in the room when not in use. However, its plastic construction raises several environmental concerns, and the dubious reliability of the mechanism combined with the potential safety concerns of a mains-powered spinning surface being in the same room as some [year 9]s makes this product somewhat unideal, in terms of meeting the PU's needs the most effectively.

Specification Points & Ideas to take forward

- A compact and space-saving design
- Using cost-effective materials, to create an ultimately inexpensive product

Closer Research (3 & 4)

Wall-Mounted shelving unit

(Link on "Sources" Slide)

0.7^2 * 0.35 Meters
Wall-Mounted

The 6th Form Room in design

£50

One very simple but nevertheless efficiency-hindering problem with the room at present, is that there isn't really any proper storage for cameras, or the objects being photographed, or other photographic equipment which the department may accumulate over time. Therefore, a storage solution such as this segmented shelving unit would be of great benefit to the set-up.

What are the interesting features?

This particular shelf is in fact wall-mounted and so saves even more space (something there is a by-no-means superfluous quantity of in the room).

What does the Target Market think?

Mr. Grover was interested in the idea of this storage solution, particularly because it is wall mounted and thereby even more space-saving in design. There are several walls in the room which would be suitable to accommodate this sort of unit. The PU also quite likes the wooden look and feel of this product.

Which Materials have been used in the products Construction?

Ikea have used veneered "oak effect" chipboard in order to keep the costs of this product down. For this reason, the product is also not of a particularly good quality of construction.

What do the reviews say?

Despite the ostensibly cheep choice of materials, the reviews award the product 4.3 of 5 stars. It is allegedly "Easy to assemble" and "Good value for money".

Overall Conclusion

This product would work well in the space available, provide enough storage for most of the current needs, and also add to the aesthetic appeal of the room.

Specification Points & Ideas to take forward

- Wall-Mounting as a means of space-saving or protection of the product?
- A Wooden "Look & feel" – Any product I make should be Aesthetically-pleasing.

Articulating Monitor Arm

(Link on "Sources" Slide)

70 * 50 CM
Fully-Adjustable

£200

Being able to view the frame of the camera prior to the shot being taken would be of great benefit to an operator because of the conventionally small size of the view finder, and sometimes awkward angles the camera is held at.

What are the interesting features?

This arm can swivel, tilt, and swing around to a large number of different positions. In addition, the monitor-interfacing plate is of the "VESA" standard, and is therefore compatible with almost all computer monitors, including those already owned by the school which saves costs.

What does the Target Market think?

The PU was really drawn to the idea of a solid and yet flexible solution like this. He remarked **that the clamping system integrated into the stand** would also be a convenient way to attach this sort of product to an existing surface, without having to first drill holes or perform another permanently-deforming procedure.

Which Materials have been used in the products Construction?

Ikea have used veneered "oak effect" chipboard in order to keep the costs of this product down.

What do the reviews say?

With 4.9 of 5 stars, most of the reviews acclaim the product to be of a very high build quality, and even imply that the durability of the arm could be PriceTag-justifingly high. In addition, the quality of the product is commended due to its metal construction and durability.

Overall Conclusion

This product is designed to be added onto an existing setup. In fact, this Arm does not include a monitor at all, which means that any product complying with the VESA standard mounting system could be attached to the end of the arm. This makes the product somewhat multifunctional, in addition to having a simple and clear intended primary use.

Specification Points & Ideas to take forward

- The product I end up making should be unique, as a means of ensuring successful entry into the market
- Having a multifunctional product, E.g. via a standard mounting system
- Being able to clamp or attach the product to an existing surface or structure.

Next Steps

The next step is to gather some feedback from wider stakeholders of these sorts of products, and evaluate this data for the benefit of my Product's Development.

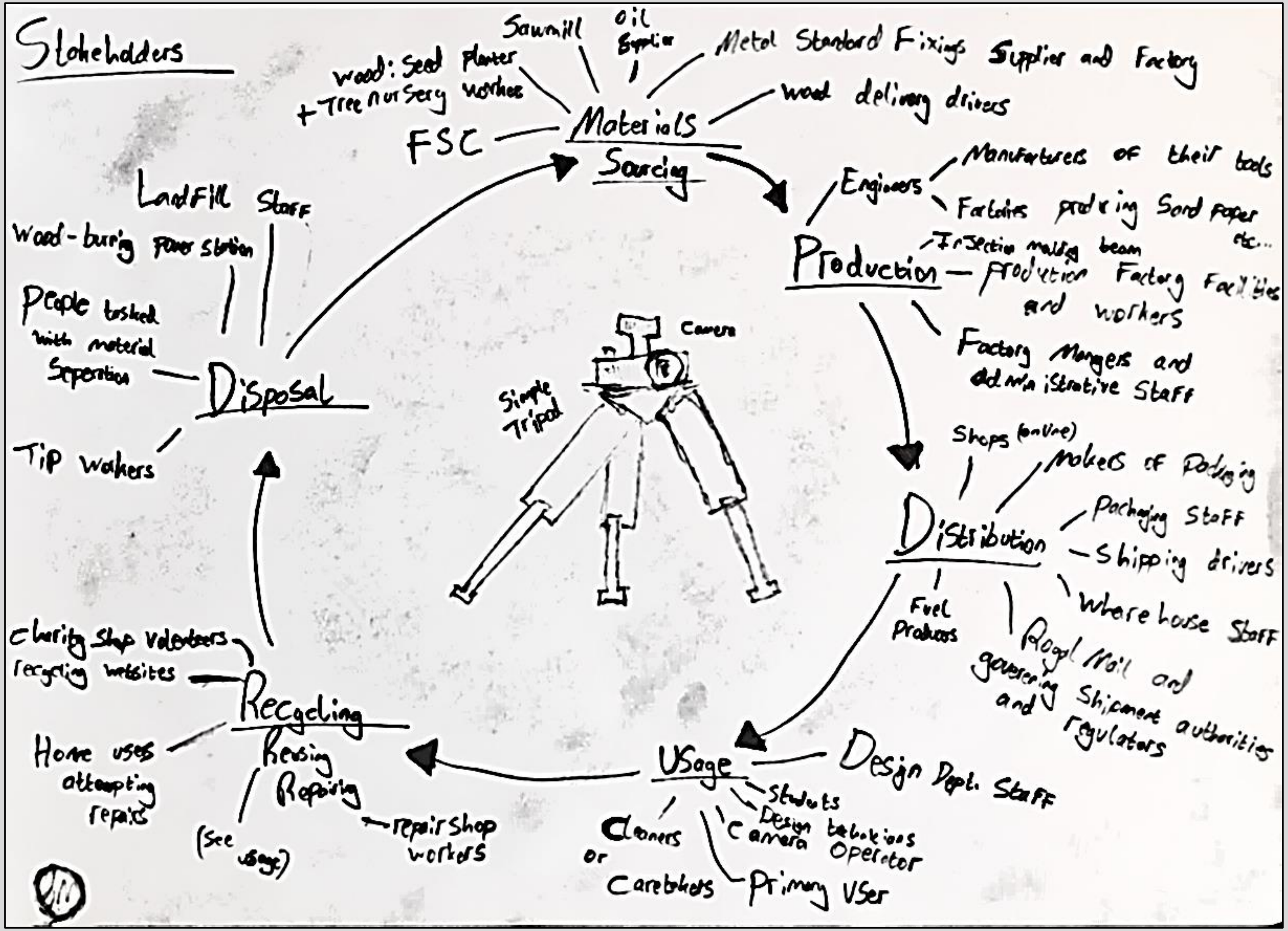
Wider Stakeholders (Questions)

Introduction

It is important to establish the requirements of the wider *stakeholders*, which is in effect a term encompassing anybody for whom this product is of significance.

Identifying the Stakeholders

As a starting point, I produced a MindMap around an example product which might suit the PU (this is just an example product and is not indicative of intentions to make it). Surrounding this, I enumerated any people, groups, or businesses who might be in some fashion affected by the production, distribution, usage, or disposal of the product in question.



Research of one's own

I felt that since the product would in fact spend most of its life amongst the stakeholders of the "usage" stage, I ought to interview some of those stakeholders. Namely:

- Students
- Design Technicians
- Teachers and Staff
- A Camera Operator
- Cleaners of the room
- Caretakers | SiteTeam
- (Potentially) The Art Dept.

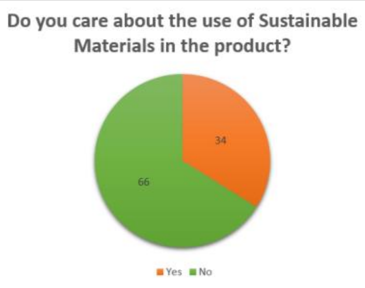
Naturally the PU is also included in this *usage* category, but more extensive research is occurring separately for this, most significant of stakeholders.

To gather research from these stakeholders, I devised a **questionnaire** with the following questions:

- *What (features) would be important in a photography-assisting product in the design dept. for you?*
- *What challenges might you face with your interactions with such products?*
- *To what extent would the size of the product matter?*
- *How frequently might you interact with the product?*
- *What do you think leads to products becoming broken over time around the site? How could this be addressed during the design process?*
- *How could the current aesthetic "feel" of the room be complemented instead of disturbed, by a new product.*

Wider Stakeholders (Answers)

Responses
With the responses from the questionnaire in, I can analyse carefully the needs of this wider group of people, and thence derive and delineate some requirements to add to the overall design brief.



I asked these stakeholders about any sustainability concerns they might have for the development stage, and created this chart showing the proportion who feel this is important. I can see that *I will need to consider and research sustainability* for this project.

Photography & Art Student (Andrew P.)

Since the Art Dept. within school does some photography, I felt that I could gain some important information and requirements from a student studying the subject. In addition, it is possible that the art department would make use of the design departments photography facilities, if they were improved. Andrew commented that **stability of the camera** is key, especially when performing more complex shots such as "long exposure" ones – this isn't something which would be done particularly frequently, but some students may wish to attempt more sophisticated shots from time to time. Capturing products from **different angles** was another point raised by this stakeholder, partly because of the need to sometimes make small animations or timelapses of an object. Other problems with existing photographic equipment mentioned included:

- Lighting fixtures sometimes get in shot – behind-camera light?
- Lens "glare" in bright natural light
- **Needs ergonomic or vibration-dampening handle**
- Too cumbersome
- Not durable enough – shouldn't have easily-broken parts

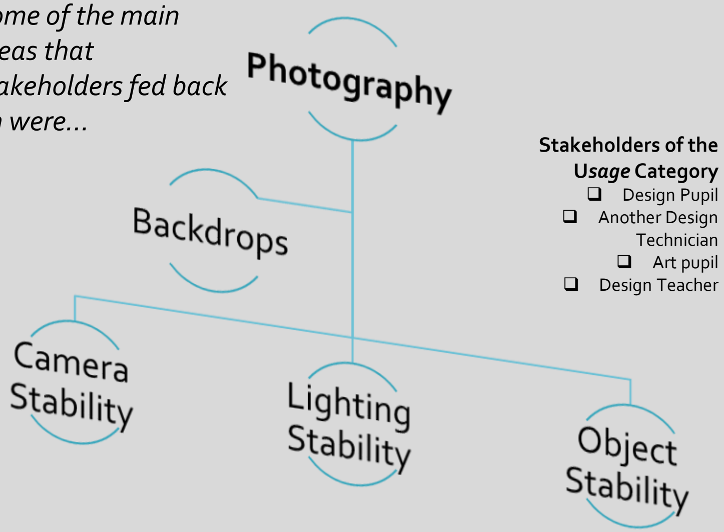
It was also noted that some difficulty can be experienced when looking through the (really rather small) viewfinder of a camera for an extended period of time. Herefore, a **larger monitor to show the real-time view of the camera** would be of some benefit to the operator. This, it seems, is especially prevalent when attempting to get shots from very low, or very high, angles.

Design Technician (Mr. Barnbrook)

Mr. Barnbrook is one of the Design Technicians in the Department, overseeing the construction of most products of students from all year groups. Owing to this, he is aware of the **potential requirements** for a large variety of pupils from all parts of the school.

- Height-adjustable for different ages of students
- Holds expensive camera very securely
- Stable
- Not bothered about colour
- Non-reflective and shouldn't look peculiar if caught in shot
- Different mounts for different cameras and phones and laptops
- Anti-vibration
- Bolted to table so can't "go walkies"

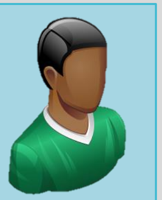
Some of the main areas that stakeholders fed back on were…



Stakeholders of the *Usage* Category
- ❑ Design Pupil
- ❑ Another Design Technician
- ❑ Art pupil
- ❑ Design Teacher

<u>Mr. Grover Feedback 08-03-2022</u>
- GreenScreens too large and process of getting background superimposed would be needlessly indirect.
- Needs to fold away but still be easily accessible. Could Fold
- Backdrop system needs to work with multiple colours of fabric for flexibility.
- Ceiling-mounted could work
- Use light from LightTable – mirrors?
- Articulating arms good for positioning and holding bounce cards or reflectors.

Design Pupil (Noah D.)



As a design student, Noah is exactly the sort of pupil who may end up using the photography solution after it is designed and built. Therefore, it was important to gather some of his input.

He mentioned that **the focus of the camera** may be a concern – a point which none of the other stakeholders had raised, and I had not hitherto considered. Whilst many modern smartphones have an AutoFocus feature, some of the larger "DSLR" cameras used in school require manual focusing, so this is still of relevance. In addition, Noah felt that the **natural light** in the room ought to be taken advantage of; it adds a certain authentic touch to photographs, and is more eco-friendly too. The aesthetic *theme* of the room in its current state, would, in this stakeholder's opinion, be complemented by a contrasting colour to the currently ubiquitous white therein.

Next Steps
Next, I shall collate the PU and Stakeholders requirements, all onto one slide.

PU And Stakeholder Requirements

Introduction

Here I more definitively state what the PU's non-technical requirements are. The requirements here are a serialisation of what the mentioned by the PU and wider Stakeholders **during the interviews** and conversations we have had.

PU Non-Technical Requirements

General:

- ✓ *[!Important]* The product **assists design students** in the process of documenting their projects photographically
- ✓ The product should be **extensible** and **adaptable** to different use cases within the photographic process (e.g. holds either a camera, *OR* a light…)
- ✓ The product is suited to, and can be used by, a range of **different ages** of student (e.g. by being height-adjustable)
- ✓ *[!Important]* The product must **not consume too much space** (anything more than ~ ½ M^3)
- ✓ The product should have an **aesthetically unobjectionable** (tolerable; utilitarian) design – possibly complementing other items in the 6th form design studio where the product is to be used. In other words, its visual appeal isn't the top priority, but ought to be nevertheless inoffensive and almost innocuous
- ✓ *[!Important]* The product should be made from **materials which are *known* to be durable** and long-lasting; the product must withstand the environment of a secondary school, wherein there are –from time to time – bouts of boisterous juvenile behaviour.

Sustainability:

- ✓ Where possible and appropriate, the product should me made from **recycled, partially-recycled**, or otherwise sustainably-sourced materials. The usage of sustainable materials should not, however, compromise the durability or robustness of the product
- ✓ *[!Important]* Any Plywood should be sourced from an **FSC-certified** supplier
- ✓ When disposed of, the product should not have any deleterious effects on the environment

Anthropometrics:

- ✓ Any **openings or pockets** in the product ought to be at least 13cm wide, and 5cm deep (from the front to back edge)
- ✓ Any **handles or grip points** should have a ~2.5cm bulge and be ~10cm in length (See forthcoming Ergonomics Research Slide…)
- ✓ *[!Important]* **Corners should be rounded**, sanded, or chamfered, in order to make the product comfortable to hold and to avoid potentially-dangerous sharp edges
- ✓ The product should not be intolerably heavy, should it need to be lifted (less than ~30 KG)

Wider Stakeholder Requirements

{Many of the PU Requirements, and…}

For Students, Staff, and Institutions:

- ✓ The product should be relatively **affordable (Less Than £100)** (bearing in mind that non-profit institutions such as schools are a primary target market)
- ✓ *[!Important]* The product should be **easy-to-use** for students; it must not be overly complicated, and should have a self-evident (ideally entirely axiomatic) function
- ✓ The product should not be able to be stolen easily
- ✓ The product does not block out so much **natural light** as to obstruct the operator taking a photograph
- ✓ If the product holds a camera, it must keep this **camera stable**, and allow steady photographs to be produced. It should also offer a reasonable degree of protection to that camera, and prevent it from being easily damaged
- ✓ The product should be **principally self-integrated**, and not have a large number of losable components
- ✓ *[!Important]* Should any **assembly** of the product be required, this should be **simple and approachable** for a relatively inexperienced adult. The focus on simplistic assembly is not, however, so paramount as to take precedence over making the product strong and robust
- ✓ If the product is **mounted to a wall, ceiling**, or other pre-existent structure in the room, this structure should not be permanently and irreversibly damaged
- ✓ Where possible and appropriate, the product should ideally comply with existing standards (e.g. VESA or the standardised camera-to-tripod screw thread size)
- ✓ The product should attempt to avoid implementing any needlessly-frustrating procedures

AXMINSTER Tools & Machinery   SCREWFIX   IKEA   …

For the Retail Stakeholders:

- ✓ The product should be easily **packageable** and able to be shipped or transported
- ✓ At the end of its service life, the product – and its packaging – must be **disposable by commonplace recycling services**. (E.g. Could use *biodegradable* packaging)

Next Steps

The next step – just before starting to experiment with Initial Ideas – is to conduct some ancillary research to enrich the designing process. I shall use my knowledge of the needs of a variety of stakeholders, in order to research the most relevant materials, techniques, and factors.

Wider Issues: Sustainability

Introduction

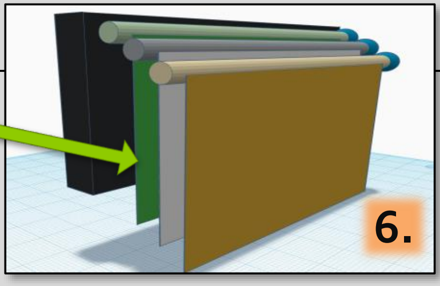
Just before I get some feedback for the Initial Ideas, I will undertake some supplementary research into which sustainable materials might be suitable for use in one or more *of* the Ideas.

Recycled Fabrics

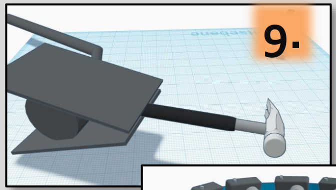
In my research herefor, I discovered *Hemp* and *Bamboo Linen* to be some examples of sustainably-produced cloth materials. Hemp cloth was originally used by the ancient Egyptians to wrap their mummies in, but is now sometimes used for the sails of ships because of its durability. Hemp is a naturally-growing plant, whence fibres are taken and woven into a cloth.

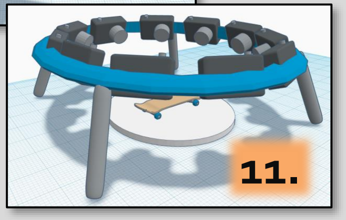
Bamboo is the fastest growing plant in the world. Incidentally, I calculated that if the lift in the *Innovation Hub* (a 3-story building) were to be replaced with a stick of growing bamboo, it would take 3 months for someone to reach the top of the building, by grabbing onto a leaf. The renewability of this plant is what makes is especially eco-friendly. Its fibres can be woven together into a fabric, in a similar fashion to Hemp.

The main idea requiring some fabric is the motorised backdrop system. The fabrics would need to be dyed with a colourant, which both Hemp and Bamboo fabrics can be.



Gum-Tec



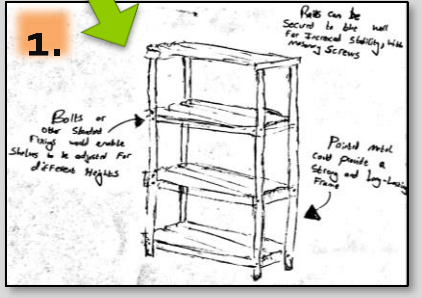


For the ends of the legs of the photogrammetry idea, some form of rubbery plastic would be needed in order to prevent the assembly from sliding around. The inner ends of the clamp for design 9 would also need some rubber, to achieve a better grip on the product being held. Gum-Tec is a rubber-like material produced from recycled chewing gum collected in containers in the streets, such as the one in this picture. The Gum is melted down in a processing plant, and new plastic is produced from what would otherwise be wasted or stuck to a pavement for several decades.

Upcycling

Links for Research on "Sources" slide

Another way to achieve a good level of sustainability in the solution I end up building, could be to reuse the materials of an old product. I discussed, for instance, how design #1 – the Shelving Unit – could be made from a softwood such as pine, but reclaimed timber may in fact be even more suitable. A popular source of reclaimed timber is old railway sleepers or BT telephone poles, and since these are sometimes hardwood, the quality (or at least value for money) of material could even be higher than that of the aforementioned pine. Not only does the reuse of this wood prevent it from entering landfill and thereby producing methane during decomposition, but it also means that no new trees need to be felled to source the timber.



Next Steps

The other wider issue to research is **Inclusivity**, which I shall do next. I will also include some discussion of the 6 Rs on the next slide, because these are related to both the sustainability and inclusivity areas.

Wider Issues: Inclusivity

Introduction

My design will be used by a variety of Stakeholders with different needs. I will now investigate what defines these different needs.

Inclusivity

Because my final product will be used within a school environment, it behoves me to think through how I can make the product more inclusive. These are the principal areas for consideration:

- **Age:** *The product must not be so tall, heavy, or large as to be unusable for especially young or old people, though, the primary stakeholders are all students*
- **Gender:** *It would be best for the product not to conform to any gender stereotypes, such as blue being a boys' colour.*
- **Race/Religion:** *There should be no religious insignia or cult branding on the product, as it must be belief-neutral in accordance with the school's policy herefor.*
- **Education Level:** *No mechanism or procedure associated with the final design should be too complicated for a person of low mental competence to fathom. For instance, Triple-oscillatory-bifold-contraction-valves are completely out of the question.*

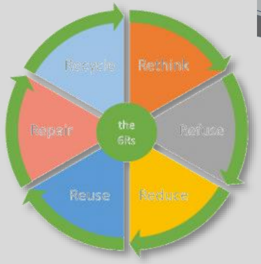
(Non-demographic Factors)

- **Medical Conditions:** *Arthritic people or those with motor-neural coordination difficulties make the ergonomic requirements I have already started considering all-the-more salient to the final design.*
- **Geographical Location:** *Because different environments and climates vary in their humidity and temperature, I cannot use materials which would expand or warp excessively in mercurial climates.*

The 6 Rs

To evaluate the sustainability of my design, I have decided to use each of the 6 "R"s as a criterium, as shown in the table ↓

I am applying these criteria not to a specific Product or Initial Idea, but rather, to all the possibilities for a final product which I have sourced from my PU…



"R"	Description	Relevance to my Product
Recycle	*Take an existing product, and reprocess the material to use again*	The Aluminium I had planned to use for Initial Idea 5 could come from a recycler of Aluminium, such as https://www.hydro.com/en/contact-us/customer-enquiries/
Rethink	*Reconsider the use of materials & products*	My research into GumTec demonstrates one possibility for a societal rethinking (in this instance, of how rubber can be made)
Repair	*Fix a broken product instead of buying a new one*	Components of my final design, such as smartphone interfaces, or electronic parts, can be from other products which had broken
Refuse	*Repudiate buying unneeded and unsustainable products*	I will ensure that my materials come from sustainable sources, and will only purchase materials once I have confirmed that I don't already have something suitable
Reuse	*Without reprocessing the material, use a product for a new purpose*	There is an old stock metal rack lying in the school garden; I may be able to use the metal bars from it to act as an arm or fixture in my final design. This would save both money and finite resources.
Reduce	*Minimise the energy consumption caused by a product during its lifetime*	The product should not use much, if any, electricity. Although there is a possibility to add some small stepper motors to automate some form of motion, this would use a negligible amount of energy.

Next Steps

Now that I know how much potential for meeting sustainability criteria there is with each of the Initial Ideas, I can review them, and use "Sustainability" as a metric of how good the design is.

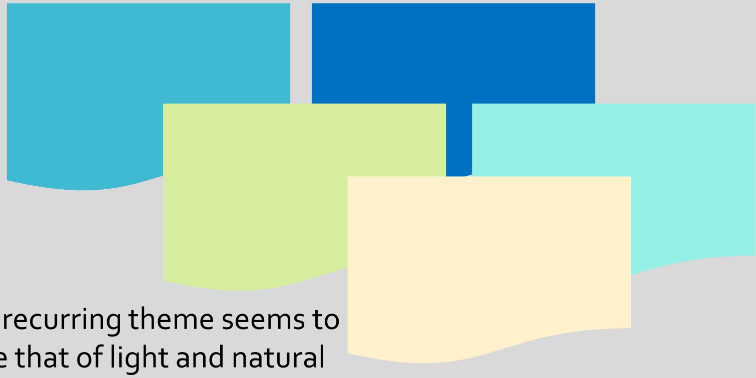
Mood Board

Introduction

Just before the design begins to become more finalised, I will create a mood board, with the input and feedback from the PU. This helps to make the forthcoming iterative process more well-rounded and the decisions herefor more informed and personalised.

Mr. Grover commented that he likes the effect of "blued" metal. This look can be achieved with by applying a special chemical to the metal for a few seconds, which improves the sliding ability of the surface of the metal, as well as making it more resistant to corrosion

I had the primary user pick out some colours he liked…



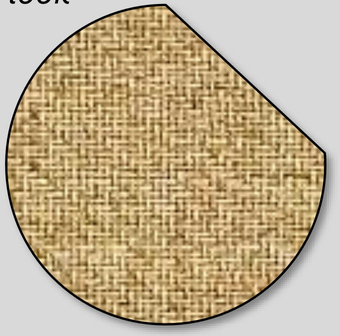
A recurring theme seems to be that of light and natural colours and materials…

The PU liked the idea of contrasting man-made mechanical components with natural materials such as the wood. →

The PU and other stakeholders picked out the aesthetic of wood. This encompassed both natural, log-sawn timber, and contrastingly, manmade processed plywood with its many layers.

I collected the opinions of some of the other stakeholders too…

Related to the research into sustainable materials, the PU mentioned that they rather like the aesthetic appeal of a ***cross-hatch, woven, layered*** *sort of look*



Metal and Mesh

Next Steps

The next step is to complement this research with some investigations of relevant design movements…

Relevant Design Movements

Introduction

To further the inspiration and creativeness provided by the mood board, I shall also conduct some research into some relevant design movements, as chosen by the PU.

1920's Design

Harsh Angles ↓

***Designers**: Charlotte Perriand and Le Corbusier*

Elegant Curves →

Transition

Bauhaus was an rebellious abandonment of the ornate and elaborate motifs from 1920's and earlier design patterns.

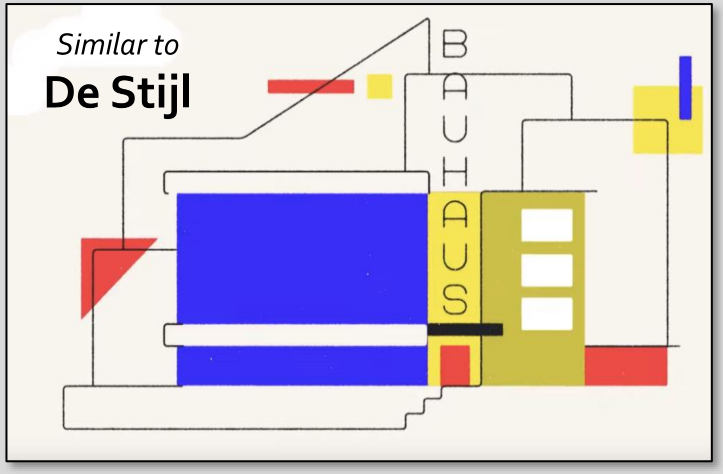
***Designers**: Marcel Breuer and Mies van der Rohe*

A Cantilever Chair

*Design **Simplification** and **Abstraction***

Similar to

De Stijl



Early Bauhaus

The Bauhaus design movement originated from a school in Germany called the "Bauhaus" (literally: house of building) which was founded by Walter Gropius in 1919.

The original idea was to do away with the style of the time (which consisted of highly ornate and intricate carvings on needlessly lavish and exotic hardwoods) and simply make products out of the materials available. This philosophy initially meant that most Bauhaus items were pieces of bent steel tube with bits of fabric stretched between them, such as this, *now famous*, Cantilever chair.

Some Bauhaus works are rather abstract and need to be stared at for a few seconds before being deciphered and appreciated...

I ought to be able to use some motifs and patterns of this Design Movement in my Final Product.

Later Bauhaus

More modern Bauhaus designs now tend to focus on having simple forms and shapes, made from a variety of ostensibly unremarkable materials including metal, wood, and plastic. The "philosophy" can be summarised as follows:

- *Circles, Squares, Triangles*
- *Primary Colours*
- *Clean forms and lines*
- *No ornamentation or embellishment*
- *Products designed to be inherently aesthetic, instead of requiring many hours of work*
- *Materials embraced and put on show*

Bauhaus

Colour Scheme

Next Steps

The next step is to look into some materials which might be suitable for the project, and are perhaps influenced by this design movement.

General Materials Research

Introduction

To better understand which materials I can use for the solution, as it is developed from the initial ideas, I shall conduct some general and preliminary research into different sorts of materials.

Wood

Meets the PU's AESTHETICS need

Using organic material from trees could provide a potentially sustainable, aesthetically-pleasing, durable, and practical means of construction for the final product.

The aesthetic appeal of woodgrain was also commented upon by the PU, and there are a variety of possibilities for different finishes that can be applied to the Wood to increase its longevity and resistance to moisture.

A Sawmill ↓

A scheme such as the FSC can ensure that timber is sustainably-sourced by planting 3 new trees for every one felled →.

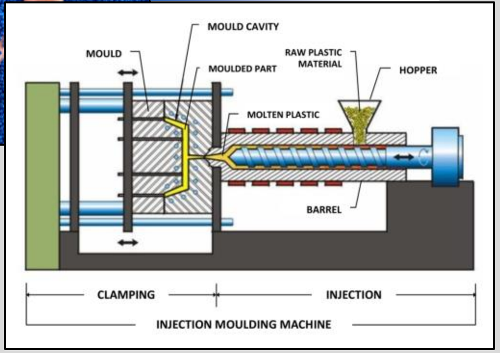
FSC

Plastics

Meets the PU's WEIGHT need

Whilst less environmentally sound, thermoforming plastics such as polypropene can produce ultimately inexpensive and durable components. Usually however, this production style is suited to mass production using processes such as injection moulding, which require small pellets of plastic, which look like the blue beads shown {to the right}. It is unlikely that I will be able to use this process in school, but I will be able to make use of pre-existent blocks of plastic and manipulate them into different shapes of component. Many plastics are naturally lubricated and can therefore be used for moving parts in mechanisms. They are – however – also rather soft and do not tend to last a long time where there is considerable friction.

An Injection Moulding Machine ↓



Metals

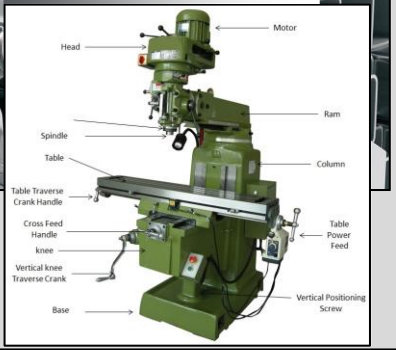
Meets the PU's SECURITY/ROBUSTNESS need

92 of the 118 elements on the periodic table can be classified as metals, although only a small proportion (~5) thereof are actually commonly used for fabricating components. The desirable characteristics are often strength and durability – as well as shock resistance and a metallic finish. Many metals also conduct electricity, which can be both an advantage, and a safety concern, depending on the use case.

Several metals – such as aluminium – have to be extracted from their Ores, which is the form the metal can be found in naturally below the earth's surface. This extraction is a costly and energy-intensive process, which is not particularly environmentally friendly either.

Alloys can be formed when multiple different elemental metals are combined together into a singular substance. Alloys tend to be stronger than their constituent parts, because there are multiple sizes of atom which make the atomic layers difficult to move past one another.

A Milling Machine ↓



For the final product, I would be able to either cast some metal, or to use existing pieces of metal and remove material from them e.g. with a Lathe or Milling Machine →.

Next Steps

Next I will take a brief look at any mechanisms which I may need to make use of in the final design. These will most likely be made from the materials researched here.

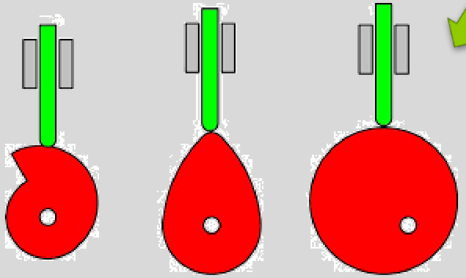
Technical Components & Mechanisms

Introduction

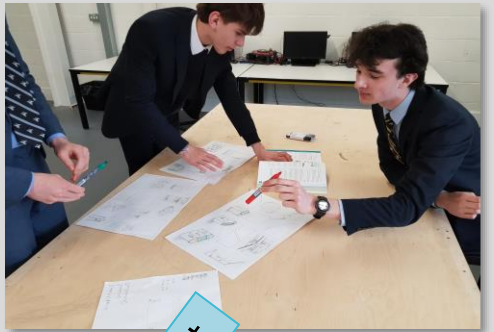
My research has indicated that I may well have to incorporate some sort of mechanism into the solution. Herefore, I shall look into some of the ***mechanical ideas*** which have appeared so far, as well as some ***new ones*** which could be useful.

Cams

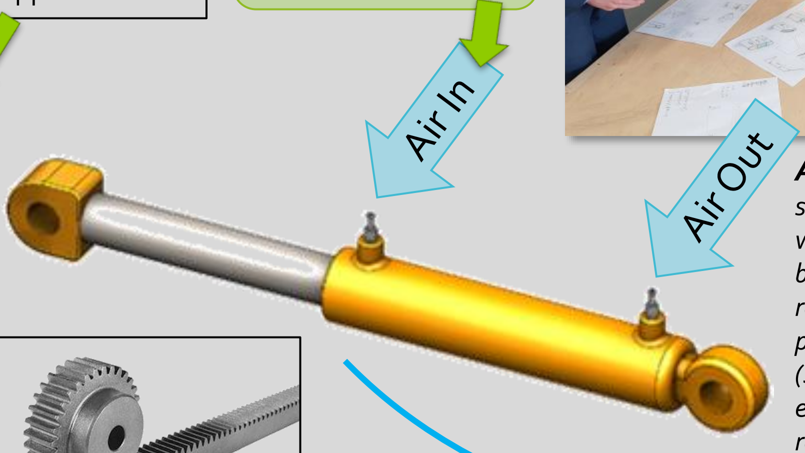
A Cam can generate a reciprocating motion from a rotational one. Different shapes of cam are able to produce ***differing timings of reciprocal output***. Multiple Cams can be placed on the same shaft, for increased simplicity. A Motor is needed to drive the axel, though it doesn't have to be a Stepper Motor.



I asked some of the other stakeholders about which mechanisms they would recommend...



Air Compressor



An Actuator *is a simple mechanism which extends a linear bar and can later retract it. They can be powered by Electricity (Solenoid) or by Air or even Water, which require a compressor or pump respectively.*

Simple Products vs Systems

I have discovered that all products can be categorised as either *Simple Products*, or as *Systems* which have multiple components.

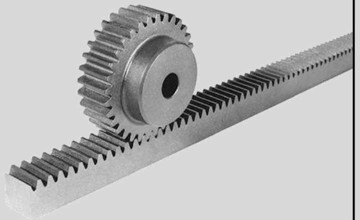
A number of additional considerations must be made for these Systems and their components, such as:

- ***Reducing friction*** between moving components
- Using a ***hardwearing material*** to create a long-lasting mechanism
- Not overcomplicating the mechanism, so that it can be ***repaired easily*** if needed.

The final product will almost certainly be a "*System*" comprising several constituent parts.

Rack and Pinion

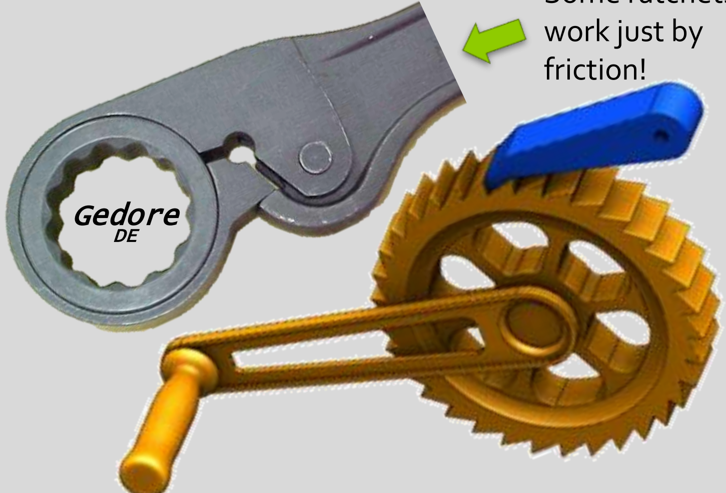
This mechanism is to some extent similar to a cam (in that it produces motion on a singular axis from rotation) but the output is linear and not reciprocating. This would be useful for moving a component in one direction to perform a task, and being able to automatically reset it later.



An electrical motor such as a stepper motor or three-phase brushless motor would be needed to precisely turn the driver gear. This motor would have to be ***powered by a MicroController*** with a special programme running on it.

A Ratchet *permits rotation in only one direction, conventionally by means of a spring-loaded finger which catches on the teeth of a cog – producing the distinctive clicking sound.*

Some ratchets work just by friction!



A Microphone Arm mechanism

To enable three points of articulation on a flexible arm, a popular design is this [microphone arm]-style mechanism.

Integrated (hidden) spring resistance Mechanism →

The main challenge herewith is getting the joints to be flexible and easily rotatable, but getting them to stay perfectly in the set position afterwards. This is typically solved by having ***springs which provide force in the opposite direction to gravity*** →.

Some more expensive solutions hide the springs by integrating resistance into the pivoting joints of the arms themselves (←).

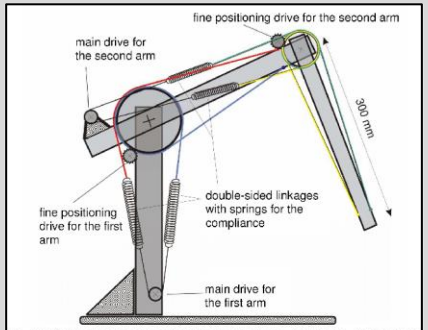


Fig. 2. Basic construction principle of the bionic robot arm. Through the

Next Steps

I am now ready to create some initial ideas using the materials, wider issues, and mechanical research

Initial Ideas (1)

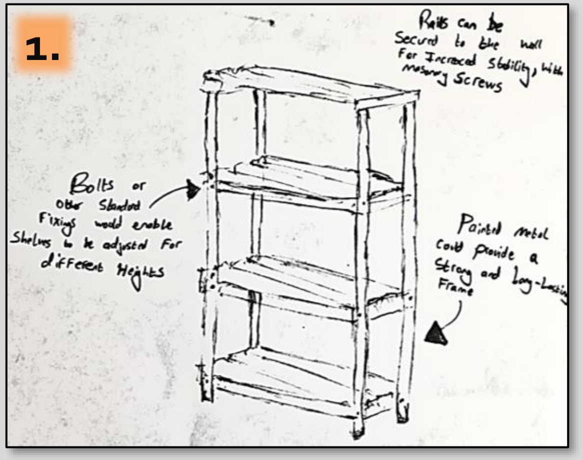
Introduction

To begin finding a perfect solution for the PU, I will produce a series of initial ideas – rough sketches and models and prototypes, in order to experiment with designs and mechanisms and parts.

In doing so, it is important that I use a variety of different modelling and representation techniques, as different materials befit different modelling use cases.

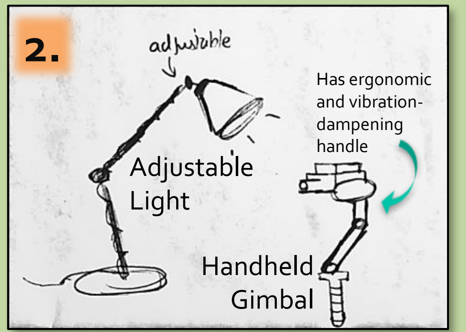
Sustainability Analysis

I had annotated this design to be of a simple metal construction, however on reflection this would not meet sustainability criteria very well. On account hereof, a more suitable material to use might be a softwood such as pine. This is still sufficiently strong, and could be painted in the desired colour scheme. I would have to ensure that the wood was coming from an FSC (or otherwise certified) source.

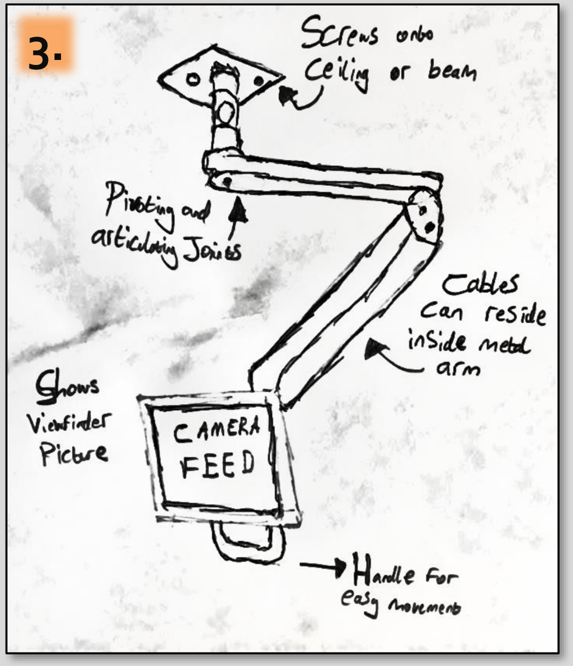


6-8-5 Designing

As a means of quickly attempting to produce a wide variety of different concepts, I decided to try out the "6-8-5" idea generation technique. Herefor, one must select a colleague with no direct involvement in the project to generate **[6 to 8] designs, in 5 minutes**. The benefit hereof is that the recruited colleague ought to be sufficiently disassociated with the project, to be able to conceive ideas beyond the scope wherein I have subliminally encapsulated myself throughout the course of the inherently *scope-narrowing* research.



The Stabilising Gimbal is the most useful of these.



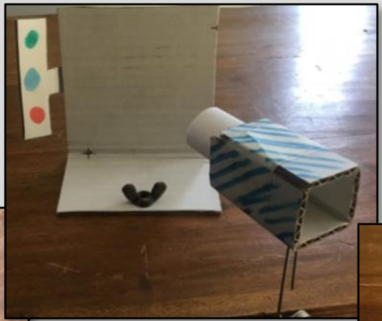
Articulating Arm AluminiumComposite Model

To effectively undertake some initial idea tests for articulating arms – an idea which has appeared several times in my research hitherto – I decided to use a sheet of aluminium composite to model the bending mechanism. I tested a few different ways of joining the bars together at the joints, and found that although [nuts and bolts] offer the most flexibility in terms of being able to disassemble the joint afterwards, they rapidly became too loose with movement of the joint. A better solution, it seemed, was to use copper rivets; I found that these could be dialled in to achieve a desired level of stiffness in motion, and that the copper almost acted as a lubricant, because it is such a soft metal. Weather or not this same principle could feasibly be scaled up to a life-size product remains to be seen.

I created a small model of something like a monitor or camera for the end of the arm, to show what this might look like, and how easy it would be to move around.

5.

Bolt-on panel of lights

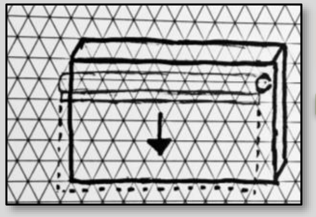


The blue striped component is a model of a large photographic light. Only by **modelling in 3-D space** like this, was I able to test out different positions for such a large object relative to the existing backdrop...

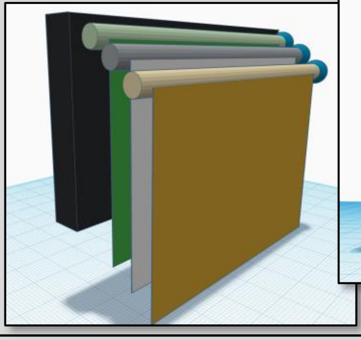
4.

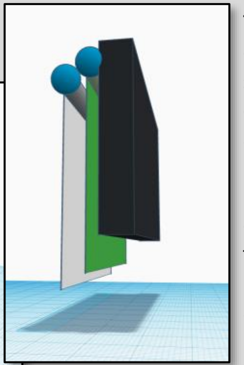
Initial Ideas (2)

A motorised backdrop deployment system for different fabrics and colours of sheet material.



6.

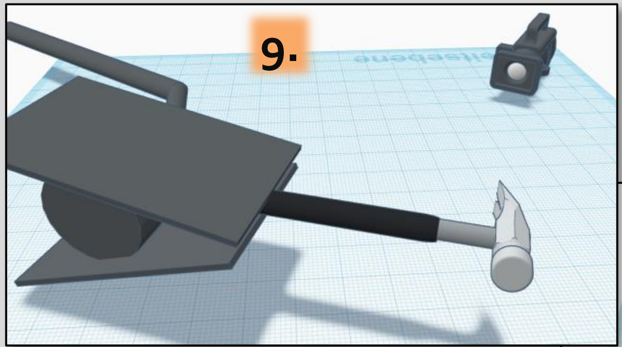




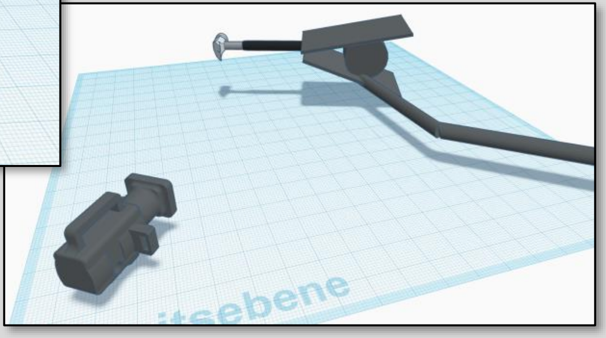
I sketched this isometrically, but realised that the model lent itself to a C.A.D. representation.

The back box acts not only as a stable and solid support surface, but also could contain the motors and control circuitry required to lower and retract each of the sheets of the backdrop material, thereby making this a relatively compact and all-in-one system.

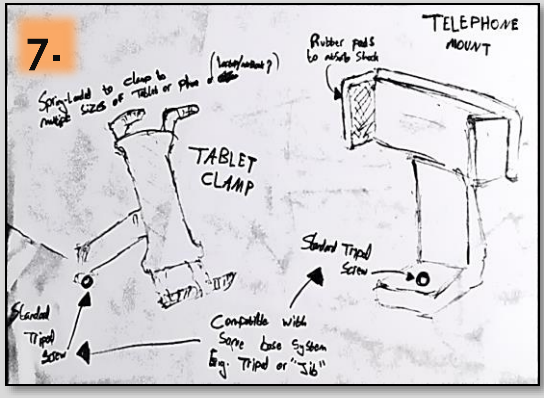
9.



A **pinching-clamp** system for holding the product being photographed



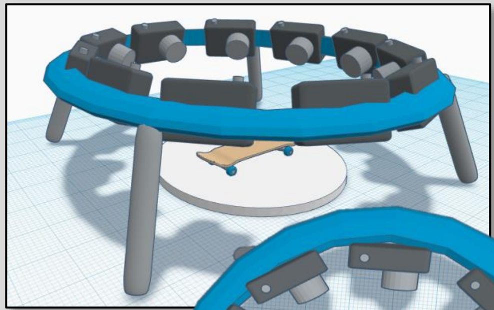
7.



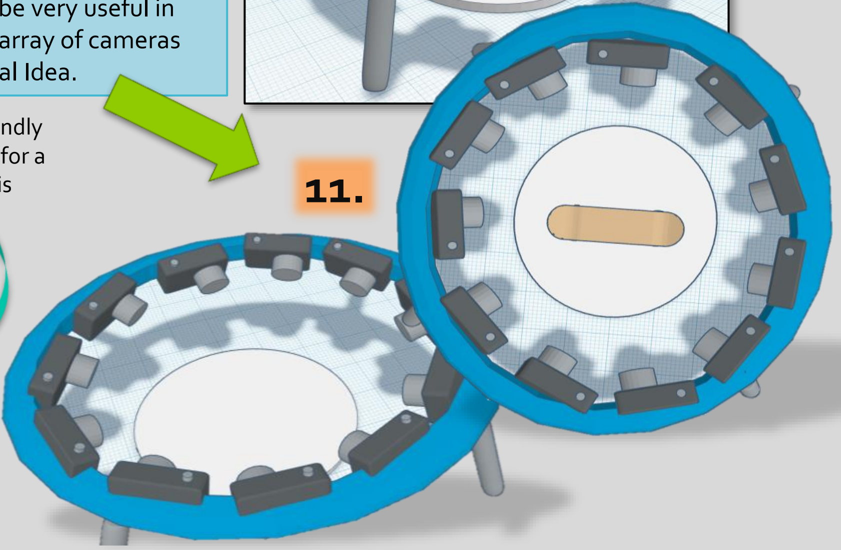
Inspired by the feedback I gained during the Stakeholder interviews, I decided to explore the possibility of being able to mount different sorts of camera devices in front of the backdrop system in the 6th form room. To this end, I sketched some ideas for clamps and mounts for telephone handsets and tablet computers. On account of the three-dimensional nature of these handsets, however, I decided to use some **modelling clay** to more effectively test how the holder might wrap around the phone or tablet.

Photogrammetry

During the most recent interview with Mr. Grover, he incidentally mentioned that C.A.M. Processes such as 3D Printing and Laser Cutting are being used more then ever before in students' work. Since then, I had discovered an interesting technology called "Photogrammetry", which is where photos of an object are taken from several different angles, and a special computer programme stitches them together into a 3D CAD model file. This file can later be sent to a 3D printer, or a CNC mill, in order to reproduce the original object. Since this functionality could be very useful in school, I have created this model of a circular array of cameras pointing at a target object as an Initial Idea.

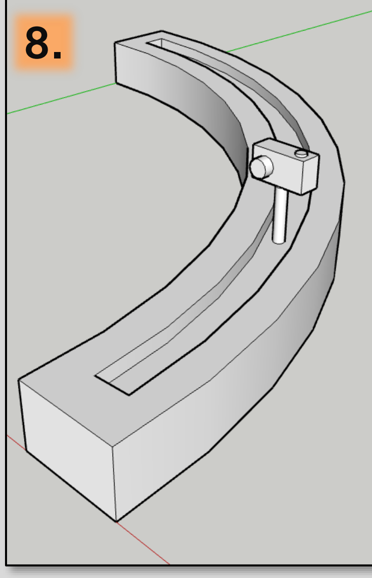


11.



8.

SketchUp

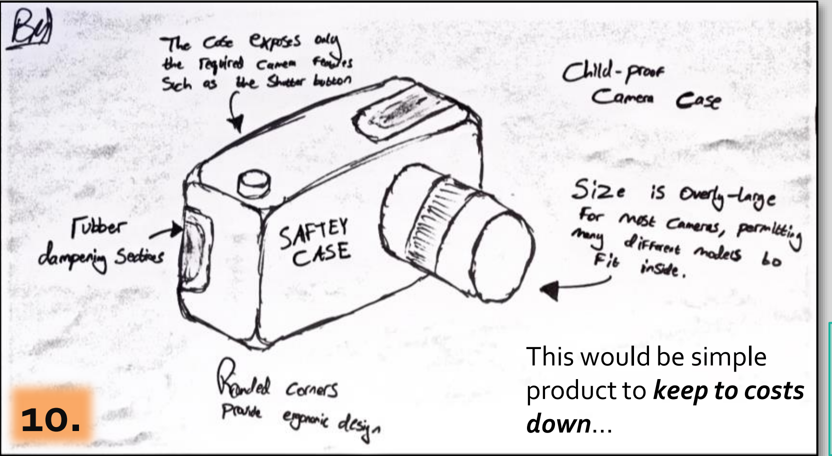


This is a CAD Model of an arc-shaped camera slider which I modelled in SketchUp.

It would enable one singular camera to see several angles of the target object.

On the balance of probability, the only way for this to operate in a suitably smooth and linear fashion, would be to motorise it and use electronics.

One of the stakeholders in the department (a teacher) commented that she didn't take kindly to misuse of her expensive camera. Therefore, this initial idea shows a rubber safety case for a camera, which exposes only the required camera features, such as the shutter button. This prevents pupils pressing other buttons and misconfiguring the camera for others.



10.

This would be simple product to ***keep to costs down***...

Next Steps

The next step is to obtain some feedback from the PU about these ideas, and then to begin to develop them with the iterative design process.

Review of Initial Ideas

Introduction

In order to identify which of the Initial Ideas are the strongest, and to work out what works well from each concept, I shall now carry out another interview with the PU, and record the results with an evaluation of each idea.

PU Need	Design 1 (Shelving)	Design 2 (Gimbal)	Design 3 (CeilingScrn)	Design 4 (Light Panel)	Design 5 (Floor Arm)	Design 6 (BackdrpSys)	Design 7 (Tablet Mnt)	Design 8 (Arc Slider)	Design 9 (PinchClmp)	Design 10 (CamCase)	Design 11 (PhtoGmtry)
Ease of use for Students	9	3	8	5	5	2	9	7	6	10	6
Size	5	6	7	3	5	2	7	6	4	6	5
Aesthetically Pleasing	6	7	5	4	5	4	4	8	3	6	8
Relatively Simple	6	4	7	6	5	3	7	6	5	9	7
Adaptable and Multipurpose	2	3	7	4	9	8	3	6	5	5	8
Ergonomic and Comfortable	4	8	6	6	9	5	5	4	3	8	9
Security, Longevity, Sustainability	7	2	8	6	7	6	3	7	3	4	6
Weight	4	2	8	3	9	4	7	8	7	4	5
PU Score	5	2	7	4	8	8	6	9	4	5	9
Total (Higher is Better)	**48**	**37**	**63**	**41**	**62**	**42**	**51**	**61**	**40**	**57**	**63**

The Review Table

The criteria used in the table are those identified during the previous stages of the interviewing process, from the Primary User and Stakeholder Requirements. The PU, for instance, had mentioned the importance of the ease of use for students, and as such, this is a factor of evaluation which now appears on the table. Another stakeholder, Mr. Barnbrook, had mentioned the potential problem of the product going missing or being stolen or misplaced, and therefore the "security" criteria has been added to the [PU Need]s column too.

PU Interview

I discussed each idea with the PU, and gained some feedback for each of the various criteria. Each PU Need has been given a score out of 10, and all the scores have been conditionally-formatted, for ease of visual identification of the strongest and weakest areas.

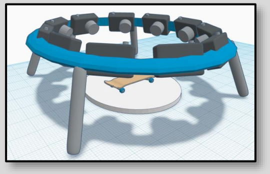
↑ Click here to Listen ↑

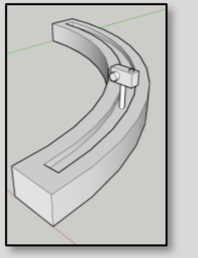
1) The PU was partial to the simplicity and potential for reliability provided by this design. He said that the storage in the room is an untackled problem which warrants a solid and long-lasting solution. He noted that the shelves would be very **easy for students to use**, but that they aren't particularly adaptable.
2) The gimbal idea (from the 6-8-5 designing) didn't prove to be popular with the PU, as he wasn't a fan of the probable complexity, and how easily the gyroscope system might break or fail.
3) The PU was drawn to this design because of it's bolted-down nature. He commented that this sort of design has a lot of potential, due predominantly to the (literal) flexibility provided by the articulating arm. He did say, however, that the metal arm might stick out amongst the current items in the room, therefore giving the design **only 5 of 10 points for it's aesthetic appeal**.
4) The light panel raised concerns about how easy it would be for students to use, and also may have been unwieldy in terms of size and placement. It wasn't awarded a high score.
5) This was one of the PU's **favourite** designs, because of how adaptable and multi-purpose it is. Unlike design #3, all sorts of items can be attached to the end of the arm, wherefore the PU gave it **9 out of 10** for adaptability.
6) The backdrop system was said to be too bulky and cumbersome to use and store.
7) The tablet and telephone mounts were a good idea because of their usefulness, but **might not last a long time** due to the small parts, according to the PU, Mr. Grover.
8) The PU was accountably interested in this concept, as it could yield some well-made panoramas of products
9) This product didn't score highly, due to it's needlessly bulky size, and lack of enthusiasm from the PU.
10) The PU said that this design isn't particularly ergonomic – it might be heavy for smaller students too.
11) The **Photogrammetry** concept attracted Mr. Grover's interest, and his only real concerns with it were the size and weight of the ring assembly.

The Best Designs

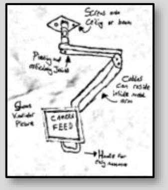
I have decided to **take forward designs [3, 5, 8, and 11]**, on account of their scores being the highest in the objective ranking of the table. In other words, these designs most closely meet the precise PU requirements derived from the interviews and research.

Both Mr. Grover and I like the idea of the multipurpose products, wherefore designs 5 and 11 are promising. The Photogrammetry was a novel concept for the PU, but he was drawn to it, and how it could be implemented.





The PU also liked Designs 3 and 8, which are versatile and could fit into several different positions in the room. The sliding aspect of the arc jig is also unique, though The PU wonders how else this same Motion could be achieved in less space.



Next Steps

Next, I will research some of the ergonomics, materials, and existing products which will be relevant to my final product. Then, I will begin iterating.

Ergonomic and Anthropometric Research

Introduction
Here I gather some preliminary and relatively generic research about the sorts of ***ergonomic considerations*** and data I will have to implement later on in the iterative refining processes.

Hands
There is a large possibility that some part of my final product will be interacted with using the hand. I therefore need to ensure that the I am aware of the ***specific ergonomic requirements*** of the hand, and the anthropometric data associated with the main chiral dimensions.

These are the data for **adolescent to adult** male and female hands. There are some female members of staff in the intended use case environment for the product, but mostly male operators are expected to use the product because it is an *all-boys school*.

Generic → Specific
I must now attempt to serialise this data and combine it with some specific data from the PU's measurements. This is important because the stakeholders of the product ***may not necessarily be around the 50th percentile of the data***, which I would otherwise use.

Handles
It is probable that the final product may have some sort of handle, wherefore I have looked into several different shapes of graspable grip.

There are two main areas of concern for a handle; the upper ***thumb resting area***, and the bulge responsible for ***accommodating the palm*** of the hand.

Because I am likely to have a simple design of handle (it's not a main focus of the product), it will probably be a **roughly bulged- or bevelled-cylindrical shape**. I can make such a shape with relative ease on a woodturning lathe, and drill a through hold for easy mounting with a bolt.

Some popular Ergonomic Handle Designs

Table 2. The results of hand dimensions (unit: mm) (standard deviation of the mean in parentheses).

item		This study		Wang et al. (2002)
male	A hand length	187.9	(7.9)	183
(Link on "Sources" Slide)	B hand breadth (four fingers)	83.6	(4.8)	86
	C grip breath inside width diameter	44.5	(5.3)	-
	D grip breath inside length diameter	35.6	(4.9)	-
female	A hand length	167.9	(6.6)	167
	B hand breadth (four fingers)	75.2	(6.2)	75
	C grip breath inside width diameter	32.2	(4.5)	-
	D grip breath inside length diameter	25.7	(5.0)	-
all	A hand length	177.9	(12.4)	175
	B hand breadth (four fingers)	79.4	(6.9)	80.5
	C grip breath inside width diameter	38.3	(7.9)	-
	D grip breath inside length diameter	30.7	(7.0)	-

PU-Specific Data
Because the intended use case for the final product will involve it being used by a variety of different users (students & design technicians or teachers), I will need to ensure that any ergonomically-important components can be held by any size of hand from that of a year 7, to that of a fully-grown adult. Most importantly though, are the PU's data, which take precedence over any smaller hands of the students.

These are the PU's Hand Measurements:

Hand Length: 17.6 cm
Hand Breadth: 7.5 cm
Grip Ø: 4.6 cm

Data also applicable for
Bars and Rails

Final Handle Data
These, therefore, are the specifications I shall aim for in my handle design:

Diameter: ~2.5cm, to ~3cm bulge
Length: ~10cm, or 3cm high knob-style pull

Next Steps
The next step is to look at some specific materials and processes which could be used for the final product…

Specific Materials and Processes (1)

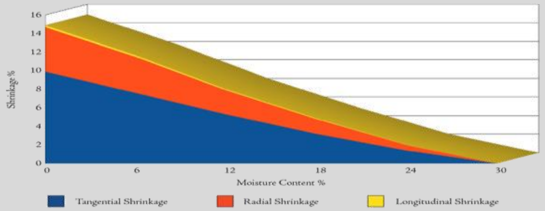
Introduction

Here I undertake some further research into which specific materials and manufacturing Processes I may end up using in the final design. I need to carefully **identify and select the most appropriate materials and finishes**, in order to be prudent and create a long-lasting and stable product.

Wood Shrinkage

To establish why it is important to protect wood from exceßive moisture intake, I have conducted some research into the extent to which wood shrinks, as it takes in increasing levels of moisture. This data is important because any wood involved in the mechanisms will need to be stable and influctuant in its dimensions.

[↑ Metrics of Wood Shrinkage ↑]



The graph shows that the most grain movement occurs when the first moisture concentration changes happen. This means that it's ***important to prevent water getting in in the first place***, so I must choose an effective protective finish.

Metal Finishes

Ferrous metals (which contain iron) can easily rust if left unprotected. Since the final product is likely to contain a mechanism of some sort, made *from* a ferrous metal, I need to determine what the best methods of protecting the metal might be.

- **Lacquer**
  This would be a transparent hard-drying coating which protects the metal from corrosion or weathering. Most lacquers last for a long time, and can be applied simply by brush
- **Galvanisation**
  Although inaccessible industrial processes would be required to actually perform this technique, it involves applying a thin layer of Zinc to the surface of the metal. The Zinc acts as a sacrificial metal and will corrode before the inner one does.
- **Paint**
  A special metal paint such as Hammerite will not form beads on the surface, and instead, offers a long-lasting protection to the metal. This is not suitable for moving parts, as the paint will wear away, re-exposing the metal.
- **Cold Bluing** (Click to see Demo…)
  This involves wiping the metal quickly with a special chemical, which turns it black. Unlike the other processes, this adds virtually no extra thickness to the metal, so it suitable for moving parts which rub against each other.

Wood Finishes

To better protect any wood used in the final product, I am obliged to apply some form of coating. As well as providing ***resistance to moisture and discoloration***, a finish can make any natural (i.e. not Plywood or MDF) boards more stable and less susceptible to shrinking and expanding with fluctuating seasonal temperatures, which ***weakens the structure of the product over time***. The main options I have are as follows:

- **Varnish**
  A varnish would provide a glossy or satin finish to a hard or soft wood. It could either be applied by a brush (which – although environmentally-friendly – is ***not suited to a batch production*** setting) or by a spray gun, which can coat many products rather quickly – however the operator must wear a protective fume mask.

As an alternative to the conventional oil-based varnish, a more sustainable solution such as ***Ronseal EcoVarnish®™©*** could be used. This is water-based, so is not only more sustainable to produce, but also less damaging to dispose of…

- **Staining**
  A woodstain is a dye or ink which penetrates the fibres of the wood and alters their colour. A variety of different colours are available →
  …which allows me to meet the PU need of "***matching the existing aesthetic of the room***". Following the application of a stain, the moisture often raises the grain slightly – so this needs to be lightly sanded over which takes more time.

- **Wax or Oil**

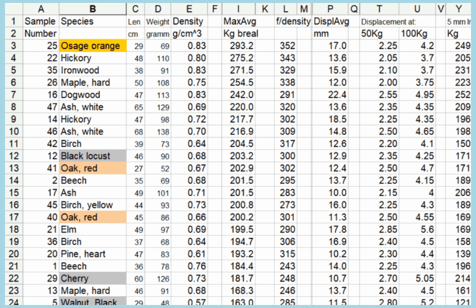
A Wax can be used to achieve a particularly professional finish on a piece of wood. They are usually applied as the final stage of finishing the wood, perhaps before a polishing or buffing.

- **Veneer**
  A process called ***Plying*** can be used to shave a thin layer of wood from a log, which achieves a repeating grain pattern. An Iron is often needed to apply the veneer smoothly. I am unlikely to use this technique in the final product as it is not in accordance with the ***Function Over Form*** principle…

Specific Materials and Processes (2)

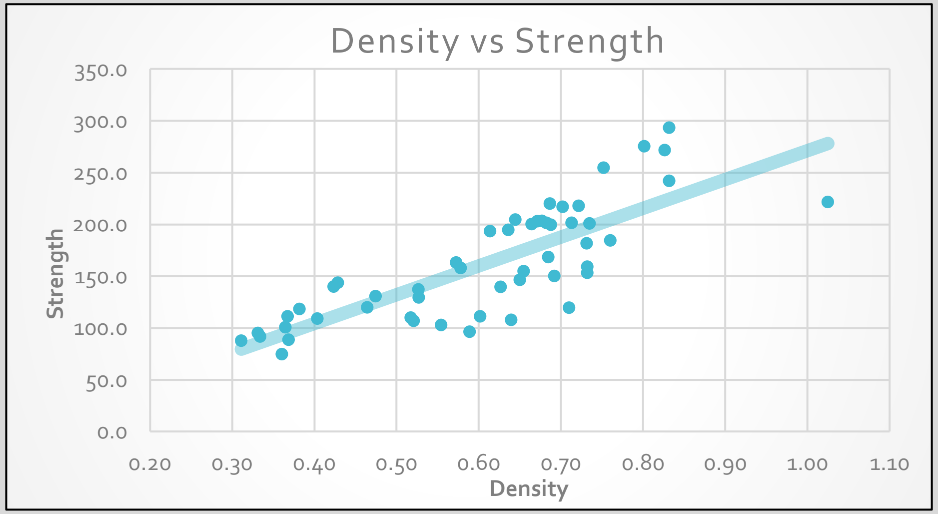
Wood Strengths

If the final design requires any wooden mechanical components, then I ought to use a suitably ***strong and hard-wearing wood***, commensurate with the anticipated forces for the product. I have found a comprehensive data source for the strength and density properties of different species of tree.



	A	B	C	D	E	I	L	P	T	U	Y
1	Sample	Species	Len	Weight	Density	MaxAvg	f/density	DisplAvg	Displacement at:		5 mm Ir
2	Number		cm	gramm	g/cm^3	Kg breal		mm	50Kg	100Kg	Kg
3	25	Osage orange	29	69	0.83	293.2	352	17.0	2.25	4.2	249
4	22	Hickory	48	110	0.80	275.2	343	13.6	2.05	3.7	205
5	35	Ironwood	38	91	0.83	271.5	329	15.9	2.10	3.7	231
6	26	Maple, hard	50	108	0.75	254.5	338	12.0	2.00	3.75	223
7	16	Dogwood	47	113	0.83	242.0	291	22.4	2.55	4.95	252
8	47	Ash, white	65	129	0.69	220.0	320	13.6	2.35	4.35	209
9	14	Hickory	47	98	0.72	217.7	302	18.5	2.25	4.35	196
10	46	Ash, white	68	138	0.70	216.9	309	14.8	2.50	4.65	198
11	42	Birch	39	73	0.64	204.5	317	12.6	2.20	4.1	150
12	12	Black locust	46	90	0.68	203.2	300	12.9	2.35	4.25	171
13	41	Oak, red	27	52	0.67	202.9	302	12.4	2.50	4.7	171
14	2	Beech	35	69	0.68	201.5	295	13.7	2.25	4.15	189
15	17	Ash	49	101	0.71	201.5	283	10.0	2.15	4	206
16	45	Birch, yellow	44	93	0.73	200.8	273	16.0	2.25	4.3	189
17	40	Oak, red	45	86	0.66	200.2	301	11.3	2.50	4.55	169
18	21	Elm	49	97	0.69	199.5	290	17.8	2.85	5.6	169
19	36	Birch	37	68	0.64	194.7	306	16.9	2.40	4.5	158
20	20	Pine, heart	47	83	0.61	193.2	315	10.2	2.30	4.4	139
21	1	Beech	36	78	0.76	184.4	243	14.0	2.25	4.3	196
22	29	Cherry	60	126	0.73	181.7	248	10.7	2.70	5.05	214
23	13	Maple, hard	46	91	0.68	168.3	246	13.7	2.40	4.5	161
24	5	Walnut, Black	29	48	0.57	163.0	285	11.5	2.80	5.2	121

(Click here for the Data Source)

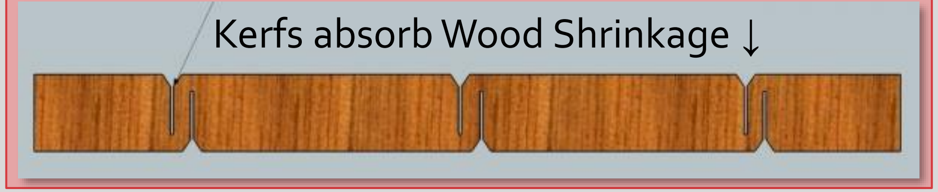


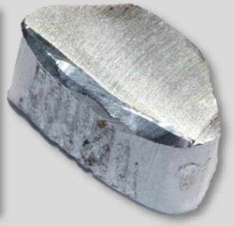
Other Options...

Instead of using a wholly natural solid wood, I could use a man-made board such as Plywood or MDF. Since ***MDF is fibre-based***, it would not be suitable for movable parts. ***Plywood is a tenable option***, and can come in several different levels of quality and thickness. TUFNOL is another possibility: it is a very hardwearing material made from layers of strong fabric soaked in resin. It can be cut with standard saws. Pictures of these materials are inserted to the right.

Alleviating Wood Shrinkage Effects

One method of preventing too much warping because of moisture level changes, is to introduce a ***kerf*** to the wood. This is a small slit which can be compressed to take up any extra tension caused. The slits can be created on a ***Laser Cutter in school***.

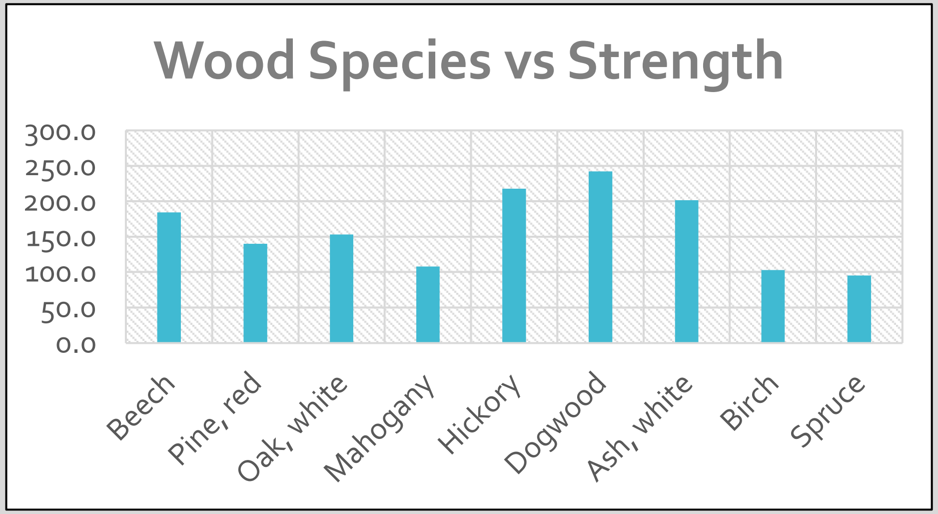




Iron Ore

Conclusions & Critical Thinking

The data from the graphs show that denser woods tend to be the strongest ones. This is not always the case, as although "*Lilac Bush*" was the densest wood, it was not the strongest – the strongest was "*Osage orange*". This wood is rather rare, however, and a tad expensive, so it is not really a realistic selection for the project; a tree such as Hickory, Ash, or Beech, is a more reasonable and plausible choice. This sort of wood is available in my school workshops, and would be suitable for making some more structural components.



Suitable Metals

As far as steels go, I have at my disposal either a high- or low-carbon steel. The more carbon a steel has, the harder it is. This is beneficial once the part is made and in-use in a mechanism, but is more difficult to work with as especially sharp tools are required to cut the material. (The carbon atoms make it harder for the layers of iron to slide over each other.) A lower carbon steel would most likely be perfectly adequate for any mechanism I need, given than the product is unlikely to be *running 24/7*.

Aluminium is extracted from its Bauxite Ore, which is found naturally in many surface level mines in Australia. It is a softer and lighter metal, effective for structural components when used in thick lengths, but less feasible for mechanical linkages or components facing lots of friction and wear.

See explaination to left...

Next Steps

The next step is to analyse some real products, to see how they implement the principles outlined on the last few slides.

Real Product Analysis (1)

Introduction

With the generic technical, ergonomic, anthropometric, mechanical, material, and design information now at-hand, I will perform some in-depth analysis on a *Tripod*.

A.C.C.E.S.S.F.M.

I will be using the following criteria as a means of evaluation:

A	*Aesthetics*
C	*Cost*
C	*Consumer*
E	*Environment*
S	*Safety*
S	*Size*
F	*Function*
M	*Materials*

Aesthetics and Finish

The metal components have a matt black finish, which is such as to complement many other items of photographic equipment. The plastic is somewhat glossy and provides a contrast to the metal. There is also a relatively small logo of white text, but it is not too large as to be obnoxious. My product ought to "complement the existing aesthetic of the room", so I shall bear this knowledge of contrasts and logos in mind.

Common Metal Finishes:

(Link on "Sources" Slide)

Cost and Advertising

At £25, this product is reasonably-priced and suitably cost-effective manufacturing techniques must therefore have been employed during its fabrication.

Taking inspiration from the branding hereon, I may (in order to promote the product) be able to engrave or emboss the logo of the school onto my product, as a means of advertising and identification.

Consumer Use and Portability

Due to the fold-away mechanism and compact design with thin tubular sections, this product would lend itself to being stored away for long periods of time, but nevertheless being quickly and easily deployable. There is a basic nylon case included with the product, equipped with an adjustable fabric carry strap. The head of the tripod folds down into an inline position, suitable to fitting the tripod into the case.

I will need to ensure that my final product can be to some extent easily moved out of the way when not in use.

Safety

As this is a floor-standing product which is not especially heavy, it is suitable for use in a school environment. If it were to topple over, its light weight would be unlikely to inflict and significant harm onto a human being. The materials used do not pose a risk in terms of their toxicity, although the plastic could snap and form sharp jagged edges which might be dangerous.

Size

This product is effective at being small in size when stored away (47cm), but sufficiently large and tall for the operator when in use (~150cm). I may have to design something which is able to adapt its size and dimensions like this.

Environment

This product does not fare particularly well by most environmental metrics; the mild steel tubes would have required mining iron ore from an open-cast mine, which may well have permanently scored the landscape. In addition, the plastic components are produced from non-replenishable crude oils, which further pollute the atmosphere during their formative processing, and subsequently, their disposal.

If I were to use these materials, it would be possible to use a more sustainable equivalent, such as bioplastics, or recycled metals or polymers.

Function and Ergonomics

The multi-hinged head permits the camera to swivel and pan, to see a greater number of different angles without having the move the product. The handle has a long cylindrical shape to it, which a hand can wrap around nicely. The length of the handle affords the operator reasonable leverage when tilting or panning the camera. The plastic material may not be the *most* comfortable choice, though it keeps the costs down. There is also a small spirit level to aid in levelling the camera head.

Conclusion

The following, are the main aspects I will be taking inspiration from. A sense of quality is achieved by the matt black and metal finish. The design is rather sleek and it is not a cumbersome product. This is an ergonomic handle providing leverage. The product implements Function, over Form. Simple manufacturing techniques have been used to keep the price low.

Next Steps

I will closely analyse one more product before moving on to the Iterations, to understand how it is constructed and which compromises are made…

Real Product Analysis (2)

Introduction

Here I analyse a wooden Monitor Arm which is installed onto a Server Rack. It was designed and built as a *one-off product*, which is relevant because I too am designing a one-off solution.

Function and Ergonomics

The multi-hinged design provides two points of articulation for the flexibility of the arm. At each point, there is also a metal pin bracket for locking the monitor at a set angle. Several holes have been drilled to allow a multiplicity of different positions to be chosen.

Conclusion

The following, are the main aspects I will be taking inspiration from. The use of wood for the substantial parts. Some form of user-adjustable angle positioning. The implementation of standards such as VESA. Using standard fixings and components such as the hinges and machine screws used to screw into the monitor. **Being able to attach the arm to an existing structure**. The appropriate size of the product.

A.C.C.E.S.S.F.M.

I will be using the following criteria as a means of evaluation:

A	*Aesthetics*
C	*Cost*
C	*Consumer*
E	*Environment*
S	*Safety*
S	*Size*
F	*Function*
M	*Materials*

Aesthetics and Finish

The product is somewhat utilitarian and has putatively been built in accordance with the "Form Follows Function" principle, wherefore it is a tad *rough-and-ready*. Having said that, the natural grain and abundance of knots in the wood contribute to a general aesthetic of solidity and robustness.

Safety

The angle-setting brackets prevent the monitor from swinging around uncontrollably, and the wood does not conduct electricity, which mitigates the risk of electric shock.

Size

This product allows any conventional size of monitor to be screwed onto it, as it is compliant with the dimensions for the standardised *VESA* Mounting specification.
The rest of the arm is not excessively large for the size of Monitor it is holding, though the size of monitor is horizontally limited by the 2^{nd} arm.

Cost and Advertising

There is no demonstrable cost for this one-off product as such, but the processes used to create it, and the use of standard off-the-shelf components such as the hinges, mean that it wouldn't have cost over ~£15 to make.

Consumer Use and Portability

The Arm can be screwed onto the side of an existing sturdy structure – in this case a half-height (wooden) Server Rack. This makes the product easy to install and cost effective, as it can simply be added onto something the user already owns.

The product is not particularly portable, though this is not an issue, owing to the intended use case for a fixed mounting solution like this.

Environment

The largely wooden construction is environmentally-sound as wood is a sustainable and renewable material which – if managed responsibly – can be replenished forever. The metal can also be recycled.
Though sustainable, the use of wood does not lend itself to mass production. A metal or plastic would be more suitable for larger scale manufacturing.

Next Steps

The next steps are to develop these four ideas based on the feedback collected here, and produce more detailed drawings and renderings of the concepts!

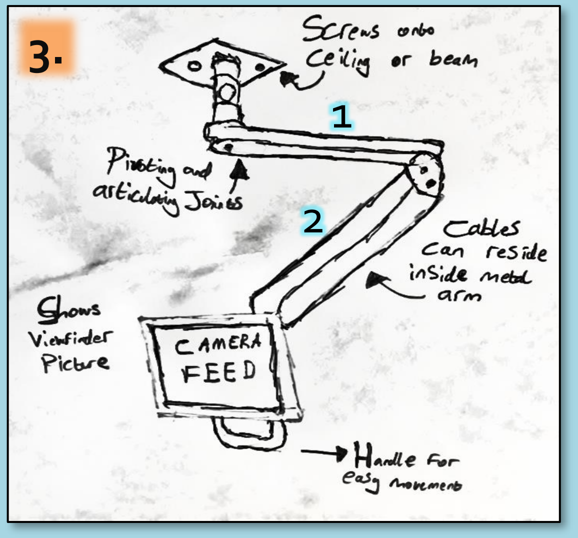
Iterative Design Development: Des. 3 (1)

Introduction

Here I begin the iteration of Design 3. This was the movable monitor on an arm, with which a camera operator could view in real-time the video image coming from the sensor on the camera.

The principal idea with the design was to make it easier to produce a well-lit and -positioned shot from the right angle. The main areas in need of improvement were the general **size, sturdiness, and safety** of the large metal arm.

The PU said…



The PU *likes*:

- Bolted-down and secure product
- Flexibility of the articulating arm

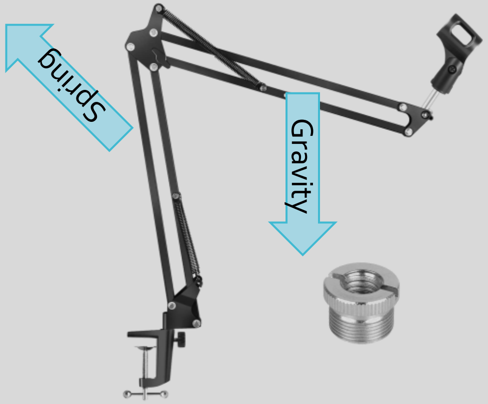
The PU *dislikes*:

- Metal arm sticks out
- Concerns about sturdiness of mechanism
- Safety and ergonomics aren't optimum

Putting this theory into practice…

The Model of this mechanism which I made showed me that I *wouldn't necessarily need to have quite so many of the constraining fixture bars* in order to have a nevertheless solid and robust arm mechanism – which is implicitly one of the PU's requirements. Around **4 per 30 cm of arm** would be enough, especially if they were to be *metal* bars instead of the wooden ones I used for the modelling. Instead of wood screws, I would attach them with bolts and machine screws, possibly with washers or thrust bearings in between.

Where some parallelogram mechanisms have **springs** (E.g.



), these springs act against gravity. **I will add some springs to my design** to make the monitor stay in the position it has been set to. *The force produced by the spring (N) must be approximately equal to the weight (N) of the resting arm.* These are tension springs, not compression springs.

Materials

For the PU's SAFTEY need

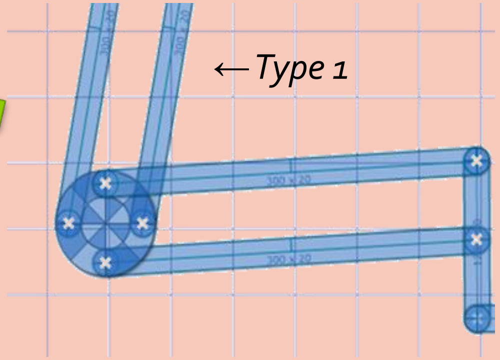
Instead of the metal with which I had planned to make the arm in the initial idea, I have decided to **change the design to use Plywood** for these reasons:

- It is **lighter**…
- …And therefore **safer** (being suspended)
- It is **less expensive**

← *These were amongst the* **PU Needs**

This means that the pivoting Extension Bar (1 on the diagram of the previous slide) and parallelogram mechanism (2) will be made from plywood bars. I will have to use 18mm plywood ↓ for this to be strong enough. The top mounting plate will still be made from 6mm steel.

Wider Research & Prototyping: Parallelogram Mechanisms



To add stability and robustness (one of the PU's requirements) to this design, I will incorporate a Parallelogram mechanism. Instead of the singular arm my design currently makes use of, this type of arm has two constantly parallel sub arms which each have a constraining fixture at their ends.

The images {above} and {below} show a **model that I made of a Parallelogram Mechanism**. The two main lengths of wood can slide past each other but they always stay parallel and are robustly connected. To make the prototype, I used two bits of old skirting board, and 12 ice cream sticks which I loosely screwed onto the main lengths. As opposed to [*Type 1*] arms, my [*Type 2*] arm has 12 constraining fixture bars throughout the length of the arm, which make it even **more solid and smoothly-operating**.

The arm ↑ more fully closed

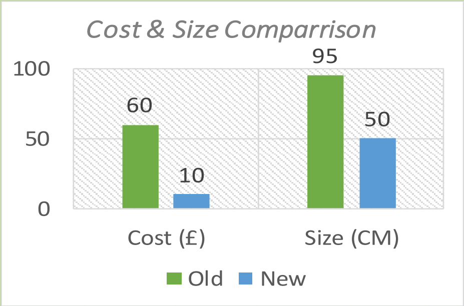
Iterative Design Development: Des. 3 (2)

Modelling & Prototyping: A Compact Approach

To address the concerns voiced by the PU about the metal arm of the original design "**sticking out**", I have created two monitor arms of a different and more compact design as a means of experimenting with reducing the footprint of the mounting solution.

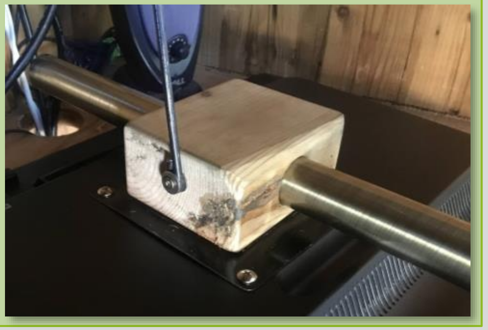
However, because the PU greatly values the "**flexibility**" of the arm I previously pitched, I have also been further exploring ways in which to implement several axes of rotation and adjustment, whilst – at the same time – better meeting another of the PU's litany of requirements: *size and simplicity*. My new design here is significantly more compact than the previous idea, but manages to be **adjustable on 5 different axes**. Each monitor can slide along the rail, and up and down on its individual vertical pole, but can also swivel over 90° from the poles insertion into the through hole and cap hole in the [monitor block] and [hook block] respectively.

In addition, because of the design simplification and optimisation employed in this second revision, the costs and ease of manufacture are greatly improved:



← Reduced Cost & Size

Simplified → Block Design

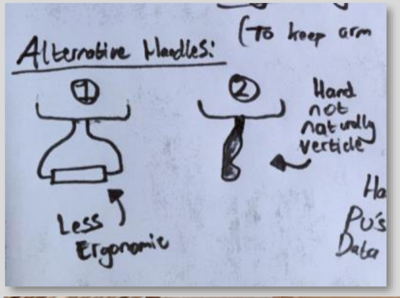


Sizes and Dimensions

Having considered the primary user's feedback about the original design being too large, I can report that the new dimensions are significantly smaller:

Total extended height:	*60*	*cm*
Total extended width:	*~40*	*cm*
Handle:	*Ø3 L7*	*cm*

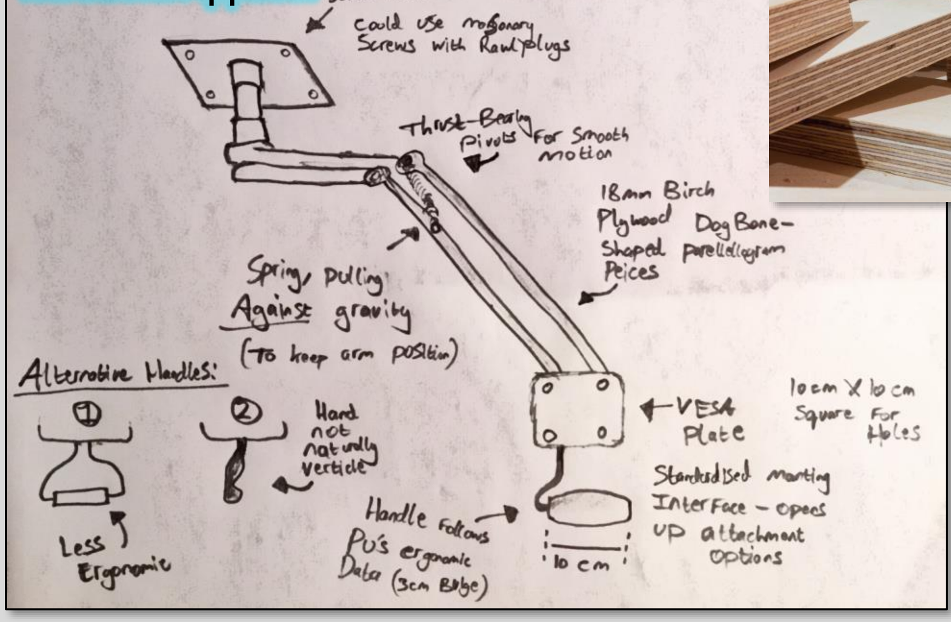
The product now is also much less large and cumbersome.



Exploring different Handle Designs ↓

Birch Plywood ↓

Iterations Applied:



Having produced this drawing, I know that the plywood bars depicted are too thin, and need to be thicker…

PU Comments on the Iterations

The Initial Idea for this design had been to suspend a Video Monitor from the ceiling, to make it easier for the camera operator. In essence, the improvements I have made have largely pertained to improving the size and simplicity and usability of the product. This is what the PU had to say about the iterations:

PU: "The `CompactApproach` models reduce the flexibility too much"

PU: "It could still do with being a bit smaller – are both sections of the arm really needed?"

↓ Making the prototype mounts…

Next Steps

The next design is No. 8…

Iterative Design Development: Des. 3 (3): Prototyping (1)

Introduction

After speaking to the PU in the *mid-way-through Initial Idea Developments* Interview (see subsequent DII Review Slide), it was realised that many students using the final product would not in fact wish to use a school-owned DSLR camera, but rather (for their own convenience) a **telephone handset with integrated camera**.

On account of this, I am adding – to this Initial Idea – the ability for the arm to hold a smartphone by means of a clamping system with quick release.

Factors:

Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

1

Testing an Existing Solution

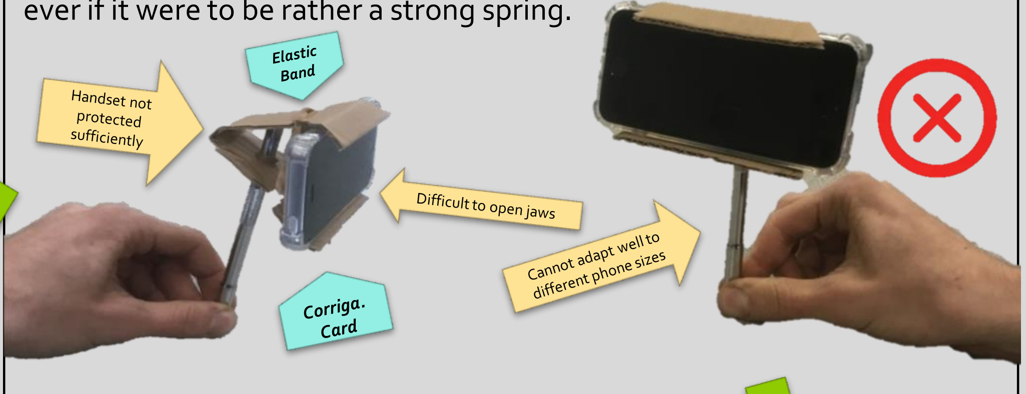
The PU happened to have a SmartPhone Mount for a car, which I investigated in order to improve on for my final product. The PU pointed out that because it was a somewhat old product, its jaws actually couldn't accommodate the PU's large modern smartphone!

This existing solution has clicking ratcheting jaws which clamp the handset. A button must be pressed on the back, to release the jaws again. This feels somewhat clunky and flimsy.

2

Prototyping an Improved Solution: Attempt 1

I firstly made a prototype model of a sprung clamping mechanism from cardboard and some elastic bands. When testing this on a real smartphone (the modern sort which is characteristically **large**, rather **heavy**, and unfathomably **expensive**), it became clear, however, that there simply isn't enough **strength** and **firmness** provided by the spring, ever if it were to be rather a strong spring.



3

I will move onto a different design prototype, to more securely hold handsets of a wider range of sizes

(See next slide herefor…)

Because of the standard VESA-Mounting plate proposed on the "Iterations Applied" drawing for Design 3, I would be able to attach the phone-clamp using this as a fixture-point. (Instead of the suction-cup).
This is because the PU has said…

PU Comments

I spoke with the PU to determine what could be improved with these unsatisfactory phone holders:

"*The Smartphone holder **must** be able to accommodate differing sizes of smartphone, particularly, very large smartphones, as this is an increasingly popular variety with students. In addition, the solution would be well-designed to attach onto an existing standardised and **secure** mounting point. The Suction cup, for instance, wasn't cutting it!*"

Data Collection

In order to better meet the PU's request for a one-size-fits-all phone holder, I will collect several data via my own primary research, into what the average dimensions (←*Width*→, ↑*Height, and* ↓*Depth*) of modern smartphones are. From these data, I will then ensure that my design **functions with at least 90% of all average smartphone sizes!**

Iterative Design Development: Des. 3 (4): Prototyping (2)

Prototyping an Improved Clamp: *Attempt 2*

The previous prototype lacked the adaptability and standardisation required by the PU, as stated in the comments on the last slide. Therefore, I am moving on to a different sort of sliding fixture-based clamp, which can be tightened more securely (thereby better meeting the Stakeholder need mentioned in the blue box).

Stakeholder Requirements!

*"Must keep [a] **camera stable**, and allow steady photographs to be produced. It should also offer a reasonable degree of protection to that camera, and prevent it from being easily damaged"*

Factors:

Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

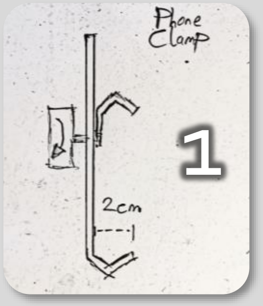
A little bit too complicated →

← Cannot be screwed onto a standardised fixing point E.g. a TriPod screw

These are the collected data from the Stakeholders, which govern the size I will make the smartphone holder…

↓ Collecting Data from the Stakeholders

Stakeholder Smartphone	*Width (cm)*	*Height (cm)*	*Depth (cm)*
Student (Max)	6.8	13.7	0.9
Student (Noah)	8.5	17	1.4
Student (Ollie)	7.5	15	1.1
Student (Tommy)	7.5	16	1.5
Primary User	7.4	15.8	1.1
Design Technician (Mr. W)	8.5	17	1.4
Art Teacher (Mrs. F)	7.5	15	1.1



1

To start making the phone clamp, I draw a quick sketch of what was needed, accounting for the PU's requests. This design allows both very small and very large handsets to be held in the same product. In addition, a TriPod screw exists on the bottom, so that it can be mounted to different fixtures.

Test: The clamp works!

2

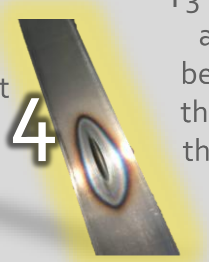
I began by bending some flat bar in a vice, using a pound hammer.

3

Then, I tapped a hold at the top of the upper clamp piece, so that a screw knob could be used from the other side. This was an M5 (standard pitch) Metal tap. The knob is from an old printer.

I used an angle grinder to cut the slit in the main long bar.

4



I 3-D Printed a part to better hold the ends of the phone.

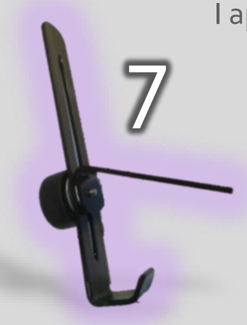
5

← This didn't really fit the phones however, so I redesigned it to accommodate more variation in phone thickness. ↓

3-D Printing the U-Shaped phone end blocks →

6

7



↑ The top clamping piece still needs to be shortened with this design.

I applied some black spray paint to prevent rusting, and match the clamp with cameras/phones.

8

Next Steps

The next design is No. 8…

Iterative Design Development: Des. 8 (1)

Introduction

Here I begin the iteration of Design 8.
In this design, I had attempted to implement an arc-shaped slider with the camera on its top. Through the evaluation of the Initial Ideas, it became clear that although the principle of this system was good and much-liked by the primary user, there *were* two main areas where the stakeholder requirements were not fully met:

- The amount of space the product consumes; the PU wants a reasonably-sized and multipurpose solution, which this – due to its large footprint – is not.
- The ability of the product to be *"multipurpose"*; though the system can photograph a number of different angles of a product, this is intrinsically limited by the rigidity of the arc shape.

These shortcomings will therefore be the focus of the iterative process for this particular initial idea.

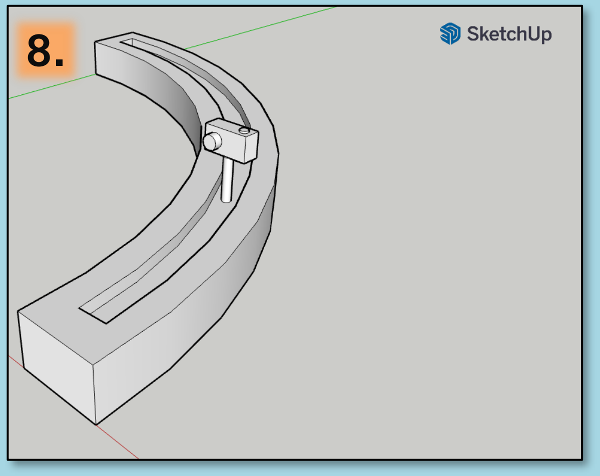
Sizes and Dimensions

In order to fulfil its function, the dimensions for this product need to be considerably smaller. On the next slide I shall demonstrate that this concept can be redesigned to consume 70% less space…

GumTec Products ↓

Rubber Feet ↓

The PU said…



The PU *likes*:
- The potential for ease of use
- The robustness and weight of the design

The PU *dislikes*:
- The size
- Its (lack of) simplicity
- The adaptability
- Rather poor ergonomics

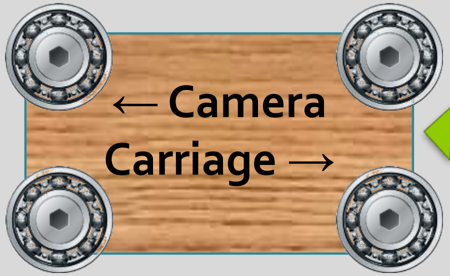
Materials

For the PU's SUSTAINABILITY need

Amongst the feedback given from the PU, was the comment that the slider itself might be susceptible to sliding around on whichever surface it lies. To solve this issue, I shall amend the design by adding soft rubber feet on its base, to provide a more sturdy and frictional contact with a flat surface.

The sustainable materials research conducted on one of the previous slides indicated that "*GumTec*" might be a suitable and ecological form of rubber-like material to use, if any of the products needed it. The pink colour of the GumTec rubber might also add the PU's aesthetic criteria, forming a sophisticated contrast with the matt black of the frame.

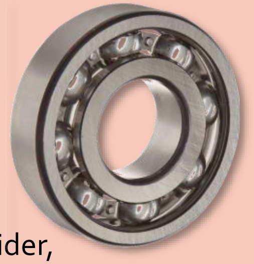
***Bearings exposed on all sides**, to avoid carriage jerking* →



Wider Research: Ball & Thrust Bearings

↑ Inside a Ball Bearing

↓ WM 6000-Series Ball Bearings



When I devised the initial idea for the slider, I neglected to conceptualise quite *how* the carriage would roll across the rails inside the arc-section box. Having thought about **the PU's need for a compact and simple mechanism** however, I have decided to use ball bearings.

Because of the standardised diametric sizes of the bearings, a Metric (*M*) size of bolt can be inserted as an easy way to secure the bearing from the inside. The inside diameter is usually denoted with a [*d*] and the outer diameter with a [*D*]. Alternatively, such bearings are often mounted by **press fitting** the outside diameter into a tight metal or plastic holder piece. Then, an axel can be easily inserted through the bearing, and a smooth rotation can be achieved for anything mounted thereon.

The thrust Bearings mentioned during the previous iteration are somewhat different from traditional axial ball bearings in that they can support a load on their sides, instead of outer edge.

Putting this theory into practice…

In order to make the motion of the sliding camera mount smooth in this design, I am adding ball bearings onto the sides of the carriage.

They would be attached with a bolt going through the middle, and the edges of the bearings would slide smoothly against the wooden edges of internal plywood rails.

Iterative Design Development: Des. 8 (2)

Evaluating different materials for the feet

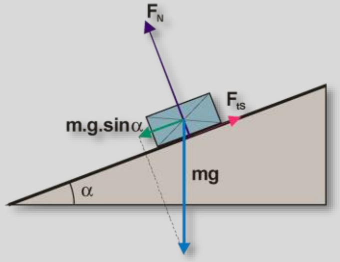
The rubber feat I had proposed to put onto the base of the arc slider were well-received by the PU, because they not only prevent the unit from sliding around, but also are made from a sustainably-sourced rubber, which recycles and recomposes old chewing gum.

However: to **ensure that GumTec Rubber Feat would be suitable**, I have decided to consider these factors:

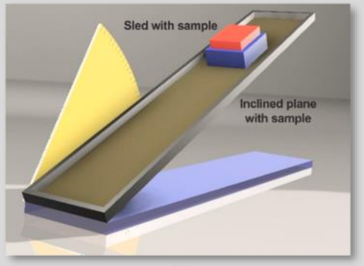
- The ability of the feet to **resist sliding around** – how much *friction* is provided by the material on a smooth surface?
- The ability of the feet to **not compress excessively** or even burst under the potentially rather considerable weight of the slider unit. If the rubber feet were to *crumble*, then they would be unlikely to do so consistently, meaning that the unit would become slanted, and thereby **unable to produce level shots** of products with its camera.
- The **longevity** of the rubber material over time; some rubbers become hard and brittle over years of use, and others even become slimy and leak an unpleasant grease. This is to be avoided, in accordance with the PU's *safety* and *ergonomics* requirements.

I already know that the GumTec rubber triumphs in terms of sustainability, so the other factors are *the deciding* ones.

To perform the friction test, a 1kg weight is placed on top of a sample of the material, and using a newton meter, the force required to pull this 10cm up the 20° gradient is measured, in Newtons (*N*).

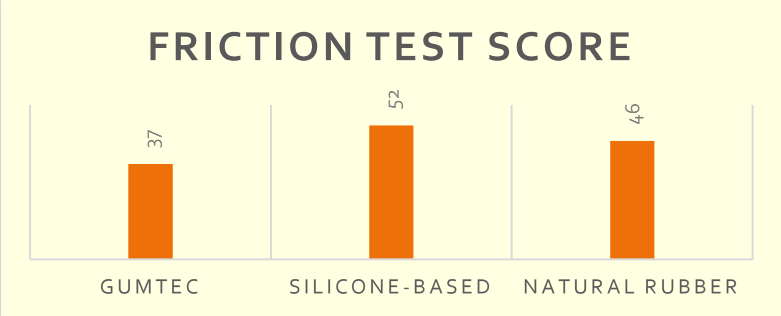


(a)



(b)

I collected these data for the GumTec rubber, a silicone-based rubber, and a natural rubber. The silicone-based (most artificial) rubber, provided the most friction.



As for the "longevity" criterium, I have found that artificial silicone-based rubbers can release an oily grease over time, which makes them unpleasant to hold or work with. Other varieties of rubber tend to become very stiff and inflexible over time. Either of these scenarios could cause the feet to stop providing the correct support and grip to the product.

Because GumTec is a very *new* innovation, there exists limited evidence concerning its longevity and decompositional tendencies.

Source: http://www.phoenix-tribology.com/wp-content/uploads/guidance/Guidance-Rubber-Friction-Tests.pdf

Factors:

Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

Evaluation

I am concluding that a silicone rubber would in reality provide the best rubber feet.

It meets the best compromise in terms of longevity, friction provided, and firmness, from the Testing performed.

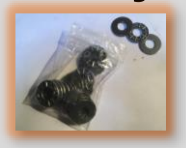
GumTec ↓

↑ Artificial Rubber

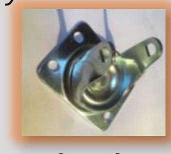
Evaluating Ancillary Bearing Types

The Camera Carriage mentioned on the previous slide requires some form of bearings to enable it to slide left and right. I have identified the following types of bearing around my house:

- **Ring Ball Bearings** *(single row)*
  (See research on prev. slide...)
- **Thrust bearings** *(with washers on each side)*



- **Roller Bearings**
  These have several rollers , against which an axel would turn, for a very smooth rotational motion.



- **Caster bearings**
  There are a series of balls between an upper and a lower plate.

I am therefore electing to continue to use the **ring-style ball bearings**, because they will be the **easiest to mount** onto the carriage, and provide a **smooth** interface on their **sides**.

PU Comments on the Iterations [0]

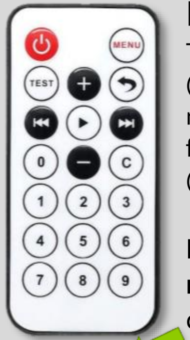
Before I draw up the iterations I have added so far (the GumTec rubber feet and Bearings for smoothness of motion), I checked with the Mr. Grover that everything I have in mind is suitable. His comments were:

PU: "It's still a little too large with the bulky arc-section case. Could that part be removed?"
PU: "I like the idea of the universal Tripod Mount; that makes the product extensible!"

As a result of this feedback, I clearly need to make some more fundamental improvements to this product's design…

Rethinking the Large Casing…

I had the idea of making the previously rigid arc shape into a **flexible linked chain of sections**, which the camera – mounted on a block of electronics and a motor – would pull through in order to move itself. This means that the photographer is no longer limited by the fixed radius of the arc, and can instead bend the chain into any desired arc-like shape. Moreover, this design makes the product considerably more space-efficient as it can be folded into a smaller shape when it is to be put away. Since the arc size can change, the *range* of product sizes the camera can orbit around increases correspondingly. This makes the product more multipurpose and adaptable too, which was one of the PU's Needs.



Electronics

To control the camera-mounting block's motors (and thereby the movement of the camera relative to the chain), an IR sensor would be fitted, and a remote control used to send IR (InfraRed) signals thither.

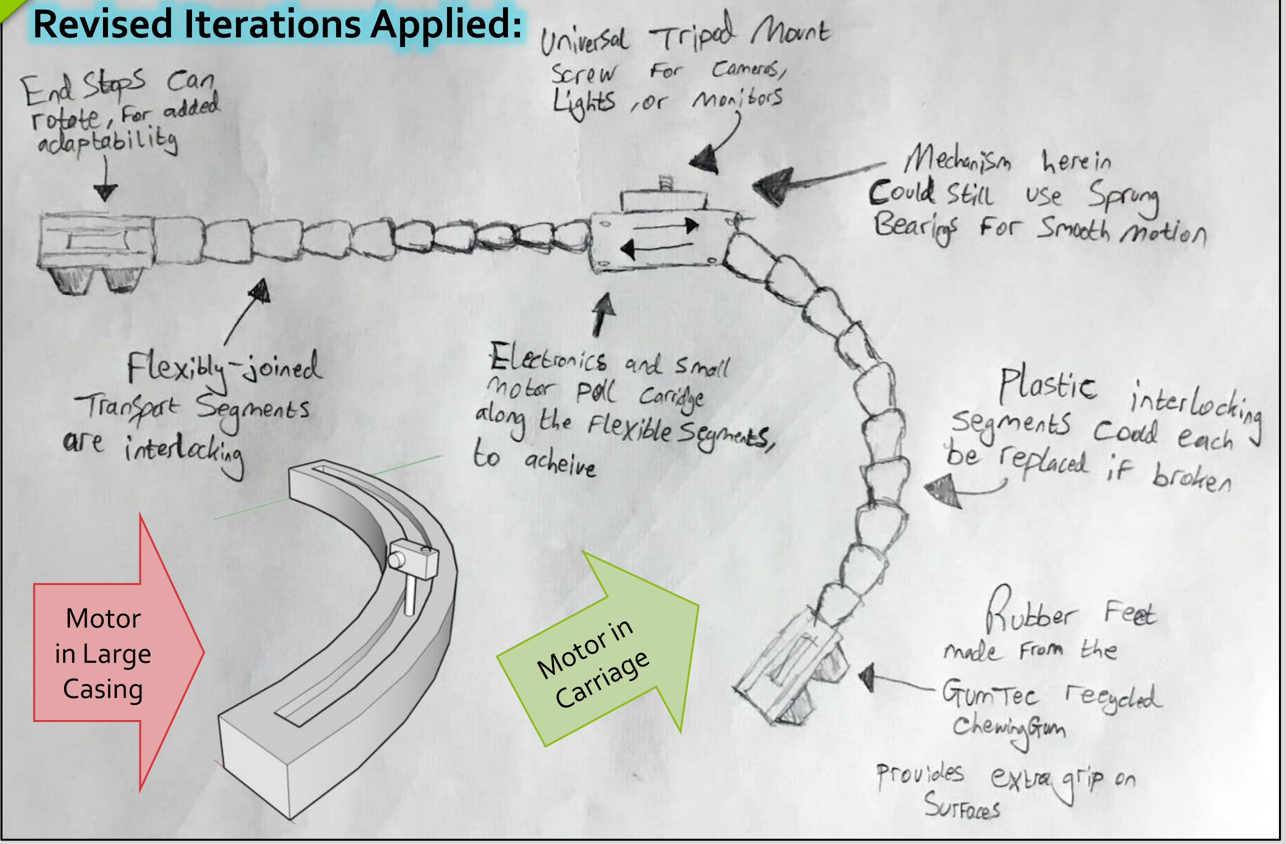
Kits of IR receivers and accompanying remotes are readily available and compatible with MicroControllers, as I shall explore with Design 11's Iteration.

Fabrication Processes

Some of the principle processes Involved in making this design are:

- **Injection Moulding** is what I would use to make each of the interlocking plastic segments. This is a fast and repeatable process, offering a high degree of accuracy but correspondingly a high upfront cost.
- **Using a Bandsaw** to cut out the metal required for the sides of the camera-mounting block.
- **Soldering** would be used when assembling the IR receiver and Arduino MicroController (*See "Electronics" box*)

Revised Iterations Applied:



PU Comments on the Iterations [1]

I collected these final comments after I had produced the drawing:

PU: "I'm not convinced that a smooth quality of pan shot would be achievable anymore; the interlocking sections look too uneven a surface"

↓ *Reviewing Iterations with other Stakeholders…*

Next Steps

The next Design is No. 5…

Iterative Design Development: Des. 5 (1)

Introduction

Here I conduct the iterative design process on design 5. This was supposed to be a

The PU said...

The PU *likes*:

- The adaptability and Multipurpose nature
- The solid and robust design

The PU *dislikes*:

- The (excessively-large) size
- The weight

From Model, → to Real Product

Because I cannot reasonably use copper rivets for a life-size version of this design, I will instead ensure a smooth pivoting motion with thrust bearings (as researched previously) and a tightenable bolt with handle for locking the position at a certain point.

Problem Solving: Space Usage

Problem: Space consumption is becoming a long-standing problem that I am facing during the iterative development process. Because all of the initial idea models and drawings were quite small (physically), this was not a noticeable issue.

Solution: Instead of having a large floor-standing base unit, I shall take advantage of one of the feature of the room's ceiling; I-Beams. These are very robust and strong, and can reportedly support loads of around **500 KG on average**.

As found in the 6th form Design Room ↓

*↑ A Structural **IBeam***

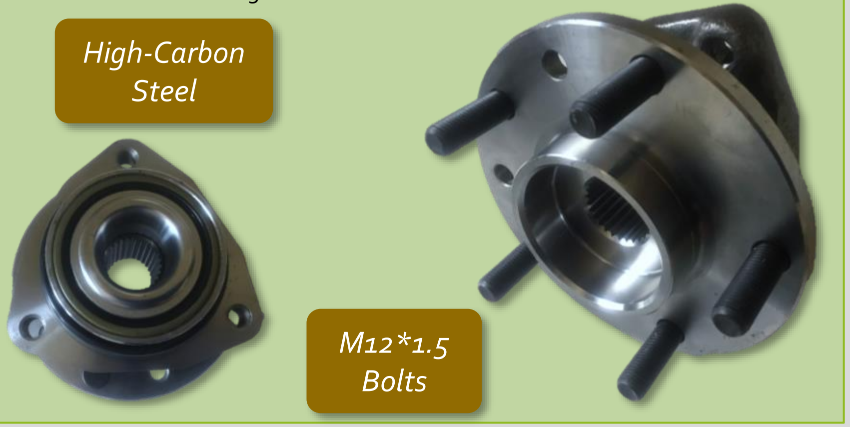
Putting this theory into practice...

The electronics could be used to automate the motion of the arm here. A **stepper motor**, belt and gear system, with accompanying Arduino or Raspberry Pi MicroController. I would write a **C++ program** for the MicroController to run, which could perhaps take serial input from a computer (e.g. over USB™) for the motion to perform, and then **mechanically and smoothly and precisely** perform the requested instruction.

Before progressing with this interesting idea, however, I will check with the PU that it would be suitable. It might come too close to violating the *ease of use* requirement.

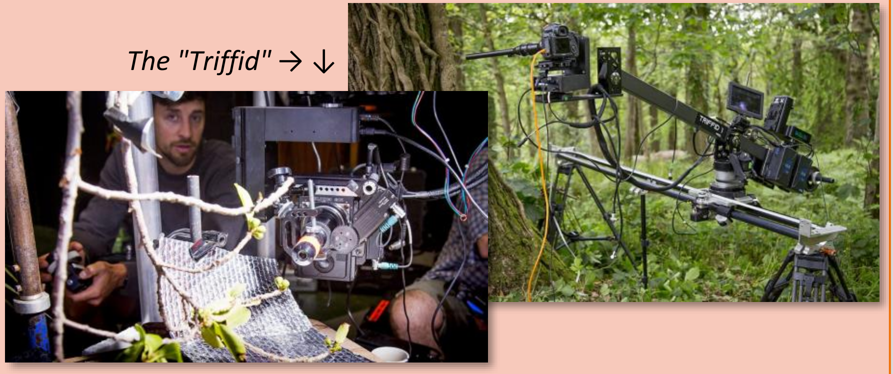
Physical Model & Mechanism Testing

Serendipitously, I recently happened across a new-old-stock *wheel bearing* from an old car, which gave me the idea of making the bottom point of articulation (1 on the model picture) use this bearing. From what I can tell, it is a high-quality machined steel, made to rigorous manufacturing tolerances and standards, for decades of use in a vehicle. The use of the part aids in meeting the PU's *robustness and durability* need, and provides a very smooth and solid turning point, with – conveniently – several threaded mounting holes and bolts.



Wider Research: BBC GreenPlanet Camera Jigs

The "Triffid" → ↓

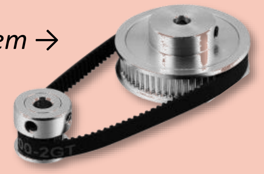


From watching the BBC's *The Green Planet* series, I remember seeing their cutting-edge self-engineered super-timelapse camera jig named *the Triffid*. It can pan very slowly and with a high degree of precision over a distance of about 4m. What makes it especially unique, however, is that it can do all this in a completely different, ultra-slow timescale. It was designed to capture the growth of plants on video, which - when played back much faster – resembles the speed of motion usually only observed with animals. In other words, the system is the first of its kind to produce videos of plants growing on a human timescale, *and* to have the camera moving and panning (e.g. up the growing stem) at the same time. The results are rather incredible: [Episode].

To achieve this precision in motion, the Triffid uses a series of *stepper motors* and taut belts, to pull the main carriage along and to change the angle of the arms. Unlike standard DC or AC motors, these usually have 4 wires coming out of them, and must be controlled via a special motor controller. Commands can be issued to the stepper motor like [move 40° in 3 seconds] or [rotate backwards 10° until the rotational resistance increases by 50%] which mean that the attached belts move a set distance in a very accurate and repeatable fashion.

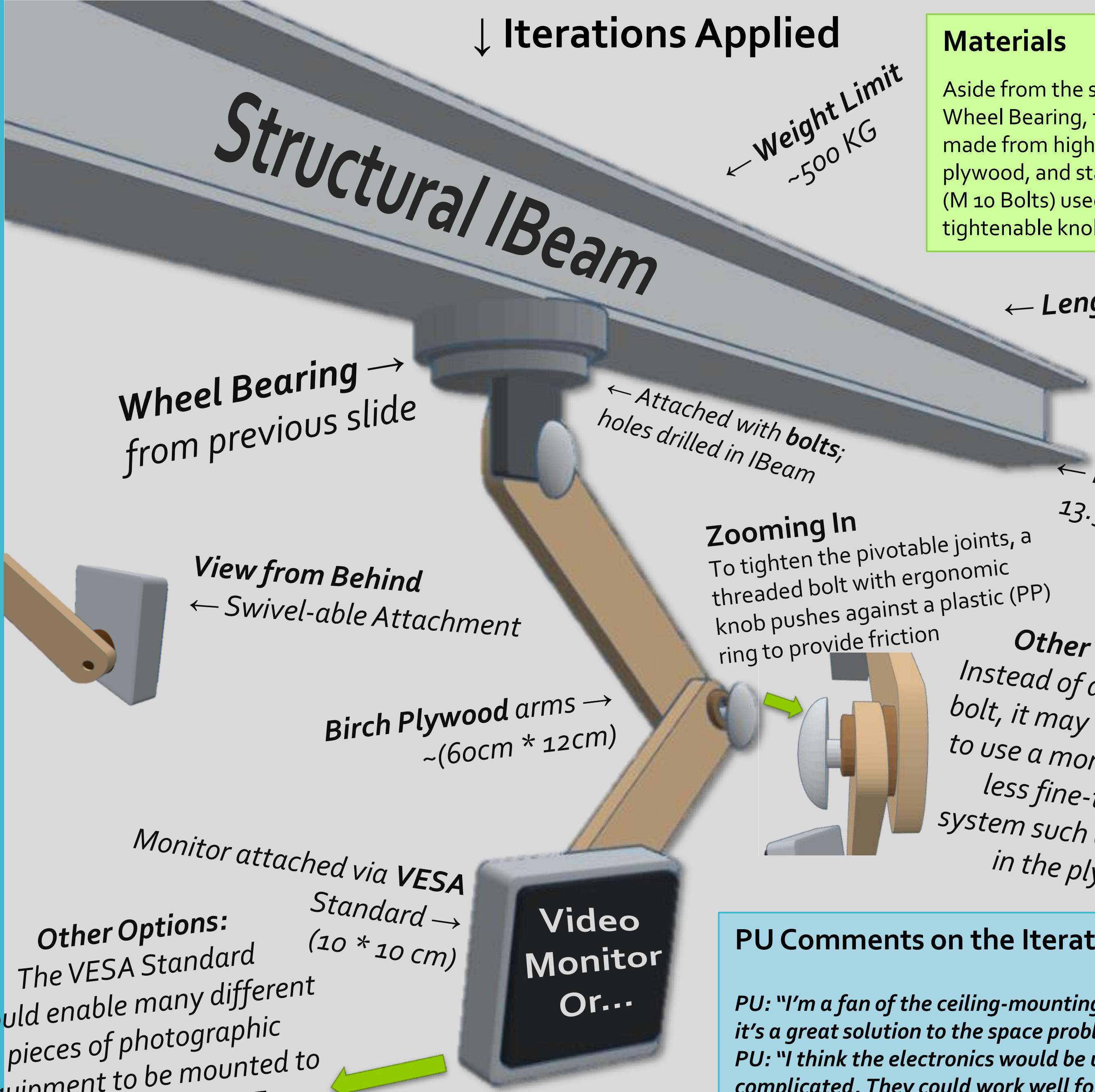
← A Stepper Motor

Belt and Gear system →



Iterative Design Development: Des. 5 (2)

↓ Iterations Applied



Zooming In
To tighten the pivotable joints, a threaded bolt with ergonomic knob pushes against a plastic (PP) ring to provide friction

Other Options:
Instead of a tightenable bolt, it may be necessary to use a more robust but less fine-tuneable system such as set holes in the plywood

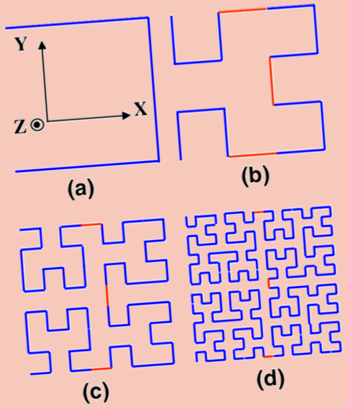
Other Options:
The VESA Standard would enable many different pieces of photographic equipment to be mounted to this same interface. E.g. a light or clamp…

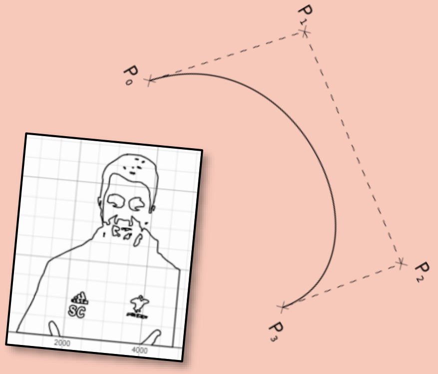
Materials

Aside from the steel IBeam and Wheel Bearing, the arms are made from high-quality birch plywood, and standard fixings (M 10 Bolts) used for the tightenable knobs.

Wider Research: Mathematical Art

To add speciality to the (currently somewhat bland and utilitarian) aesthetic of this product, and to pertain to the scholarly nature of this product's intended setting, ***the PU commented that*** I should look into some more **mathematical or scientific styles** which would fit well within a classroom.





Hilbert curves and **Bezier Curves** both share the principle of having different *Orders*, with each order including two or more instances of the order below itself, in a recursive fashion. Because of this, there is an appealing beauty about the complex shapes and patterns which can be created from such simple base patterns and rules.

Bezier Curves are mathematically-consistent and -describable curves whose shape is dependent on an array of *control points*, which each have an *(x,y)* coordinate pair. *Linear Interpolation* is used to form a straight lines between each control point and the next, and this is done on multiple *orders* until a smooth curve is formed. When multiple curves like this are put together, **an entire image can be drawn onto a graph**. Earlier this year, I wrote a computer programme to demonstrate this in video form.

PU Comments on the Iterations

PU: "I'm a fan of the ceiling-mounting here; I think it's a great solution to the space problem"
PU: "I think the electronics would be unnecessarily complicated. They could work well for a few months, but there aren't really the skills required to fix that sort of thing in the department…"

Putting this theory into practice…
These Art Styles could be applied as a laser-cut, pyrographic, or paint-based pattern, to the side(s) of the product, to increase its aesthetic appeal.
I will *speak* to the PU about these before committing to any one of them…

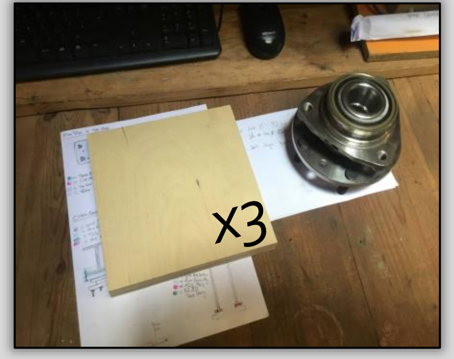
Next Steps

The ceiling-mounting to save space seems indubitably to have be very much approved-of by the PU, so this feature will most likely make it to the final design.
I will therefore make a **model** of it, to optimise its design.

Iterative Design Development: Des. 5 (3): Prototyping

Introduction: Here I make a *prototype* of the assembly to hold the bearing to the bottom on an IBeam. It needs to allow the bearing to *turn smoothly*, and must be *very sturdy*.

↓ Starting with 12mm 20*20 Ply



↓ Forstner Drilling

↓ Jigsawing

↓ Filing

↓ Measuring for accuracy

↓ Stacking the layers

Next Steps

The next step is to improve this initial model by acting on the Feedback from the PU, which was gathered in the demonstration Video. This involves some investigations into handles, lubrication, and the upper arm plate.

↓ Pre-drilling Punching

↓ Clamping

↓ Pilot Hole Drilling

↓ Sanding edges

↓ Counterboring

↓ Removing square neck with bench grinder ↓

PU Comments

PU: "Side-to-side functionality needs to be developed. Could be lubricated with a material such as Teflon."

I also recorded this video of obtaining the PU's feedback on this model. [↓]

To ensure that I was **accurate** in making this prototype, I used:

- A MM Ruler, Calculator, and sharp pencil
- Several Paper templates for accurate and repeatable hole locations; Standard Fixings (M10 Bolts, washers, and Wing Nuts)

↓ Hacksawing

↓ Angle Grinding

↓ Test-fitting

↓ Wing Nut Prep.

↓ Squaring-off

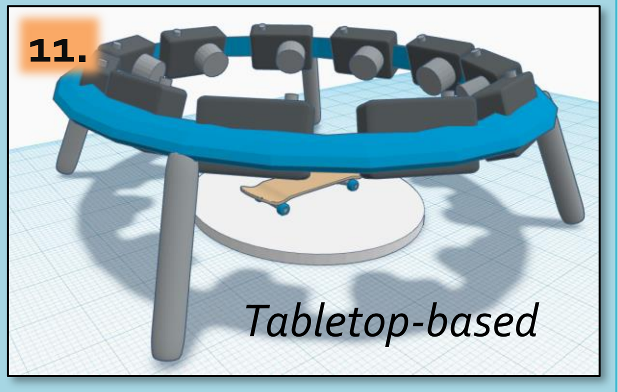
Finished Model ↓

Click Here to watch video

Introduction

Here I begin the iteration of Design 11.
This was a photogrammetry system, allowing the PU to quickly take pictures of a product from multiple angles, and create a 3-D Computer model of the original object, ready to be E.g. 3-D Printed.

The PU said...



The PU *likes*:

- It's Adaptable and Multipurpose
- The Aesthetic theme
- The fact that it simplifies an otherwise complicated process (Photogrammetry)

The PU *dislikes*:

- It could be hard to use
- It's not very robust and long-lasting
- It's rather large

Fabrication Processes

- Pipe bending a hollow aluminium Tube, and using a sleeve with screws at the ends
- Tapping threads into the aluminium to attach the DoveTail mechanisms with M6 Bolts
- Painting with Hammerite Metal Paint

Putting this theory into practice...

To automate usage of the photogrammetry system, a Microcontroller can be used to fire the shutters of all the cameras simultaneously, getting them to all take a picture at the same time. This is the desired manner of operation for photogrammetry, because a consistently-lit object produces the best results when the images are fed into the photogrammetry software and assembled into the 3-D Model.

Conveniently, there exists a standardised protocol for DSLR cameras to remotely trigger their shutters via a cable.

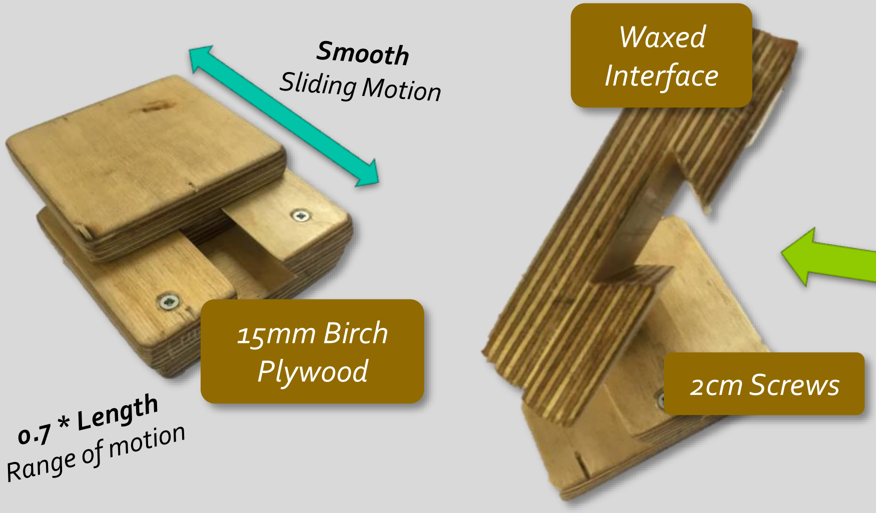
For each camera therefore, ***one end of such a cable would be connected to the camera, and the other, plugged into the MicroController's GPIO*** (General Purpose Input Output) Pins. For this purpose I would use a RaspberryPi, owing the generous number of GPIO pins offered, and the fact that it can be programmed in a variety of high-level programming languages such as C++.

A Remote Shutter Button

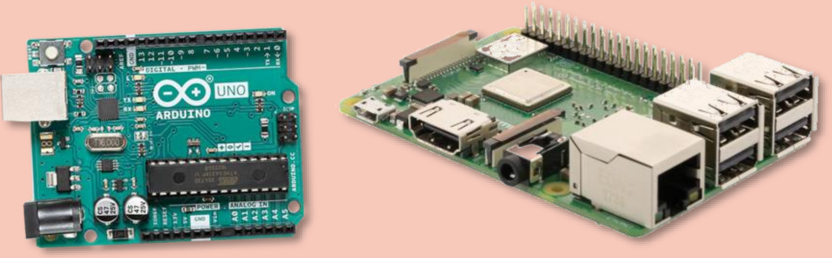
One button to control **all** the cameras

A DSLR Camera

For the PU's EASE-OF-USE need



Wider Research: MicroControllers & PLCs



Because I anticipate using some electronics in this design, I have conducted some preliminary research on Micro Controllers and the slightly more advanced *Programmable Logic Controllers (PLCs)*. Many standardised electronic components **(LEDs, Motors, Buzzers, Sensors, MicroSwitches etc.)** can be plugged into Micro Controllers and programmatically controlled according to a pre-written computer programme which executes a series of commands to accept inputs and deliver outputs through predefined pins.

The "*Ardino*" is a small Micro Controller which can have a programme flashed onto its **EEPROM** (Electronically-Erasable Programmable Read-Only Memory). The are a series of GPIO Pins, to which the other components connect.

Alternatively, because it may be beneficial to enable to the user to have a greater and more flexible level of control over the product, I could use a Raspberry Pi. Instead of being a *MicroController* or *ProgrammableLogicController*, this is a fully-functional single-board computer which runs a primitive UNIX-based operating system. It would be able to accept more advanced and high-level user interaction such as through a WebPage or SmartPhone Application. This can **provide a convenient means of controlling** and possibly automating the operation of the electronics in this product.

Modelling & Prototyping: Easier Camera Attachment

Because each of the camera modules in the current design is bolted onto the main ring Assembly, they cannot be easily removed and used elsewhere.

To solve this, I have experimented with DoveTail joints as a sort of quick release system which holds the cameras firmly when in use, but permits a convenient means of release. From creating and testing this prototype, I have learned that for optimum smoothness in operation, it is best to coat the interfaces in wax, which provides lubrication.

Iterative Design Development: Des. 11 (2)

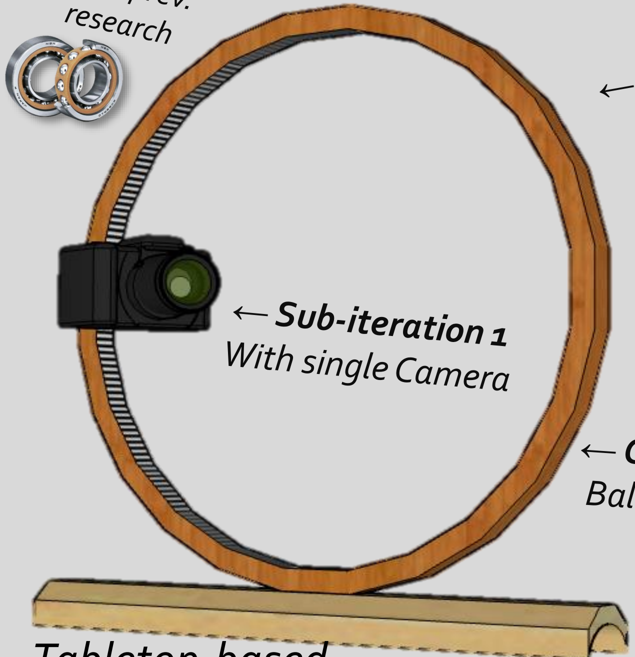
After making the iterations (on the prev. slide), I showed them to the PU, who gave these comments →

Bearing these in mind, I have therefore devised this new design!

PU Comments on the Iterations

PU: "The number of cameras required for the system to work is still prohibitively high; that would be too expensive"

Bearings →
From prev. research



← Diameter
~95 CM

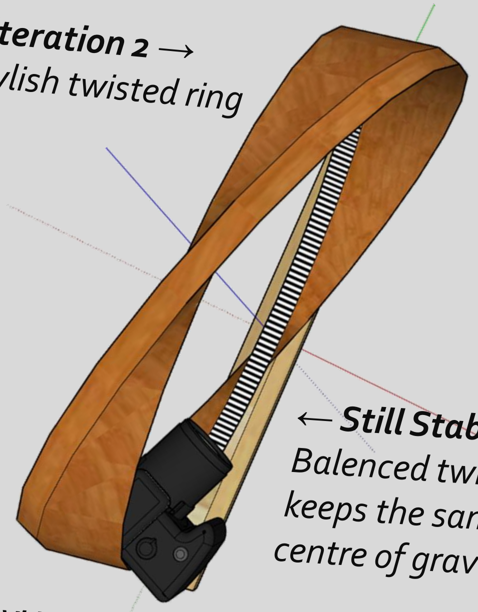
← Sub-iteration 1
With single Camera

← Camera travels around ring
Balenced twist keeps the same centre of gravity

Tabletop-based

← Stand
110% Width of ring

Sub-iteration 2 →
Added stylish twisted ring



← Still Stable
Balenced twist keeps the same centre of gravity

↑ Video Mode...
...would have to be used on the camera, because holding the shutter button would be very tiresome. Still images could then be derived from the video afterwards.

Sub-iteration 3 →
With Camera attachment bar

Monochrome Stripes →
Enable optical encodes to precisely determine the relative position of the camera via processing on a MicroController

PU Comments on the Iterations

PU: "This is much more affordable with just the one camera, though still rather large. We'd also need a separate pedestal for the product being photographed"

Materials

The outer ring is to be made from 3 laminated plywood layers, and the base from a suitable hard-ish wood such as beech or ash.

↓ Reviewing Iterations with other Stakeholders...

Critical Thinking

A real Photogrammetry Studio

From Model, → to Real Product

To make this design in real life, I would have to take the following into account:

- Laminating plywood to create the elaborate shape would mean first having to create precisely the right mould. This would be time-consuming and actually use a large volume of materials in and of itself.

Sizes and Dimensions

Having considered the primary user's feedback about the original design being too large, I am pleased to report that the new dimensions are significantly smaller:

- Diameter: 75cm (Thickness: 3.5cm)
- Twist angle: 5° (Base depth: 20cm)

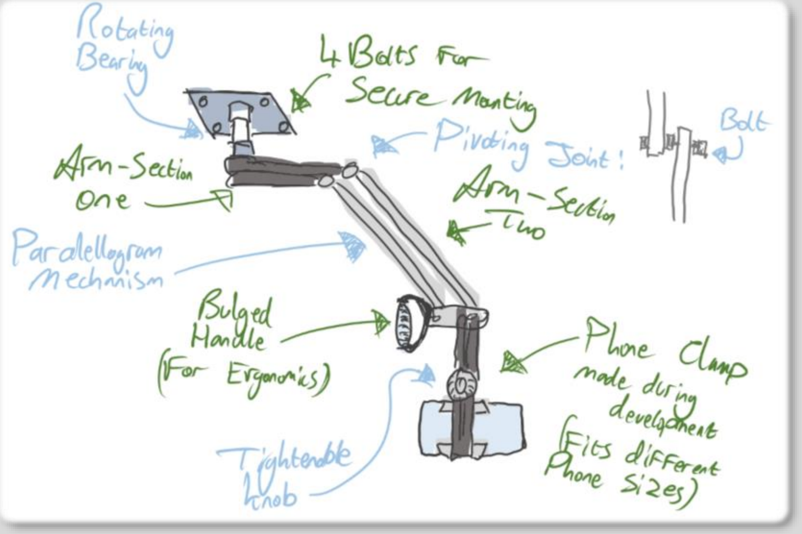
The design now is also much less cumbersome and easier to move around.

Next Steps

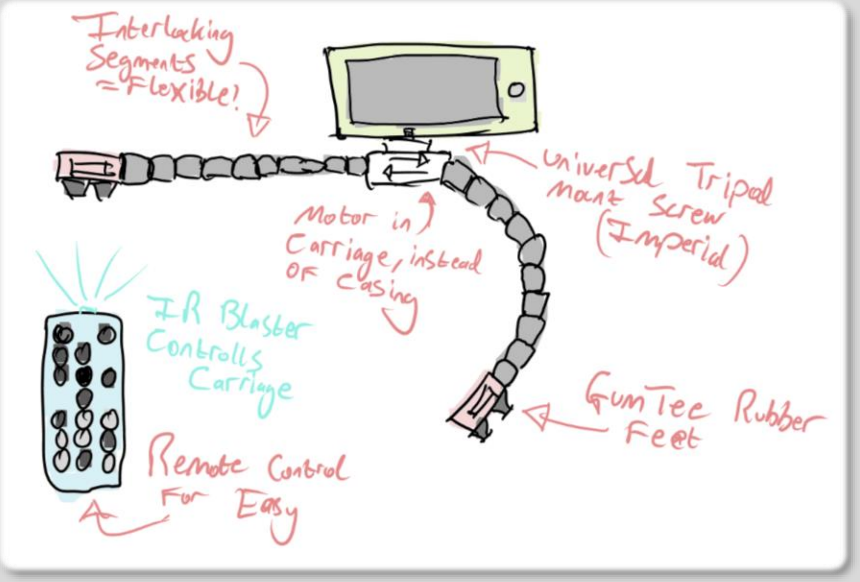
The next step is to further review and evaluate the developed initial ideas, before conflating them into a final design.

Iterative Design Development: Resketching

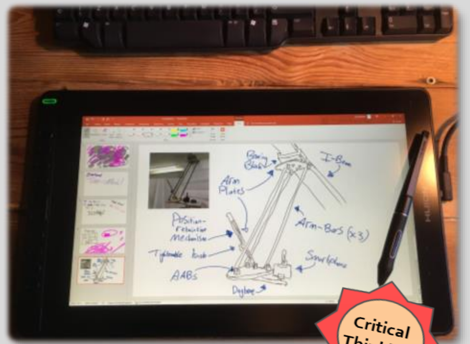
Design 3



Design 8



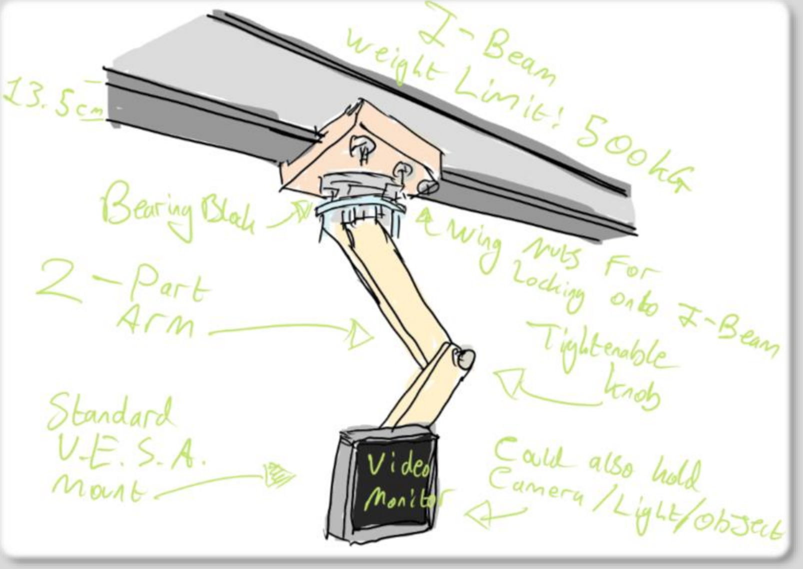
I used a Graphics Tablet to re-sketch each of the four developed initial ideas



Critical Thinking

I did this to find another way of presenting the ideas to the PU

Design 5

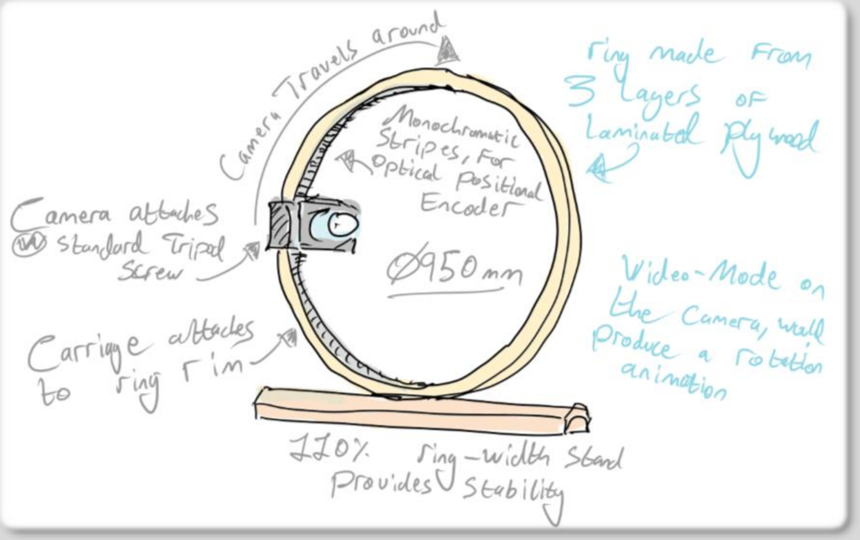


In so doing, I included features of the iterations which hadn't previously been drawn onto the main post-iterative presentation, such as the bearing-block for design 5, phone clamp for design 3, and the remote control for design 8.

The Graphics Tablet proved itself to be effective, and did afford me a great deal of flexibility, though the drawings do look a little Quentin-Blake-like…

These drawings were shown to the PU for the forthcoming interviews…

Design 11



Introduction

Here I evaluate how well each of the developed initial ideas meets the PU's needs, as well as how feasible they might each be to fabricate.

Revisiting the PUNs

The last time I checked-in with the Primary-User-Needs was after the creation of the Initial Ideas. I'll now do it again...

I also met with and obtained the views of several other stakeholders...

Before Iterative Development...

PU Need	Design 3 (CeilingScrn)	Design 5 (Floor Arm)	Design 8 (Arc Slider)	Design 11 (PhtoGmtry)
Ease of use for Students	8	5	7	6
Size	7	5	6	5
Aesthetically Pleasing	5	5	8	8
Relatively Simple	7	5	6	7
Adaptable and Multipurpose	7	9	6	8
Ergonomic and Comfortable	6	9	4	9
Security, Longevity, Sustainability	8	7	7	6
Weight	8	9	8	5
PU Score	7	8	9	9
Total (Higher is Better)	**63**	**62**	**61**	**63**

Assessing Conformity with PUNs...

Before I developed the Initial Ideas, I had evaluated how closely the met the PU needs. Now that they are developed, I have re-asked the PU what they think of the iterative development improvements I have made...

This makes it clear that Designs 3 and 8 do **not** effectively meet all of the PUNs. **D3** has become a little too complicated, and does not look subtle enough. **D8** is not ergonomic enough, and the PU had concerns about its ease of use.

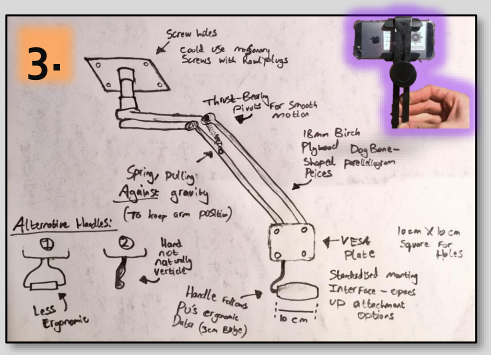
Therefore, it appears that D5 and D11 most-closely conform with the PU's needs.

After Iterative Development...

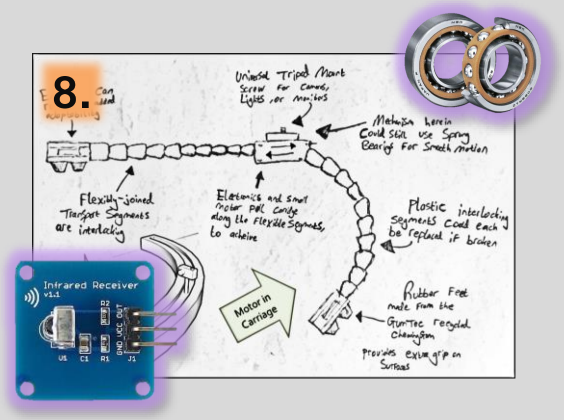
PU Need	Design 3 (CeilingScrn)	Design 5 (Floor Arm)	Design 8 (Arc Slider)	Design 11 (PhtoGmtry)
Ease of use for Students	8	7	7	8
Size	8	8	9	7
Aesthetically Pleasing	6	8	7	8
Relatively Simple	7	7	7	8
Adaptable and Multipurpose	7	9	8	7
Ergonomic and Comfortable	8	9	6	8
Security, Longevity, Sustainability	8	8	7	7
Weight	8	9	8	8
PU Score	8	9	6	7
Total (Higher is Better)	**68**	**74**	**65**	**68**

Iterations Applied:

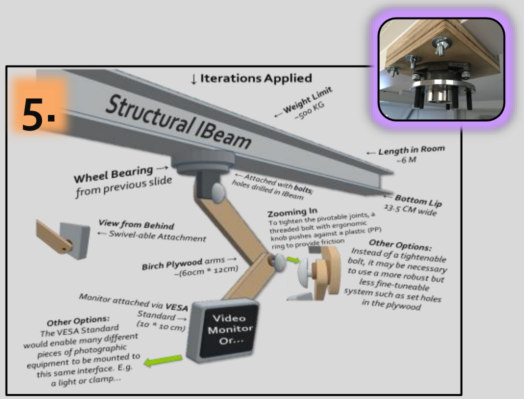
As a reminder, the designs looked like this after applying the iterations...



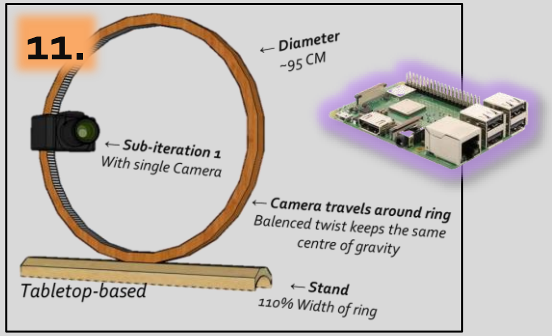
PU Score: 8/10



PU Score: 6/10

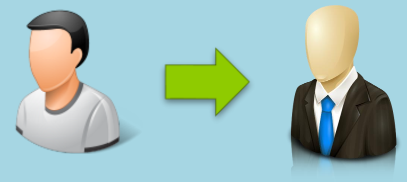


PU Score: 9/10



PU Score: 7/10

PU Circumstances Update



Due to external circumstances, my current PU – Mr. Grover – is no longer available for interviews and contributions to this project.

Therefore, I am changing to one of the **Wider Stakeholders**, who has had an involvement in stipulating the requirements and recommendations for this product, from the very start: **Andrew P.**. His last interview can be found on §[Wider Stakeholders (Answers)].

He is a photography student, and will actually *be* one of the primary users of the final product, which is to say that his needs and requirements for the product are much the same as those of Mr. Grover.

Parenthetically, this accounts for the different voice in the forthcoming audio Interviews…

With some initial PU Feedback (from the new PU: A.P. (≠ M.G.)), I will now decide how to **conflate** the best bits into a final prototype…

What Worked Well…?

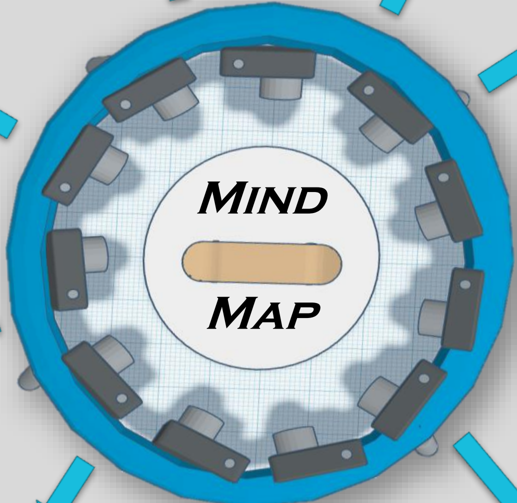
There were a number of common-themes which appeared throughout the Iterative Design process. They ought therefore to be highlighted, and possibly incorporated into the Final Design.

These ideas may well make it into the final design, but I will firstly ask the PU what he think of each of them.

I have indicated the PU's thoughts on each concept, by means of the ticks and crosses…

✗ Or ? Or ✓

The PU did however say, that screwing directly into the ceiling, would not be admissible… → ✗



A Good Idea: Mounting on the ceiling ✓
The concept of saving space by using the ceiling as a fixture point was raised several times throughout the iterations, by the PU.

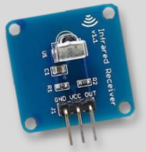
For Robustness's Sake: Using tough Materials ?
I postulated that the designs ought to use slightly-overly-strong and durable materials, so that they .

The "BearingBlock" from design 5 provided a solid interface, conforming to the I-Beam's Shape

Saving Money: Using one moving Camera…
…Instead of many static cameras. ✓
This was noted to be a more user-friendly, cost-effective, and space-saving way to enable the Photogrammetry feature.

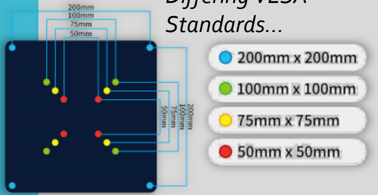
School-wide Compatibility: Support for students' phones ✓
Being able to clamp smartphones onto the rig, as these are a commonplace form of camera.

Automating Repetition: Electronically-controlled Components ?
I could use a Microcontroller to trigger a camera shutter remotely, or stepper motors to precisely control the positions of arms or other moving components.



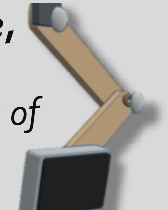
Standards Conformity: Tripod Screws or VESA Mounts ✓
By integrating a standard such as this, the product would be able to accommodate a variety of different devices: Cameras, Monitors, and Lights.

Differing VESA Standards…



Adaptability: Removable Attachments
E.g. the Sliding Dovetail model I made. ✓
This allows a camera to be quickly removed.

Camera Movability: Flexible, connected arms ✓
Most designs involved a series of joined arms or bars.



The Arms were joined by pivot points, for design 5. This used a Thrust Bearing to prevent locking and the mechanism seizing-up.

Factors:
Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

Additional PU Feedback

I bid the PU make some further remarks on the ideas presented by me so far, particularly any negative feedback…

*"I **don't like the idea of screwing directly into the ceiling** – I'm not even sure if the ceiling in the room would be suitable for large screws and rawl-plugs with an axial load.*

Instead, it might be more suitable – and less permanently committing – to fix an arm onto an existing structure – such as a table. The problem with this, however, is that tables vary in their thicknesses and heights, so the final design wouldn't necessarily be movable to different rooms.

Therefore, the idea of the I-Beam as a fixture point is very good; there are often I-Beams of standard sizes in rooms where photography needs to occur. This idea makes the product portable, standardised, and securely-affixed."

*"Developed Initial Idea 8 would be **too expensive because of the Injection Moulding**; this is a one-off product not one for a production line. Therefore, this needs to be either redesigned to use an alternative material, or scrapped in favour of one of the other ideas."*

When asked about the ***Mathematical Art Styles*** for the iteration of Design 5, the PU commented that "*the undue addition of additional aesthetic components to the design only overcomplicates things. It's better to keep it simple!*"

The PU: **Andrew**

*"Because proper and **even lighting** is paramount for photography, the product will need to account for providing an evenly-lit backdrop area, against which the Product can be photographed. The product itself should not block light, but if it is too large to permit all background daylight from passing through, then it could perhaps integrate some form of Light."*

Ancillary lighting may be required →

*"If the product needs to be moved around – or along a structure such as an I-Beam – then there ought to be a **handle or grip** to make this easier, and to avoid strain."*

*"Whatever the product ends up being, its **size does need to be kept down**. It can't take up too much floor space, though could in some way fold-away, if it were to be a larger product. This folding-away would necessarily have to be in itself an easy and straightforward process however."*

I need to keep the size down, or by other means ensure that the product dosen't consume much floor space…

Next Steps
The next step is to draw conclusions on the DIIs

Reviewing the Developed Initial Ideas (4)

Interview 1

Mid-way through Initial Idea Developments

↑ Click here to Listen ↑

The comments from this interview are written up in the blue boxes on the Initial Idea Development slides. They have been acted on, in order to form the final iterations for each of the four ideas.

Interview 2

Finished Initial Idea Developments

Summarised Transcript

Gist: Likes the drop-down arm concept – several iterations seem to have leaned towards that. Likes the IBeam mounting too.

- 1) Mathematical Art Styles – might look like I'm trying to cram too much in there; the Handle with just one-sided attachment is more elegant – but could be improved even more; do you need both of the two sections in the arm?
- 2) Remote Control is a good idea; not sure about the flexible path mechanism – looks flimsy; we don't really need to take so many video panoramas of products in the Dept anyway – mainly photographs; in reality it may be that any electronics installed simply break over time, and render the product unusable.
- 3) Screwing into the ceiling isn't a good idea; the IBeam mounting is more suitable.

These comments have been used to inform the *Conclusions*, written in the blue box to the right…

I showed the iterations to some of the other stakeholders in the Dept. to gather their comments… ↓

…These comments have been added to the conclusions drawn in the blue box to the right… →

Common Aims

It became clear that there was a common goal with designs 3, 5, and 11:

"…We don't want just a Photogrammetry system – something more multipurpose would be better for the school environment…"

Therefore, the forthcoming slides will see these ideas conflated into a singular product, to meet all of the PU's needs. Specifically, I will focus on both the overhead-ibeam-arm and the photogrammetry concepts.

↑ Noteworthy Remarks herefrom ↑

The PU highlighted the following during the interview:

- Not only are 3-D objects being photographed – but also sometimes 2-D pieces of paper. The problem with this at the moment is that shadows are easily cast onto the paper, and this produces an unclear image. Therefore, development of design 5 will require consideration of **how light can pass through** the arm.
- The **mounting of smartphones** must remain a priority; students' devices will be the primary means of photography, as opposed to DSLR cameras.

Next Steps

As the blue box says, I have decided to take forward Design 5, because the PU has made clear that it is their personal favourite, and that it meets the most of their PUNs. Therefore, it will become the basis for the final design, onto which the improvements and additional features will be added.

Next, I will therefore conflate the features of designs 11 and 3 – which aren't worthy of being discounted completely – into the 5th design, where this is possible, and dosen't begin to compromise on other PUNs such as simplicity.

Final Conclusions on the Developed Ideas

Before I conflate the Developed Ideas into a more final-design like specification, I will summarise the conclusions that have been made about each idea, from both my development, and the input of the PU in the numerous interviews and comments collected…

Design 3 – Ceiling Monitor

This idea goes only some of the way towards meeting the PU's needs. It has been praised for being ceiling mounted – which saves precious floor space – but requires permeant, hole-necessitating screws to affix it. It was also rated by the PU as not being particularly aesthetically-pleasing, and the almost-all-metal design would could make it more challenging to meet the sustainability wishes of the PU. **Therefore, I will be partially taking components of this design forward.**

Design 8 – Chained Slider

The developments made hereto had been innovative – in that they saved a considerable amount of space whilst affording the user a greater degree of flexibility with camera track positioning – but ultimately made the design not robust enough. Since this was one of the PU's primary needs, this design scored poorly for not implementing it. Nevertheless, it was rather a good-looking design, but made too many compromises. **Therefore, I will not be taking this design forward.**

Design 5 – Overhead I-Beam Camera Arm

This design was subject to particular adulation from the PU, on account of its space-saving and flexible mechanism. The Prototype I made of the Bearing-Block also proved to be versatile and robust in the Video I showed on §[Iterative Design Development: Des. 5 (3): Prototyping]. Its "Ease of use for students", however, only scored 70%, which means that I shall need to improve it before this could become the final design. **Therefore, I will be taking the majority of this design forward.**

Design 11 – Photogrammetry Ring

The PU was still very fond of the Photogrammetry Idea (the semi-automated process of creating a 3D model of an object, from many 2D images of it), but the implementation of that Idea into this design leaves several points to be desired: The size, adaptability, and durability. **Therefore, I will be partially taking components of this design forward.**

Conflating the Developed Initial Ideas: FD-Proposition-1

Final Design: *Proposition 1*

This proposal for the final design, will act as a starting-point. The forthcoming iterations to it will see it transform into the ultimate final prototype…

Introduction

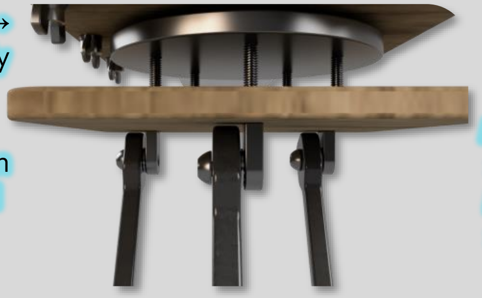
The previous slides have left me with a comprehensive evaluation of the developed initial ideas.

Next, I shall combine the successful aspects of the developed initial ideas, into a Final Design. This – in turn – will then be developed with additional input from the PU, as well as testing of physical materials and processes, and safety considerations.

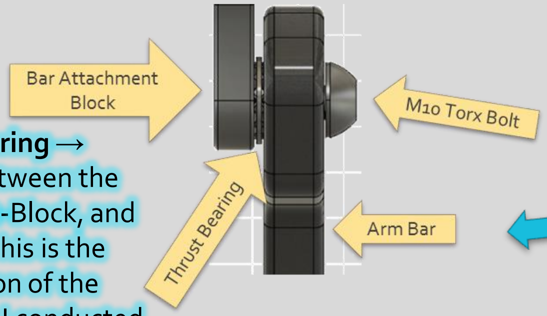
The lower arm plate, onto which the camera is to be mounted →

The Arm-Attachment-Blocks, connecting the upper- and lower-arm plates to the arm-bars ↑

The Arm-Bars → attach indirectly to the upper-arm plate, allowing the arm to pivot around the wheel bearing



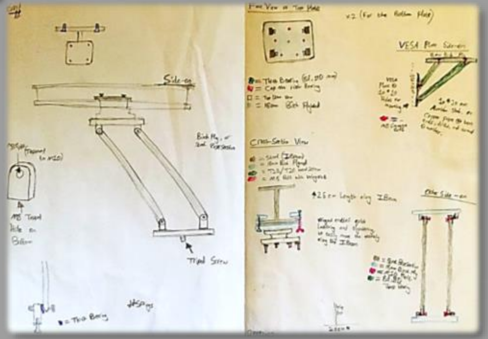
↑ *"The Arm attaches to the Bearing-Block; The Bearing-Block attaches to the I-Beam; The I-Beam attaches to the Ceiling…"*



A **thrust-bearing** → is positioned between the Arm-Attachment-Block, and the Arm-Bar. This is the implementation of the bearings research I conducted during the iterative development.

Final Design "Proposition 1": C.A.D. Model

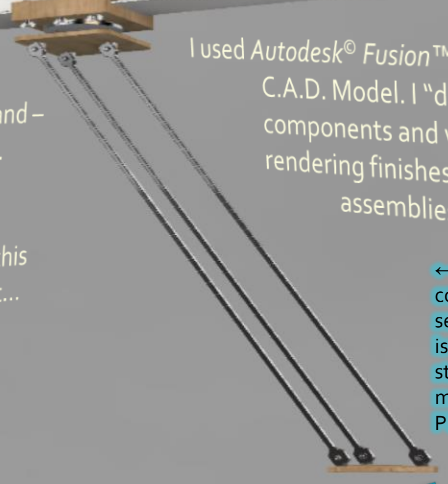
↓ *Initial Sketching*



I will show this proposition to the PU, and – on the next slide – record his feedback.

This feedback will then inform the development of the final design, from this model, to the ultimate physical product…

I used Autodesk© Fusion™ 360® to make the C.A.D. Model. I "dimensioned" all components and was able to apply rendering finishes to different sub-assemblies.



← This arm does not comprise 2 sections, as seen previously. Instead, it is of a simpler, more sturdy one-section design, more closely meeting the PU's robustness need.

Left to do…

This *proposition* still lacks some of the required PU features, but nevertheless serves as a starting-point for the development process. I'll still need to:

- Finalise the means of camera attachment to the lower-arm plate
- Ensure that the materials are suitable, monetarily and mechanically
- Implement a position-retention mechanism, to keep the arm at a user-set height.

Factors:
Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

There are three Arm-Attachment-Blocks per arm plate, because 4 is too many →

The I-Beam is of the standardised UK 203 x 133 size, and the existing Bearing-Block has been designed to accommodate for only this specification →

Final Design: *Proposition 1* – PU Feedback

In order to provide a trajectory for the following final-design-development, I will now determine my PU's thoughts on the final design "*Proposition 1*" from the previous slide…

One clear trend was the need to keep the size of the product down; this was commented upon by the PU for all four of the Developed Initial Ideas.

The PU expressed approval of the one-section arm; this is not only a more durable design, but also allows for a higher topmost angle than the previous two-section arms from the initial ideas' iterative development processes.

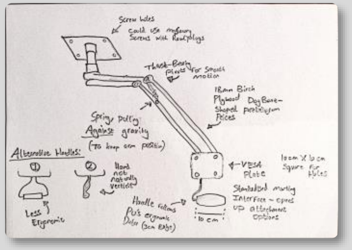
← Ergonomics development on the proposition will make use of the PU's anthropometric data.

See also: Safety Considerations for the FABRICATION PROCESSES, in the Risk Assessment…

Safety Considerations for the PRODUCT

Myself and the PU identified the following Safety Concerns with the proposed final design:

Safety Concern	How to address this
Reckless and irresponsible students would be able to swing the arm from side to side, potentially at each other. This would be dangerous.	The forthcoming development will see me implement a means of position retention, whereby the arm will no longer swing entirely freely.
There could be sharp edges on a number of the metal components, on which people could potentially cut themselves.	I will ensure that all edges are chamfered, countersunk, or rounded-over. This will alleviate the problem of lacerations coming from contact with my product.
Users of the room may be running, and could bump their heads on the **overhead** contraption.	This could – in fairness – be said of any structure in the room. The overhead nature makes it marginally more risky, but the solution is largely to simply encourage care and dissuade people from charging about the room. There will be no obnoxiously-sharp corners.
The camera – mounted at the bottom of the arm – could fall onto the floor, which would damage both itself, and potentially the feet of its operator.	I will guarantee a secure and reliable mounting mechanism for the camera, which does not dispose it to risk of falling.



One point raised by the PU was that mounting a light on the bottom would be useful too. He mentioned that many standard photography lights use the ¼-inch tripod screw for mounting, which means that I wouldn't have to make many adjustments in order to accommodate this additional functionality. I would simply have to ensure that there is sufficient clearance for the dimensions of the light, surrounding the tripod screw.

Pre-FD-Development Interview

After the final design proposition, but before the iteration hereof into the final design.

↑ Click here to Listen ↑

Summarised Transcript:

"It's a pretty effective start, meeting most of my needs. I particularly like the new arm, without the two sections (less to go wrong), and with the two arm plates (plenty of space for secure mounting).

However, I would postulate the following for areas of improvement…"

- *The arm needs to lock into a set position. Holding it manually cannot achieve the required stability.*
- *The Bearing-Block will need to be easy to drag along the I-Beam. This might require some form of handle.*
- *The materials do not necessarily have to be over-engineered, in order to be robust. The metal Arm-Attachment-Blocks – for instance – could conceivably be manufactured out of wood, and still be sufficiently strong.*

Next Steps

The next step is to use these remarks to effectuate the development of the proposition, into the final physical design.

I will take into account the need for a better arm design, the position-retention system, the possibility of light mounting, as well as ergonomics and tribology.

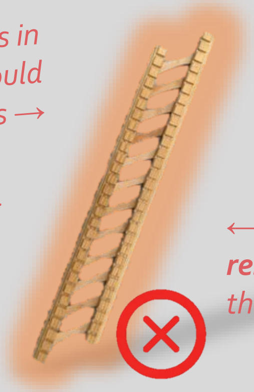
Introduction: Here I make a *prototype* of an alternative arm mechanism. I need to improve on the stability and safety of the original arm (from the Developed Initial Ideas).

Old 2-bar Arm: Shortcomings

Next Iteration

Too many linkages in which children could trap their finders →

The arm feels somewhat flimsy, thereby not meeting the PU's robustness requirement →

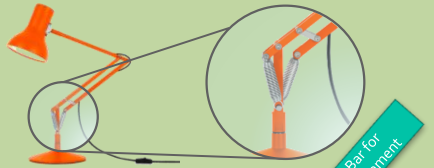


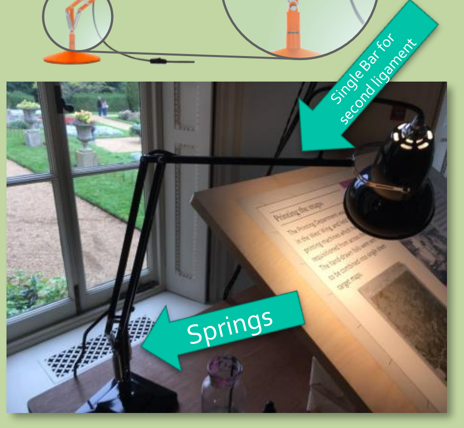
← Not enough stability provided by only two bars. This makes it difficult to mount the top and bottom plates onto.

*← It would be difficult to integrate the required **locking and resistance** functionality with this arm. This is needed to retain the set position without somebody constantly holding it.*

Real-world Inspiration

Whilst at a National Trust property one weekend, I noticed the parallelogram mechanism in this lamp, which uses **THREE bars** instead of the **FOUR** I *was planning* to use! If I could get this principle to work for my design, then I would be able to *even more closely* meet the PU requirement of not taking up too much space, whilst still creating a **robust** and **sturdy** product.





PU Comments

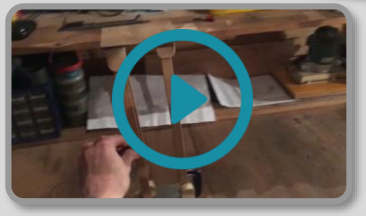
Problems with the previous arm:

PU: "The 2-bar design does not provide enough stability, and there might be some safety concerns regarding the number of side linkages."

Comments on this arm:

PU: "This is much better! It's more solid, steady, and stable."

I also recorded this video of this mechanism in motion, to show how smooth and robust it is...



Click Here to watch video

New 3-bar Arm Design: Fabrication Processes

Measuring, Punching, Drilling, Screwing, Testing...

I asked Mr. Grover about both arms (and the SmartPhone Clamp), to see what works well, and what I need to do next.

Click Here to listen

The plates permit easy mounting →

← The three arms (vs two) provide much more stability and a stronger interface with the upper and lower plates. One of these plates will be attached to the bearing block.

Thrust bearings are used to keep the motion of the arms smooth and resistance-free →

It is significantly safer than ↑ the 2-part arm, in that there are no linkages for finger-trapping.

← Springs or another mechanism now need to be added, to retain the position of the arm as set by the user. I shall perform this iteration on the next slide...

Final Design Development: Arm Mech. (2): Position Retention (1)

One the previous slide, I showed how I managed to create an effective arm mechanism, which – in accordance with the PU's requirements and feedback – was sturdy and safe for use in a school environment.

Now, however, I must devise a way of retaining the position of the arm, after the desired position has been set by the user. My initial thoughts on how to solve this problem are as follows:

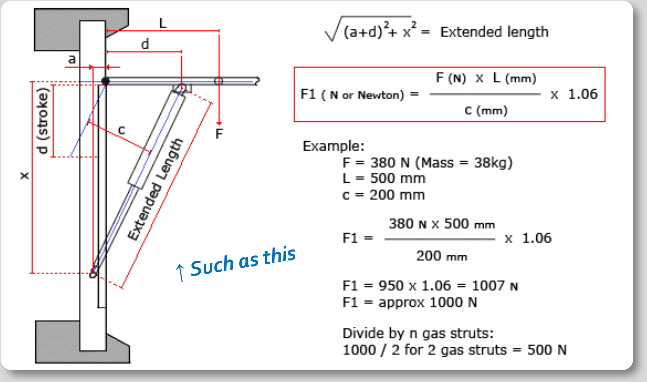
- Have a system of **springs** connecting the bars of the arms, in such a way that the forces of gravity are counteracted.
  ↑ I will test this system first, in the hope that it will work as I intend… (see below)
- Have a **tightenable knob** on one of the linkage points, which can lock the entire mechanism. (When the arm moves at all, then *all* linkage points must undergo an extent of rotation; preventing this rotation would mean that the arm could not move at all)
  ↑ I may resort to this, if an automatically-setting method does not work…
- Have a **gas strut** which extends and contracts as the arm moves. The gas strut retains whatever position is set.

← I can already tell that this is unlikely to work, because the gas strut only pushes outwards; it does **not** retain a set position…

↑ Such as this

↑ Testing the strut

↓ The Formulae I used in vain to determine the correct springs for position retention ↓



↑ Such as this

↓ Testing two springs instead of one ↓

Testing the Springs

Critical Thinking

I firstly tested just one spring, but quickly figured out that I needed to mount the springs in such a way as to have a spring at its *longest*, when the arm is in the position where the *most gravity* is acting on it (i.e. at 90* flat).

This proved to be successful for pulling the arm upwards in one direction, but upon swinging the arm to the opposite, the spring would be placed under so much tension as to **deform it**.

I then attached a spring to counteract this one – to pull the arm up to the other side, in the hope that the two springs' forces would **cancel-out**.

However, after testing this several times, I could not get it to work. Therefore, I am moving on to an alternative mechanism more like a gas strut, perhaps with a knob.

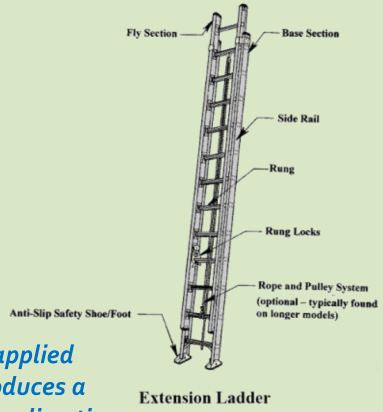
Pulley & Rung Possibilities

The PU mentioned in the interview that one way of shortening a connective fitting would be via a chord with some sort of hook on the end. This hook would be able to attach to one of several different heights of hook, which can act as ***pre-set positions*** for the arm.

↑ The sort of Pulley I had in mind ↑

↓ Rungs, such as would be used ↓

↑ How force being applied in one direction produces a force in the opposite direction.



Extension Ladder

Because the springs did not work, I shall prototype a strut-based system next…

Final Design Development: Arm Mech. (2): Position Retention (2)

Wider Research: Position Retention on larger Camera Jibs

Discovering that the springs were not effective for position retention on my arm has led me to question how this is achieved on more industrial solutions.

I realised that large Camera "*Jibs*" make use of a counterweight, whose job it is to counteract the force of weight (mass * gravity) provided by the camera. For this reason, an operator can vary the number of counterweights depending on the mass of the camera.

However: on closer inspection, I do not think that this counterweighting system would be suitable for my variety of arm. Whilst this arm is clearly split into two "*halves*", pivoting on a CenterPoint, my arm is not. My arm has no midpoint around which to hinge, which means that there is nowhere to fit a counterweight in this style.

Nevertheless, this research has given me the idea of perhaps using a pulley and chord system, to hold gravity-counteracting tension against the arm.

At this point, I therefore have two main options to pursue, for getting the arm to stay in a position set by the user:

- A **pulley-and-rung** system (explored on prev. slide), or
- A **tightenable strut** mechanism.

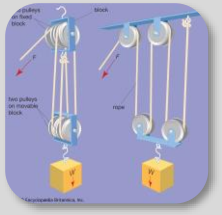
I showed the PU my ideas and research on what a "*Pully & Rung*" system might looks like, and received ↓ the following feedback…

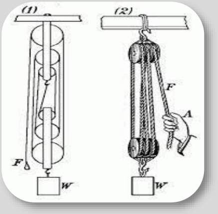
PU Comments

Remarks on the Pulley & Rung system:

***PU:** "Now that I can actually visualise what the pulley & rung system might look like (from those pictures), I'm thinking that it may be a little bit more inelegant and hard-to-use than I had imagined."*

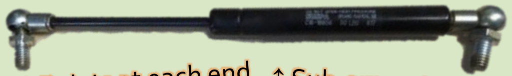
In corroboration with this PU statement, the fact that the pulley-and-rung system would necessitate a wheel (or potentially several) and multiple runs of chord, with hooks and rungs, makes it difficult to implement and increases the likelihood of the mechanism breaking over time and therefore the product becoming unused (as ineluctably happens to so many pieces of equipment in the Design dept.). In addition, there isn't a need for the effort-reduction system provided by a ↓ **block and tackle** ↓.





Developing the Tightenable Strut Mechanism

- I shall start by looking back at the gas strut:



- Taking these two identified features forward, I will now create a **prototype** version of the variety of tightenable strut I have in mind:

Flat sliding bars ↑

Small wing nut to tighten extension ↓

Creating this prototype has been a fruitful process, in that I can identify the following **shortcomings**:

- *THE ARM FOLDS INSTEAD OF RETRACTING!* I'm astonished that I failed to foresee this problem – but that's what the prototyping process is for. To fix this on the final design, I'll need to add some side *wings* which keep the motion linear, and prevent the mechanism from taking the path of least resistance.
- The attachment points at the end are – on this prototype – functional, but do provide an unideal level of resistance. If there are any leftover thrust bearings from the arm attachment points, then they would be put to good use as mechanical lubrication here.

Next Steps

This arm design is a definite improvement, and next I'll make some modifications to the Bearing Block…

Introduction: Here I refine the BearingBlock component. I need to address the lubrication, handle, and locking functionality, as were commented upon by the PU.

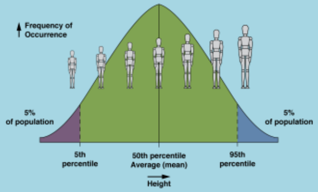
The current Bearing Block

The present bearing block prototype (as shown to the PU during the iterative development of Initial Idea 5) is effective, sturdy, and aesthetically satisfactory.

However, the PU fed back that it could do with:

- **A Handle**
- **Some locking ability**
- **Lubrication (for sliding across the I-Beam)**

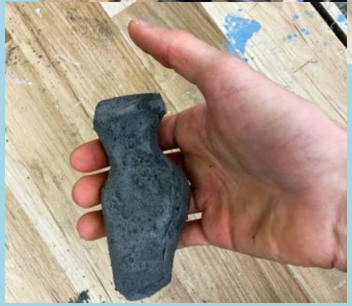
I am therefore going to refine the bearing block's design to include each of these three improvements. I shall start with the handle. I have modelled an **ergonomic shape from some foam**, to comfortably fit in the PU's hand, using the dimensions are from the PU's ergonomics data. Whilst the ergonomic datum suggested only that I make a bulged cylindrical handle, I know that this is not necessarily the most comfortable solution, for which reason the handle is not a simple cylinder.



↑ ***Bulge size in accordance with PU's anthropometric datum and 50th %tile*** →

↓ **Filing**

↑ **Testing the grip**



↓ **Woodturning a handle for the Bearing Block** ↓

Means of attaching a Handle

A knob for tightening the block onto a set position on the I-Beam will make use of a Threaded bolt, to achieve an amplification of a comparatively-small rotational force into a much larger linear force. There is a compromise to be made between a very **high-TPI** thread (which can provide a large amount of force) and a **low-TPI** thread, which moves in the linear direction much more quickly. An M5 to M12 thread (at standard pitch (TPI)) would be perfectly suitable, and well within this compromise's sweet-spot.

I have identified two types of bolt which can be inserted into a hole drilled into the existing wood of the bearing block; 1 and 2 .

← PU Comments

Feasibility of handle attachment:

PU: *"Now that you've shown me how and where the handle would actually need to be attached, it does look rather large and somewhat incongruous"*

Comments on this arm:

PU: *"This is much better! It's more stable, and "*

I also recorded this video of this mechanism in motion, to show how smooth and robust it is...

Knob Selection:

I located a number of different knob designs to show the PU. These were off-the-shelf components, which make commercial manufacturing easier.

The PU chose one particular knob with a good fit to his hand. He did say that – actually – an excessively large knob such as what I had modelled out of foam, would not fit well with the bearing block's size, as it would be too large. We therefore continued with the smaller brass knob.

Refining the Arm-Attachment Blocks → 

My plan had hitherto been to make these blocks from solid mild steel. I have – however – realised that this proposition may portend the following disadvantages:

- Cutting through 1cm-thick, solid mild steel, would be at-best cumbersome, and is indeed likely to be somewhat inaccurate in its results.
- This would necessitate a great deal of sanding and corrective material removal, after cutting, which wastes metal.
- Therefore, using this material would also make the entire fabrication process slower and less celeritous.

I spoke to the PU about this, who had the following to say:

- "Yes; as well as what you've pointed-out, the metal would also make the product heavier. It's a less *sustainable* material too."
- "...Owing to this, I'm happy for you to use (something like) Plywood instead"

On account of this feedback, I performed a test to evaluate the rigidity and suitability of the corollary; Plywood. I determined that by using two slightly-*oversized* woodscrews (shaft ⌀ 3mm) in two slightly-*undersized* holes (⌀ 3mm), I could achieve a very **tight and firm fit**!

Factors:

Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

Next Steps

The next step is to add the lubrication to the BearingBlock.

Final Design Development: BearingBlock Lubrication

Introduction

Here I work on the issue of lubricating the I-Beam against the Bearing Block. *(I have already ruled-out Vaseline.)*

The system does not require a huge amount of lubrication, as the block is only to be moved occasionally. Nevertheless, a long-lasting solution is required, which is robust and will not wear out.

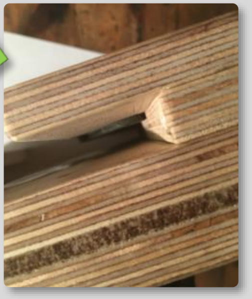
I shall begin by evaluating different possible materials herefor, and then consider the tolerances and how to affix the lubricative material. This is an application of ***tribology***; *the study of lubricants and friction-reduction*.

Problem:
When I tested the BearingBlock in real life with the PU, we found that it didn't slide particularly smoothly on the IBeam.

Because of the PU's comments from the BearingBlock Review Video *<See cref="slide:{IDD}: Des. 5 (3): Prototyping" />*, I experimented with different options for lubricating the interface of the BearingBlock and the IBeam.

My first idea was to use a strip of **copper**. This is a soft metal (*importantly, softer than the IBeam, so the harder IBeam isn't hereby damaged*) which I could affix to the undersides of the bracket part of the BearingBlock.

Under Here



A problem, however, with this copper strip, is that it is very difficult to attach. I cannot simply glue it onto the wood because it would not be reasonable to assume that even a very good glue would hold the strip on permanently, and withstand the vibration caused by moving the bearing block along the rather course surface of the I-Beam.

Because one of the PU requirements was to not permanently damage any structural components within the room, I had to think of an alternative means of attaching the wheel bearing to the I-Beam, which dosen't involve drilling holes with a MagDrill. To this end, I proposed the previously-shown Bearing-Block component.

UK Standardisation Compliance

This One

Next Steps

The next step is to investigate some of the standards which I will implement into the final design, to make it more versatile.

← Therefore, I tested out this TEFLON PAD material, which was much better. It left no marks on the I-Beam, and was easier to attach!

Refining the bar-attachment hinging mechanism:
I made a prototype of the hinge, to check that it worked as intended...

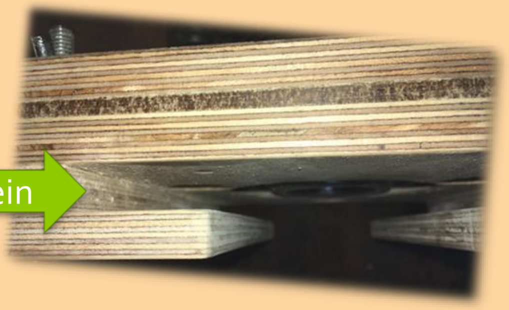
Keeping within the tolerances!

By adding something to lubricate the sliding of the Bearing Block on the I-Beam, I am eating into the available space in the clamping part's gap, here:

I am afforded 12mm of space in this gap, owing to the thickness of Plywood used.

7mm is consumed by the presence of the I-Beam, leaving 4mm of room for a means of lubrication, and at least 1mm of play, so that the mechanism isn't completely bound-up and intransitive.

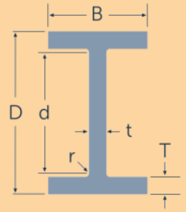
Herein

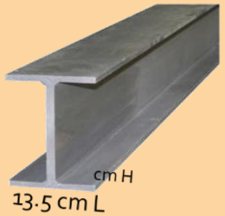


↓ UK Standardised IBeam Dimensions ↓

Size	Weight	Depth	Width	Web Thickness	Flange Thickness
(mm)	*(kg/m)*	*(mm)*	*(mm)*	*(mm)*	*(mm)*
127 x 76	13	127	76	4.2	7.6
152 x 89	16	152	89	4.6	7.7
178 x 102	19	178	102	4.7	7.9
203 x 102	23	203	102	5.2	9.3
203 x 133	25	203	133	5.8	7.8
203 x 133	30	207	134	6.3	9.6

This thickness datum means that I cannot select a lubrication material which is more than 4mm tall.





I have therefore elected to use the **Teflon-like plastic**, because it meets the best compromise between wear-resistance, lubrication-provided, thickness, and indeed cost. I have attached the pads with some Philips screws which do not protrude. This allows the pads to be replaced in the future, which makes the product serviceable.

Final Design Development: Standards Investigations

Introduction

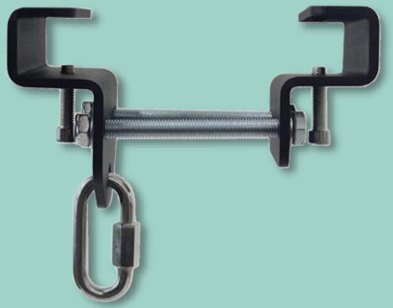
Here I investigate some of the standards that I ought to implement into the final design.

Implementing standards affords me several benefits, including making the product more multi-purpose versatile, and long-lasting. For example, if I conform to a standard mounting fixture specification – such as that of VESA – then *any* receptacle product which also conforms to this specification, will be usable with the arm jig I am making here. This means that not just monitors would be mountable, but also {Mini PCs, Projectors, certain lights, etc.}. Therefore, if the user decided that a monitor arm is no-longer needed, then they could fit an alternative product instead.

The standards which I and the PU have considered so far in the project, are:

- **V.E.S.A.** – primarily for monitors
- **¼-inch Tripod Screw** – primarily for cameras
- **I-Beam Mounting** – sometimes used for mounting Multimedia Projectors or other hanging equipment. For example, I found this ↓ Existing Product online, which achieves a similar goal to my Bearing Block, which I modelled back on §[Iterative Design Development: Des. 5 (3): Prototyping]…

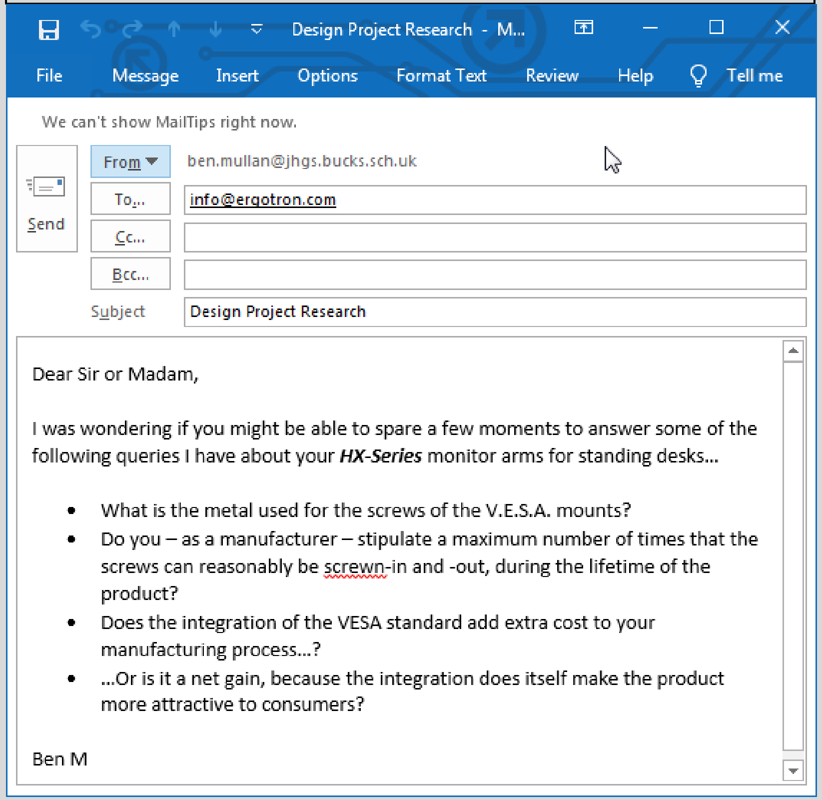
This would not be suitable for my PU, because it couldn't securely hold a camera →



← A commercially-available I-Beam Mount, for a hanging object such as a light, rope system, or a boxing punchbag.

Real-time Evidence: Company Correspondence

To find out about the ramifications and considerations for using the VESA standard, I decided to send an Email to a Monitor Arm company, who implements the V.E.S.A. standard themselves…


Design Project Research - M…

File Message Insert Options Format Text Review Help Tell me

We can't show MailTips right now.

Send

From: ben.mullan@jhgs.bucks.sch.uk

To…: info@ergotron.com

Cc…

Bcc…

Subject: Design Project Research

Dear Sir or Madam,

I was wondering if you might be able to spare a few moments to answer some of the following queries I have about your ***HX-Series*** monitor arms for standing desks…

- What is the metal used for the screws of the V.E.S.A. mounts?
- Do you – as a manufacturer – stipulate a maximum number of times that the screws can reasonably be screwn-in and -out, during the lifetime of the product?
- Does the integration of the VESA standard add extra cost to your manufacturing process…?
- …Or is it a net gain, because the integration does itself make the product more attractive to consumers?

Ben M

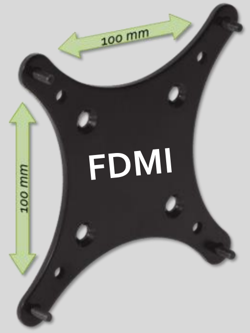
…I received the following response:

Thank you for your enquiry. I have collated the following information for you regarding the questions you asked:

- *Our screws and the corresponding nuts are made from a high-quality, high-carbon steel, which enables us to provide long-lasting operation and durability.*
- *We do not officially provide such data; we don't find that our customers frequently need to screw-in and then unscrew their monitors regularly.*
- *It does add some extra cost to the process; about 6% all things considered. However, **we do not have to pay for licencing agreements** in order to make use of the standard, which makes it open.*
- *It is worth it, because there would otherwise be no standard for the mounting of the monitors and – occasionally – other devices such as projectors.*

Regards,
Ergotron Customer Services (est. 1998)

Video Electronics Standards Association (VESA) FDMI



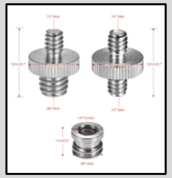
Technical Specification:

The horizontal and vertical distance between the screw centres respectively labelled as 'A', and 'B'. The original layout was a square of 100mm. A 75 mm × 75 mm (3.0 in × 3.0 in) was defined for smaller displays. Later, variants were added for screens with as small as a 4 inches (10 cm) diagonal.

Standard "1/4-20 UNC" TriPod Screw

Technical Specification:

Per ISO 1222:2010,[1] the current tripod bolt thread standard for attaching the camera calls for a 1/4-20 UNC[2] or 3/8-16 UNC thread.[3] Most consumer cameras are fitted with 1/4-20 UNC threads. Larger, professional cameras and lenses may be fitted with 3/8-16 UNC threads, plus a removable 1/4-20 UNC adapter, allowing them to be mounted on a tripod using either standard.



The proposed I-Beam mounting by means of the BearingBlock. I-Beam dimensions are standardised…

PU Decisions

A VESA-Mount vs a Tripod-Screw:

PU: *"Whilst it may still be worth testing the VESA system for usefulness later on, I can't really see the department needing to mount a monitor more frequently than needing to mount a camera. Therefore, the TriPod screw would be better for this product. It would still enable us to hold a sufficient variety of different pieces of photographic equipment; many lights also use such a screw."*

The I-Beam Mounting

PU: *"I have already ratified this as a good idea – use it!"*

Next Steps

As is elucidated by the PU feedback, I will be incorporating the Tripod Standard, and not the VESA Standard, into the final design.

The next step is to perform some trials and physical tests on some mechanisms which may be used.

Further Physical Testing

In addition to the numerous models and prototypes I have already presented, I wanted to test out some of the mechanical and physical materials and components of the design, before committing to them for the final design specification.

Factors:

Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

Introduction

Here I will create mock-ups and models of the following physical components:

- **The Arm-Attachment-Block's Bolts**
- **A VESA Mount**
- **Geometry for the**

Arm-Attachment-Block's Bolts

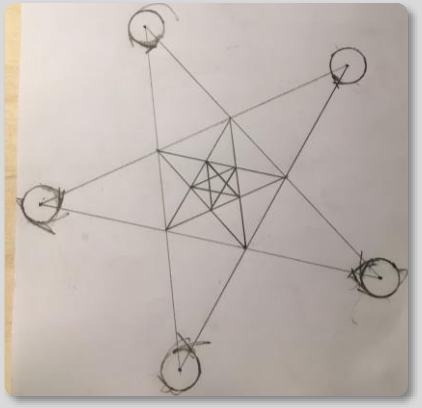
I have modelled the mechanism I plan to use for attaching the arm-bars to the Arm-attachment-blocks.

Critical Thinking

I realised from this, that I only really required one thrust bearing, instead of the two my proposition had suggested.

Nevertheless: In order to make doubly sure that I am meeting the PU's requirement that the product be durable, and hold up to menacing lower years fiddling with the mechanism, I shall still use two thrust bearings per joint, where this is possible. I have enough thrust bearings to use two, on most of the joints.

For the upper-arm plate, I used geometry to find the centre of the pentagon ↓



Modelling a VESA FDMI Mount

The Flat-Display-Mounting-Interface would allow any standard monitor to be mounted onto the end of the arm.

I made this FDMI plate, and tested it with a real monitor. It did fit, though there was rather a lot of pressure on the end of the wooden bar.

I discussed this with the PU…

PU Feedback & Changes:

- *Only really need to be able to hold a camera/smartphone*
- *Tripod screw would be better than VESA*

Next Steps

The next step is to draw-up the Final Design.

Final Design

This is the resultant functional design, incorporating all iterations.
From here, I will create orthographs and a cutting list, and then have my design reviewed for a final time, before beginning the fabrication…

Introduction

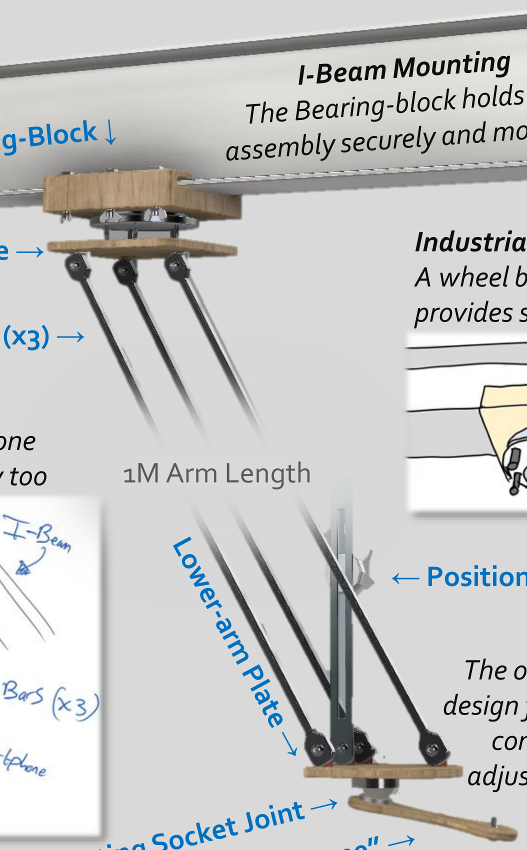
Here I present the CAD model, created from the Final Design's technical specification. I have also included some graphics-tablet presentation.

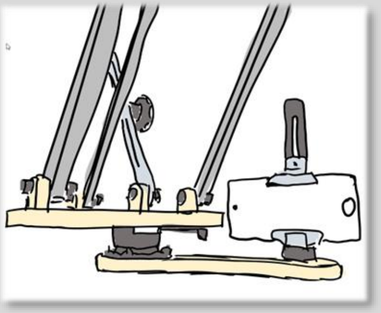
Geometric Optimisation

The PU's input concerning having enough space and mounting points (for future expansion) on the lower-arm plate, have led to this change in shape

I-Beam Mounting

The Bearing-block holds the assembly securely and movably



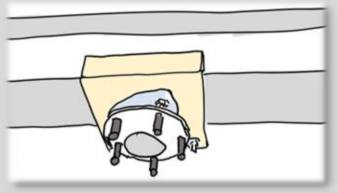


Flexibility

Three points of articulation (Bearing, Arm, and Dogbone) enable a great deal of adaptability in angles for photographs

Industrial Componentry

A wheel bearing from an old car provides smooth & steady rotation

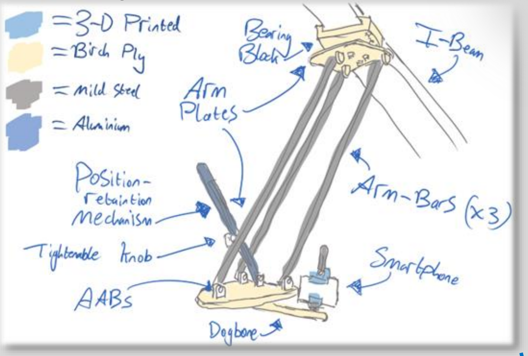


Integral Joints

Most components are attached together with locking-nuts and bolts. This allows the assembly to be taken apart easily.

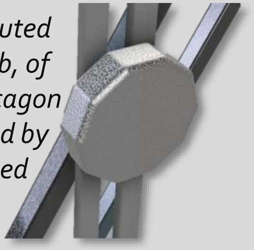
Smartphone Mounting

This sketch shows how the phone clamp fits onto the tripod screw too



Ergonomic Interfaces

The PU's hand measurements contributed to the tightenable knob, of diameter 60mm. Its decagon shape was also inspired by the shape of the closed hand.

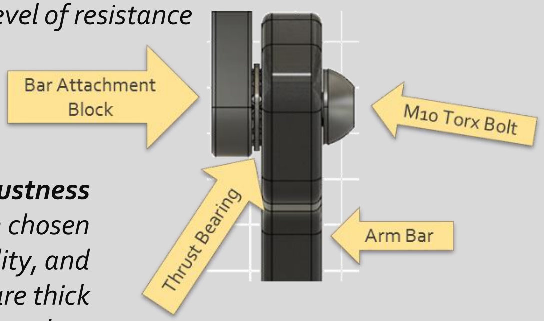


Stability

The one-section, but 3-bar design for the arm affords it a compromise between adjustability and stability

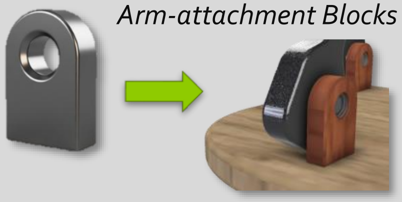
Designed for the Long-term

Thrust bearings ensure that even if the bolts become looser or tighter, the arm will continue to provide the same level of resistance



Material Upgrades

The PU's comments about not over-engineering already-sturdy components has led me to use 15mm plywood, instead of mild steel, for the Arm-attachment Blocks



Standards Implementation

The Tripod screw made it through as a standard mounting format, supporting cameras, lights, and the smartphone clamp made earlier

Robustness

All materials have been chosen because of their durability, and all components are thick enough to support more than the expected weight

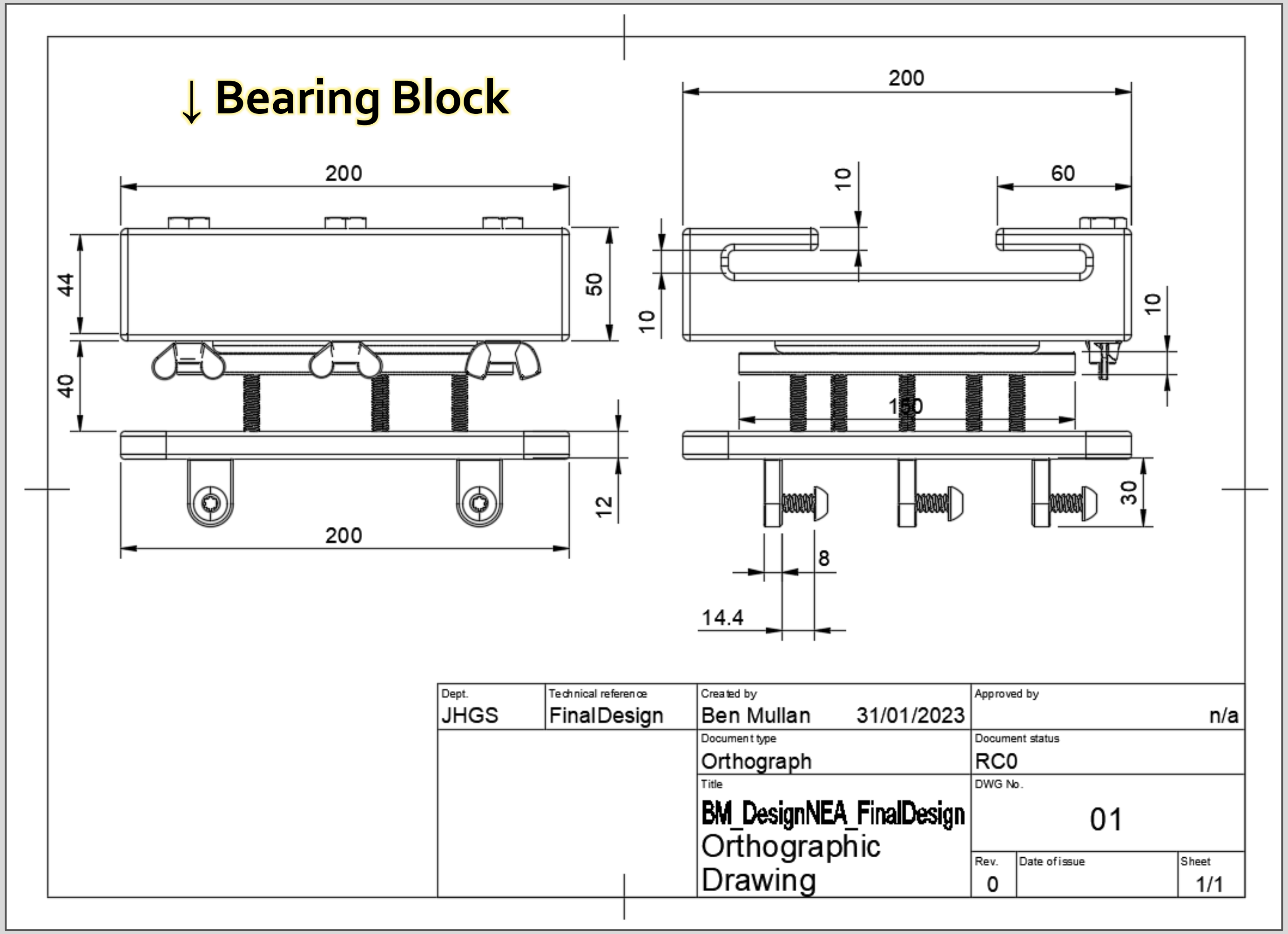
Next Steps

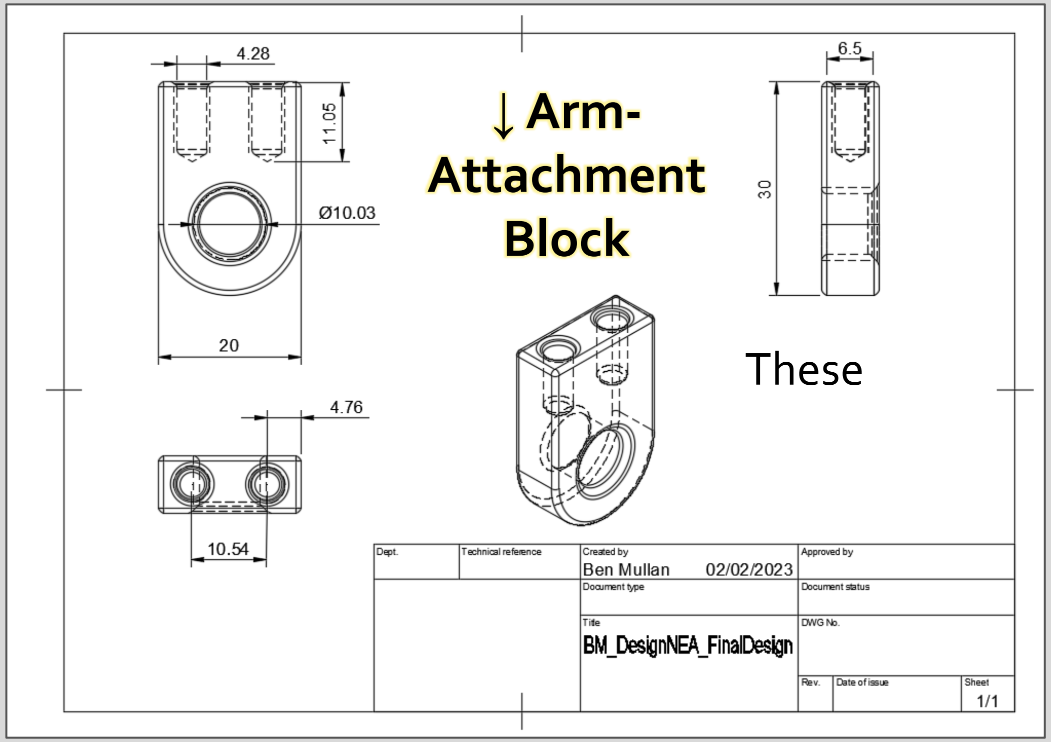
I will next present the cutting list herefor.

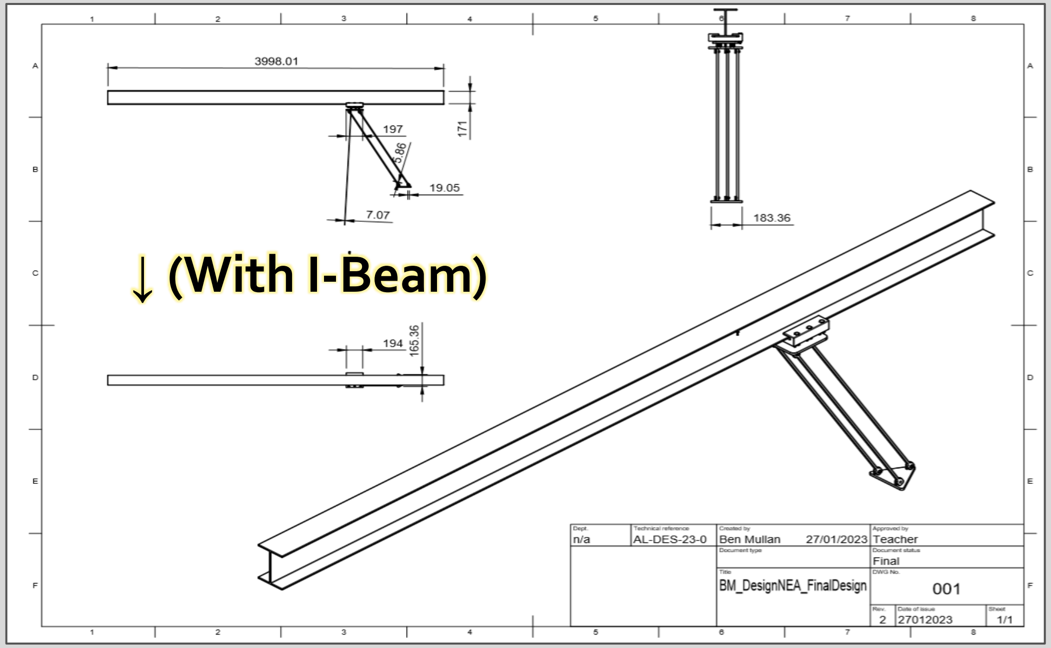
Final Design (2): Orthographs

Orthographs!

To clearly represent the specification and interface to which the components of my Final design are to be made, I have produced these Orthographs. (*Ortho-* comes from the Greek meaning straight, as in orthodontist or orthodox.)







Next Steps

The next step is to make the final design. Some of the components – including the bearing block and smartphone clamp, have already been refined during the hitherto iterative feedback process. These components will simply be added to the final design, instead of being re-made. (The PU has demonstrated in the interviews that he is happy with these existing components)

Final Design (3): Technical Specification

Introduction

Here I outline the technical requirements for the final prototype.

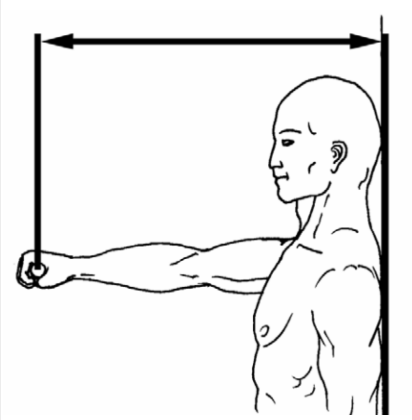
Since the Final-Design-Proposition-1, the following principal changes have been made:

- Articulating camera bar at bottom – discovery of articulating socket joint
- Position-retention mechanism
- Arm-Attachment-Blocks are wooden and not metallic
- Knob on BearingBlock for pulling it along
- No longer have the triangular lower-arm plate
- Beeswax finish (instead of nothing)

Ergonomics

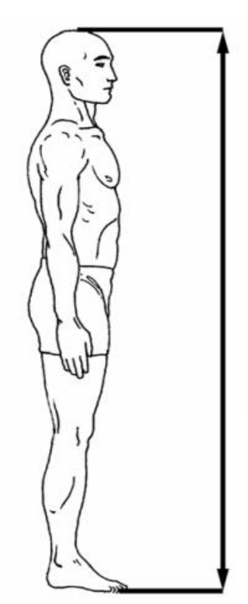
I have identified a data-source to use for ergonomics, providing me with the average arm lengths and heights of males in the UK, in 2003. Because my product is to be used by many different stakeholders within the school, I cannot rely on the PU's anthropometric data alone.

These data have governed the arm-bar length of 1.00M for the final design. Previously – for the initial proposition – it was 1.5m, but this meant that the camera would be too low for most people.



MALE
N = 1774

Centimeters		Inches
75.07	Mean	29.55
3.68	Std Dev	1.45
92.10	Maximum	36.26
62.60	Minimum	24.65



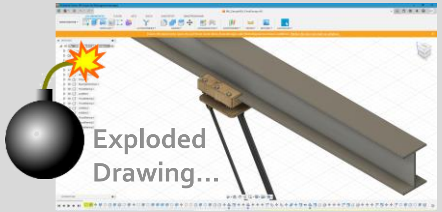
MALE
N = 1774

Centimeters		Inches
175.58	Mean	69.13
6.68	Std Dev	2.63
204.20	Maximum	80.39
149.70	Minimum	58.94

Parts (Cutting) List

These are all the components I require to make the final design. The total cost is £49.00, which is well within the PU's budget. Admittedly, this would be a fair bit more expensive, if I had had to buy the wheel bearing (which I procured **for free** from an old Chevrolet Blazer).

Part		Dimensions (mm)			Notes	
Component	**Material**	**Thickness**	**Width**	**Length**	**Quantity**	**[]Cost**
Upper Arm Plate	Birch Ply	12	210	210	1	£3.00
Lower Arm Plate	Birch Ply	18	210	240	1	£3.00
Dogbone (Mount)	Birch Ply	18	10	25	1	£2.00
Arm Attachment Blocks	Mild Steel	10	20	30	6	£6.00
Thrust Bearings	High-carbon Steel	*	18	18	10	£7.00
Arm Bars	Box-section Steel	15	15	1000	3	£10.00
Wheel Bearing	High-carbon Steel	124	131	131	1	£0.00
BearingBlock Base	Birch Ply	12	200	200	2	£3.00
BearingBlock Wings	Birch Ply	12			2	£2.00
BearingBlock Spacers	Hardboard	5	200	80	2	£1.00
BearingBlock Fixings	Mild Steel	*	M8	100	3	£1.00
T25 WoodScrew	Steel	5	*	60	14	£1.00
M10 Bolts	Steel	*	*	80	3	£2.00
M8 Bolts	Steel	*	*	70	9	£5.00
M12 * 1.5 pitch Nuts	Steel	*	*	10	5	£3.99
Tripod-thread Screw	Steel	*	*	30	1	£0.00
OBJECT TOTAL						**£49.99**



Materials

The Plywood I am using comes from an FSC-certified source. For every tree chopped-down, two new ones are planted.

Sizes and Dimensions

For the dimensions, I have decided to stipulate a tolerance of ±1.5%. This provides me with enough accuracy, whilst at the same time, not binding me to an unforgiving and thereby time-consuming level or precision.

Next Steps

The next step is to create a plan, then make the product, and then get more PU feedback as I go.

Final Design: Fabrication: Plan (1)

Introduction

Here I delineate the steps I will need to take in order to create the final physical prototype.

I will do this by means of a **Flow-Diagram.** Where there is a diamond shape, this represents a decision.

On the next slide, I will also provide a Tab-Index Notation (TIN) version of the process, which – one must concede – is somewhat easier to comprehend than the fabled flowchart. The TIN shows the process in a tree-like structure, instead of a linear one.

- Start
- BearingBlock…
- Mark out the materials for the bottom block, ears, and lubricative
- Cut materials: 12mm ply, and 4mm hardboard
- Are the materials exactly the right size? — No?
- Cut the circular hole in the three sheets for the bottom block
- Start with a 50mm hole-saw
- Cut the remaining material away with a JigSaw
- Use a rasp to sand the inner hole to be smooth and round
- Screw together main block component
- Pilot holes are needed, due to the diameter of the woodscrews (~4mm), and the likelihood of the plywood to split
- Drill holes for bolts to hold on the "ears"
- Insert correct fittings, including wing nuts, to secure ears to main block
- Once tightly screwed together, sand all surfaces to be flush
- Are all faces flush? — No?
- Insert the Wheel-Bearing into the block, using the M10 bolts
- Upper-Arm Plate…
- Mark out the square upper-arm plate with a ruler
- Cut this out on the BandSaw
- Mark the radii for the corners with a compass and pencil
- Use the disc sander to remove the corner material, to produce a rounded shape
- Lower-Arm Plate…
- Create a paper template, for the shape of the lower-arm plate
- Use a prit-stick to glue it onto a sheet of 18mm plywood
- Use a JigSaw to cut this out
- Sand the edges to be smooth, ensuring that any burn marks are removed
- Arm-Attachment-Blocks (AABs)…
- Make a template for the block shape
- Use this template 6 times to accurately mark out the blocks
- Cut the blocks out with a fine-tooth wood saw, such as a tenon saw
- Are the blocks all exactly the same size as the template? — No?
- Sand off the top corners with the Disc Sander
- Use a set square to ensure that the bottom face of each block is exactly 90* from the other faces; it is the datum edge
- Mark-out and drill two holes in the bottom of each Arm-Attachment-Block, to later accept the screws
- Drill the corresponding holes in the Arm Plates, so that the holes align with those of the AABs
- Create a jig to ensure consistent hole spacing
- Punch the locations of the holes using a small hammer and centre-punch
- Drill these holes with a 3mm HSS bit
- Pre-thread the holes manually using a T25-ScrewDriver and screw
- Position the AABs over the holes in the Arm Plates, and screw them down firmly
- Are all 7 bearing blocks secure? — No?
- Arm-Bars…
- Mark out 3x 1m lengths of mild steel box-section steel, using engineers' blue and a scribe
- Cut this with a HackSaw
- Ensure that there is no sharp bur left on the end; sand this off
- Round the edges of the bars slightly
- Mark, punch, and drill the holes in the 6 ends of the bars
- Use a countersink bit or bur-removal-tool to make the metal around the holes smooth and safe again
- Add the position-retention bar to the middle arm; an M8 nut is placed inside the middle bar, to provide the friction for the knob
- Lower camera mount…
- Make a paper template for the dog-bone shape, using a compass
- Stick this to a sheet of 18mm ply, and cut it out on the BandSaw
- Sand off the template
- Rout around the edges of the dogbone shape, to apply the round-over
- Drill a though-hole on one side of this dog-bone, in the centre of the circle previously drawn by the compass - This hole will accommodate a tripod screw
- Insert the tripod screw into the hole
- Screw the dogbone shape onto the bottom of the articulating-socket, and the other side thereof, onto the underside of the lower-arm plate
- Assembly…
- Mount the BearingBlock onto the I-Beam
- Mount the Arm-Bars using the M8*70mm bolts, in the order [Bolt → Washer → AAB → ThrustBearing → Washer → LockingNut]
- Tighten these bolts until there is no wiggle-room
- Are the nuts either too tight, or not tight enough? — No?
- Mount a camera onto the tripod screw of the dog-bone arm
- Final Sanding and Finishing…
- Give all components a final sanding; there should be no sharp edges at the end, and the metal components ought to even be slightly shiny, wherefore I am using a high-grit sanding sponge
- Apply a beeswax coating to the wooden components with a soft rag
- Wait for this coating to dry
- Is the coating dry? — No?
- End

Going Forward…

I will use these steps in the creation of my final physical prototype, to ensure that I do not miss any important processes.

Final Design: Fabrication: Plan (2)

↓ Here is the TIN version of the process tree, as explained on the previous slide… ↓

1) BearingBlock…
- A) Mark out the materials for the bottom block, ears, and lubricative
- B) Cut materials: 12mm ply, 4mm hardboard
- C) Cut the circular hold in the three sheets for the bottom block
  - Start with a 50mm hole-saw
  - Cut the remaining material away with a JigSaw
  - Use a rasp to sand the inner hole to be smooth and round
- D) Screw together main block component
  - Pilot holes are needed, due to the diameter of the woodscrews (~4mm), and the likelihood of the plywood to split
- E) Drill holes for bolts to hold on the "ears"
- F) Insert correct fittings, including wing nuts, to secure ears to main block
- G) Once tightly screwed together, sand all surfaces to be flush
- H) Insert the Wheel-Bearing into the block, using the M10 bolts

Timing: This should take ~300 mins

2) Upper-Arm Plate…
- Mark out the square upper-arm plate with a ruler
- Cut this out on the BandSaw
- Mark the radii for the corners with a compass and pencil
- Use the disc sander to remove the corner material, to produce a rounded shape
- Mark-out and cut the hole for the bearing, filing the edges for smoothness
- Mark-out and drill the 5 holes needed for the wheel bearing's bolts

Timing: This should take ~60 mins

3) Lower-Arm Plate…
- Create a paper template, for the shape of the lower-arm plate
- Use a prit-stick to glue it onto a sheet of 18mm plywood
- Use a Bandsaw to cut this out
- Sand the edges to be smooth, ensuring that any burn marks are removed

Timing: This should take ~60 mins

4) Arm-Attachment-Blocks (AABs)…
- A) Make a template for the block shape
- B) Use this template 6 times to accurately mark out the blocks
- C) Cut the blocks out with a fine-tooth wood saw, such as a tenon saw
- D) Sand off the top corners with the Disc Sander
- Use a set square to ensure that the bottom face of each block is exactly 90* from the other faces; it is the datum edge
- Mark-out and drill two holes in the bottom of each Arm-Attachment-Block, to later accept the screws
- Drill the corresponding holes in the Arm Plates, so that the holes align with those of the AABs
  - Create a jig to ensure consistent hole spacing
  - Punch the locations of the holes using a small hammer and centre-punch
  - Drill these holes with a 3mm HSS bit
  - Pre-thread the holes manually using a T25-ScrewDriver and screw
  - Position the AABs over the holes in the Arm Plates, and screw them down firmly

Timing: This should take ~180 mins

5) Arm-Bars…
- A) Mark out 3x 1m lengths of mild steel box-section steel, using engineers' blue and a scribe
- B) Cut this with a HackSaw
- C) Ensure that there is no sharp bur left on the end; sand this off
- D) Round the edges of the bars slightly
- E) Mark, punch, and drill the holes in the 6 ends of the bars
- F) Use a countersink bit or bur-removal-tool to make the metal around the holes smooth and safe again
- G) Add the position-retention bar to the middle arm; an M8 nut is placed inside the middle bar, to provide the friction for the knob

Timing: This should take ~120 mins

6) Lower camera mount…
- A) Make a paper template for the dog-bone shape, using a compass
- B) Stick this to a sheet of 18mm ply, and cut it out on the BandSaw
- C) Sand off the template
- D) Rout around the edges of the dogbone shape, to apply the round-over
- E) Drill a though-hole on one side of this dog-bone, in the centre of the circle previously drawn by the compass - This hole will accommodate a tripod screw
- F) Insert the tripod screw into the hole
- G) Screw the dogbone shape onto the bottom of the articulating-socket, and the other side thereof, onto the underside of the lower-arm plate

Timing: This should take ~120 mins

7) Final Sanding and Finishing…
- A) Give all components a final sanding; there should be no sharp edges at the end, and the metal components ought to even be slightly shiny, wherefore I am using a high-grit sanding sponge
- B) Apply a beeswax coating to the wooden components with a soft rag
- C) Use satin black spray paint to prevent the phone-clamp from rusting

Timing: This should take ~60 mins

8) Assembly…
- A) Mount the BearingBlock onto the I-Beam
- B) Mount the Arm-Bars using the M8*70mm bolts, in the order [Bolt → Washer → AAB → ThrustBearing → Washer → LockingNut]
- C) Tighten these bolts until there is no wiggle-room
- D) Mount a camera onto the tripod screw of the dog-bone arm

Timing: This should take ~60 mins

Health & Safety

During the fabrication process, I will ensure that I am aware of the following safety precautions when using tools in the workshop:

- **Awareness**: Remind myself of the locations of emergency stop buttons, before switching on a power-tool. These are sometimes foot-operated
- **PPE**: Some power-tools necessitate the wearing of additional protective equipment, such as goggles for a bench drill press, or ear-muffs for a loud jigsaw, or gloves for an angle grinder.
- **Additional Dust-Collection**: Dust is deleterious for the respiratory system, so I will be wearing a mask when using any handheld electric sanders, and switching on the shop-vacs when using the bench-mounted electric sanders
- **Hazardous Substances**: The varnish or beeswax I am to apply at the end of the project, could be harmful in large quantities, especially if inspired or imbibed. Therefore, I will be wearing gloves to minimise skin-contact with the chemicals, and taking care to not inhale any of it either

Some quick research online revealed that I had made a critical oversight; seemingly one of the largest modern safety problems is suit-wearing professionals falling over on clearly-signed wet floors, in amusingly inelegant positions.

Time Management

To ensure that I finish the fabrication of the final prototype before the deadline, I have added timing estimates in emboldened brown to the TIN plan. When conducting the processes, I will use the same font styling to denote how long the processes actually took me. If any are unexpectedly long-winded, then the component to compromise on will be the rounding and routing of the plywood parts. This would save enough time to still make it.

Next Steps

The next step is to produce an in-depth risk assessment for the fabrication processes. This will decrease the chances of injury, because I will be more aware of the dangers associated with the various tools.

Final Design: Fabrication: Risk Assessment & Wastage

Introduction: Risk Assessment

Here I will conduct a risk assessment to identify processes which are part of my planned fabrication, and which could be dangerous.

I have assigned a "likelihood" and "severity" score out of 5 (0 being not likely at all; 5 being ineluctable) to each major risk, so that I can see which processes require particular precaution.

I have then added a number of safety measures which I must take, in order to assuage the chance of injuring myself or others in the workshop who are gleichzeitig in the workshop.

See also: Safety Considerations for the PRODUCT, in the PU Feedback for Proposition 1…

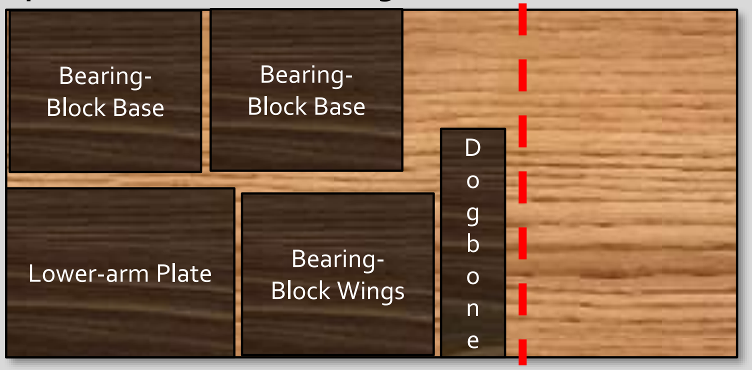
Risk	Liklihood	Severity	Precautions
Laserations or cuts occuring whilst using the table, band, or circular saws 	2	4	• The member of staff operating the table saw ensured that the writhing knife was engaged… • …and the dust extraction turned on • They also wore goggles, gloves, and ear protectors
Hair, ties, and other handing items could get caught in the drill press as the chuck rotates 	2	3	• When using the drill press, I wore goggles • I clamped my work down when required • I ensured that the emergancy stop button was working • I tucked my school tie into my napron
Fingers could come into contact with the disc sander, and receive a burnishing 	3	2	• When using the disc sander, I kept my fingers behind the yellow safety line • I wore goggles too
When using the Jig-saw, the undercutting blade could remove a finger 	3	4	• I used two strong F-Clamps to secure the workpeice, instead of my fingers • I wore goggles
The angle grinder's sparks could damage my eyesight 	3	2	• I wore goggles • I wore ear protectors • I wore grippy silicone fabric gloves

Introduction: Wastage

Now I will calculate how I can make the most efficient use of the raw sheets of plywood which are needed for my product. Doing this will help me to meet the sustainability criteria for this project, as I will minimise the proportion of the material that I waste. I will achieve the material saving, by determining how to effectively tessellate the individual sheets.

I identified the best value sheet of plywood for my use case, which is 606mm * 1220mm: https://www.wickes.co.uk/Wickes-Non-Structural-Hardwood-Plywood---18-x-606-x-1220mm/p/111736 From this source, it costs **£19.50**

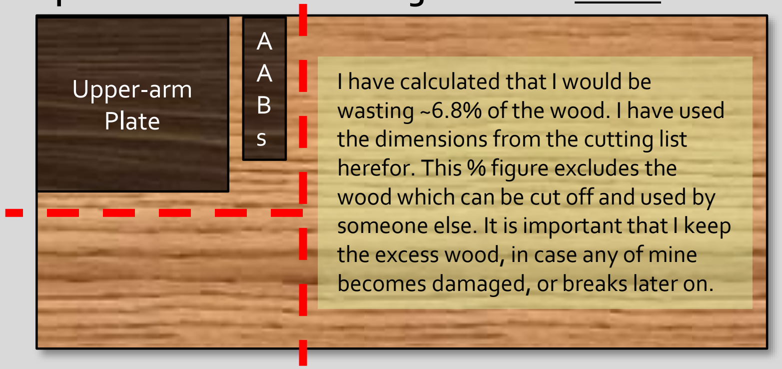
I produced this to-scale diagram of the 18mm sheet & components ↓



The interstitial gaps are to account for the 3mm Kerf of the Table-Saw Blade

The Red dashed lines show the points whereat the sheet can be split into still-usable material for someone else; these parts will not go to waste

I produced this to-scale diagram of the 12mm sheet & components ↓



Therefore, the only real waste is the 3mm Kerf, and the leniency space

The tolerance is +/- 1.5 %.

Next Steps

The next step is to make the final design. Some of the components – including the bearing block and smartphone clamp, have already been refined during the hitherto iterative feedback process. These components will simply be added to the final design, instead of being re-made. (The PU has demonstrated in the interviews that he is happy with these existing components).

Final Design: Fabrication (1)

Introduction

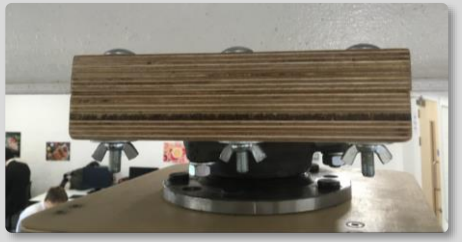
Here I begin the production of the final physical prototype. At this stage, I already have the following sub-components read for use, from previous stages in the development process:

- **The SmartPhone Clamp** from the iterative development of initial idea 3
- **The BearingBlock** from the iterative development of initial idea 5

Each of these sub-components still require the improvements (as are described on the Final-Design-Development slides) to be made to them.

I will now make the final prototype, following the 8 overarching sub-steps outlined in the fabrication plan...

↓ The knob, fitted to the bearing-block...



1) The Bearing-Block

In its current state, after having been tested during the iterative development of design 5, the bearing block requires the following iterations, as was explained during the final-design-development:

- ***A Knob**, with which to pull the block along the I-Beam*
- ***Lubricative pads**, to ease the sliding motion along the I-Beam, and reduce wear on both the Block, and the I-Beam*

To fix said shortcomings, I took the following steps...

Critical Thinking

A) Attaching the knob

I measured the diameter of the thread of the chosen knob with a pair of digital callipers: 5mm. I then selected a drill bit 2 mm less than this, with which to drill the pilot hole: 3mm.

However, I found that this 3mm hole was too small to accept the thread of the knob without cracking the surrounding wood. Therefore, I used a larger 4.3mm bit instead, which provided a more-than-sufficient tightness of fit.

B) Fitting the lubricative pads

On the previous development slides, I had experimented with using a copper strip as the lubrication-providing material. This – however – proved itself to be not soft enough, and to be cumbersome to attach to the underlying wood.

Therefore, it was decided that a Teflon pad would better meet the needs of the PU, and reduce friction to a greater extent.

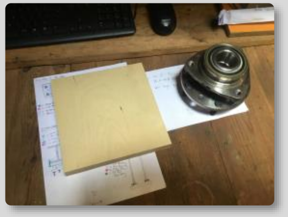
To attach it, I identified a particular size of screw whose head fit within the countersunk recess of the pad, such as not to protrude above the surface (which would scratch the I-Beam).

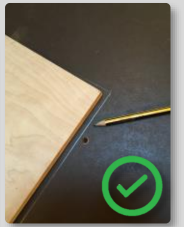
← The Final Bearing-Block

The Teflon affixed pad ↑

2) The Upper-arm Plate

I am going to make this component for the first time here. Its job is to bear the three high Arm-Attachment-Blocks, which hold the arm bars.





Timing: This took ~30 mins

A...B) Marking out ... Cutting

*I began by marking out the 250mm * 250mm birch plywood square I required for the plate. This was then cut on a TableSaw, by a member of staff.*

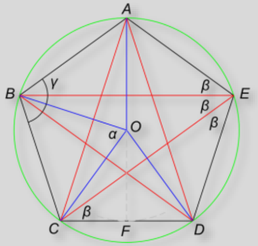
C...D) Marking out ... Sanding

I then used a compass to consistently mark out the material to be removed at each corner, and used the electric disc sander to remove this material.

I drew lines from each of the four corners, to each opposite corner, forming a cross whose intersection marked the centre of the square. I then used the compass to draw the ⌀85mm hole, through which the wheel bearing fits.

Timing: This took ~10 mins

Using some basic Euclidean geometry, I determined the positions required for all five holes, through which the bolts from the bearing will fit. →



$$Y = 3ß$$

Health & Safety

I must take additional precautions when using the drill press, disc sander, and table saw...

- The member of staff operating the table saw ensured that the writhing knife was engaged, and the dust extraction turned on
- When using the drill press, I wore goggles, and clamped my work down when required
- When using the disc sander, I kept my fingers behind the yellow safety line

E) Cutting out the bearing hole

*↑ As discussed earlier during the development, the 5 bolts sticking off of the wheel bearing are M12*1.5 pitch. I ordered nuts for these from the internet.*

← I used a right-angled try-square to precisely get the CenterPoint. I then used a punch to ensure that the drill bit would find exactly the point I had marked, first time.

Timing: This took ~20 mins

← With a 50mm hole-saw, I removed most of the material. This took some time, and I applied several pulses of force to the workpiece throughout the drilling.

I used the hole locations from the pentagon, to punch and drill the holes using a 12mm HSS bit.

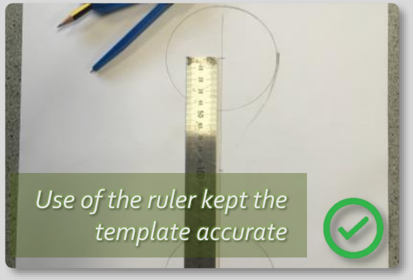
← I then removed the remaining material with a Jigsaw. I had to clamp the workpiece down firmly for this process. The jigsaw did not leave particularly smooth edges, so I filed them afterwards ↓

Critical Thinking

↓ I then checked that the bolts fit correctly through the holes, inserted some M12 washers, and tightened down the upper-arm plate...

3) The Lower-arm Plate

I shall be rather summary in describing the process of creating the lower-arm plate, because it is almost identical to that of the upper-arm plate, save for the omission of the holes in the centre.



A…B) Marking out … Cutting

*I began by making out the specified shape. To do this, I used a piece of software I wrote called GraphPictures, to generate a precise **Bezier** Curve, which formed a perfectly even arc for the template, which I then drew in pencil. This was sufficiently accurate, because I was going to round out the bend shape on the belt sander anyway.* ←

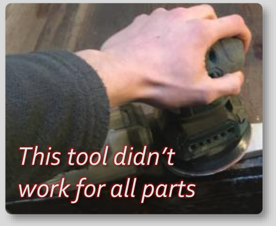
Critical Thinking

Because this was 18mm plywood, I felt it best to use a bandsaw for the cutting-out, instead of the jigsaw I had gotten away with for the upper-arm plate's 12mm plywood. →

Timing: This took ~30 mins

C) Sanding

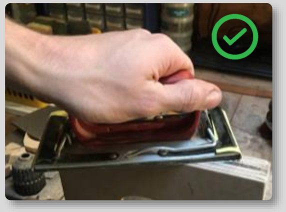
I required a rigorous means of sanding the 18mm ply, for which reason I used a random orbital sander. This was significantly faster than only using paper.



I sanded the faces of the plate in this way, but found that it was difficult to use the orbital sander for the narrow edges of the plywood, as this was not a suitable tool for the job.

Therefore, for sanding the edges, I used a sandpaper-holding pad with a handle. This meant that I was still sanding with a flat surface, and thereby maintaining accuracy. → Timing: This took ~20 mins

This process was repeated on the other plates that required sanding…



I used an F-Clamp to hold down the workpiece…

Quality Check!

To ensure that the edges of the plywood were smooth enough (after cutting, filing, and sanding), I used a comparison block, whose edges I had previously rounded to the required extent. This meant that each of the softened-edges of each face of each board of wood, were sanded to roughly the same radius and smoothness. This aided in making a more consistently-high-quality final product

4) Arm-Attachment-Blocks (AABs)

These blocks enable the arm-bars to attach to the arm-plates. There is a thrust-bearing between the AABs and the bars, to allow the mechanism to move without the need for uneven or excessive force.

← ***I made a mock-up of a single AAB, to give credence to the presumption that I would use an M10 bolt. This was too large, so I changed to M8…***

Accuracy

In order to cut out the sheets for the upper- and lower-arm plate precisely, and to the scale of my CAD plan, I used a try square and rule. This gave me a perfectly-90* reference edge (the "*datum*" edge).
The pencil I was using was also sharpened several times during the marking-out, to maintain the clean and thin lines/marks.

A…C) Templating … Cutting

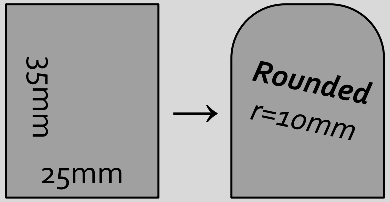
I marked 7 of the 25 * 35 mm pieces of 15mm plywood, from a larger sheet. I then cut these out with a tenon saw. Although I could have used a faster and more aggressive saw, it was important to keep these blocks very accurate, and the smaller, blunter teeth of the tenon saw in question made for a smooth cut with minimal tear-out.

I used a steel rule to accurately score lines across the 7 blocks. I then used a pair of digital callipers to mark the intersecting vertical lines. This provided me with a cross on each block, which I could use to centre-punch the precise location of the structural through-holes for the bars' bolts. →

Timing: This took ~20 mins

D…G) Sanding … Drilling/Screwing

I rounded the corners of the blocks in the following fashion ↓ (Disc. Sander)



I then inverted all of the blocks in a wide-jaw woodworking vice, and used a similar length-wise ruler technique to consistently mark out the locations for the holes on the bases of the AABs.

The next step was to mount these AABs onto the arm plates. It was critical to get the positioning spot-on, so as to ensure alignment between the top and bottom plates.

Timing: This took ~40 mins

I used a try-square to get a consistent 90*, and measured from the edge of the plates, instead of the centre.

I then used a centre-punch to allow the drill bit to more easily find the hole location during drilling. This allowed the drilling to go swimmingly. I then used 4*40mm countersunk screws, to attach.

5) Arm Bars

These are the lengths of metal which attach the upper- to the lower-arm plate, via the Arm-Attachment-Blocks. There are 3 1m-long bars.

Quality Check!

To ensure that the arm bars were to-spec in terms of their dimensions, I took the following steps:

- Measure and cut all three bars individually to the 1-meter length
- Compare the lengths of all three bars, and determine what the longest possible length for all 3 bars can be, accounting for variations in the bars' lengths
- Use the bench grinder to remove small increments from the longest two bars, until all bars are exactly the same length.

Critical Thinking

***Final Check**: I stood all 3 bars next to each other on a flat surface, checking that the top edges met at the same height*

E) Marking & Punching

I used a metalworking try-square to score a consistent perpendicular line across the ends of the bars. The implement used to perform the scoring was a sharp scribe. **Timing: This took ~10 mins**

I then centre-punched the holes, to ease the forthcoming drilling.

E) Bur-removal

My first attempt, was to use a metal-working bur-removal tool to make the edges of the holes safe. This was important, because the M8 bolts which go through these holes must be able to turn smoothly. Excrescences of swarf would impede this smooth rotation.

In reality, however, this tool was unable to provide a consistent roundness along the whole circumference of the opening.

G) Adding the Position-retention Bar

An angle grinder was used to remove the centre slot of the 300 * 25 mm aluminium bar, which then had a hole drilled in the bottom, and was sanded and polished with a buffing-wheel and paste. I then set the M8 nut inside the middle arm-bar, and screwed the knob into place, with a couple of brass washers in between.

Timing: This took ~20 mins

A…D) Marking … Grinding

I used engineers' blue to mark out the 3 required 1-meter lengths of mild steel box section 15*15mm steel bar. I clamped this firmly in a sturdy metal-working vice.

Next, I cut along my markings with a hacksaw. I wore safety glasses, a hard-hat, and a high-vis jacket for this perilous operation. I also took the precaution of conducting a category-5 sterile irradiation of the area afterwards, just to be one the safe side. I then used a bench grinder to round the sharp corners slightly.

E) Drilling

I used an 8mm drill bit to accommodate the M8 bolts. I applied drops of oil onto both the workpiece, and the drill-bit, before the drilling. This was done to prevent overheating, and to lubricate the bit as it span and cut.

Critical Thinking

Timing: This took ~10 mins

To hold the ends of the bars securely, I clamped them firmly in an engineer's vice, making sure to position the part of the bar through which the hole was to be drilled, over the middle part of the vice, where there is no supporting material underneath. This meant that I wasn't drilling into the vice, and the drill-bit could pass through easily.

E) Countersinking

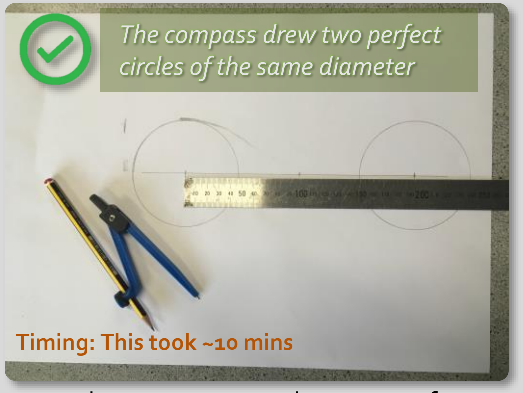
Because the yellow bur-removal implement wasn't the right tool for the job, I gave a large countersink attachment a go. This was more effective, as the tool remained in contact with even force applied to all regions of the holes circumference, throughout the smoothing operation. This gave a more consistent result, and was less time-consuming too – which was important considering that I had to perform this step 16 times.

Timing: This took ~10 mins

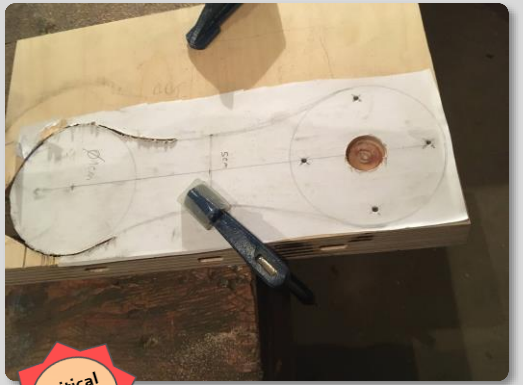
← This would have been a more suitable sort of countersink for metal

6) Lower Camera Mount (inc. "Dogbone")

The final sub-assembly left to make is that of the lower camera assembly. This requires a wooden dogbone-shaped part on the bottom, to which attach the articulating socket joint, and the smartphone clamp, attach via screws. The screw at the end of the dogbone is a standard tripod screw, onto which the smartphone mount can be fitted, via a small tubular adaptor.



↑ I used a compass to produce two perfect Ø8cm circles, in accordance with my CAD Model's dimensions. I then sketched smooth Bezier curves between these, to form the desired dogbone shape.

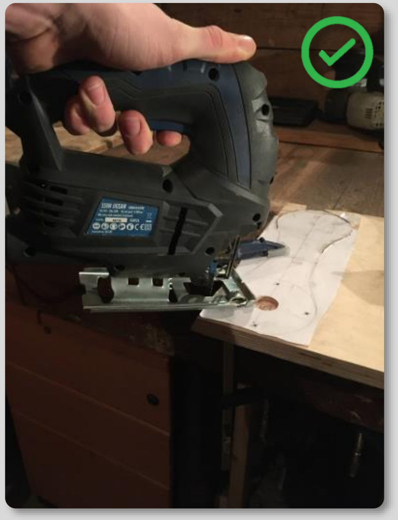


Critical Thinking

↑ I left one edge of the workpiece overhanging the workbench, such that the jigsaw blade could reciprocate freely underneath.

←↓ A...C) Marking ... Sanding

I marked out, cut, and sanded the dogbone shape in the same fashion as all the previous pieces, this time using a jigsaw owing to the thickness of the plywood.



↑ The table saw used to cut out the initial square allocation of plywood

Accuracy

As has been mentioned in-passing, I find it effective to centre-punch the surface of the material, prior to drilling. This means that the drill-bit easily and unambiguously finds the intended point for the hole. This technique takes out the guess-work for aligning the M4 threaded bolts, for §6G.

PU Comments

I took this opportunity to gather some PU-feedback on my progress with the building. I showed the PU what I had so far...

PU: "The jigsaw isn't leaving smooth enough edges; a reasonable amount of sanding it going to have to be done afterwards." ↑ Because of this feedback, I have sanded up to 240 grit instead of just 150

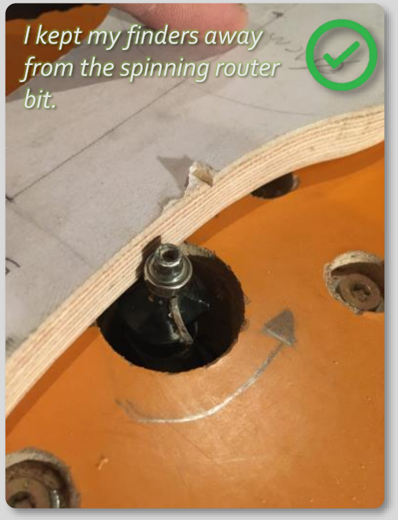
PU: "The M4 machine screws look and feel as if they'll be more than sufficient for the weight of any camera; I'm happy with the security of the mount."

PU: "Using 18mm ply for the dogbone piece was definitely the right choice; anything thinner wouldn't have been strong enough to provide enough grip for the TriPod screw."

Timing: This took ~5 mins

D) Routing

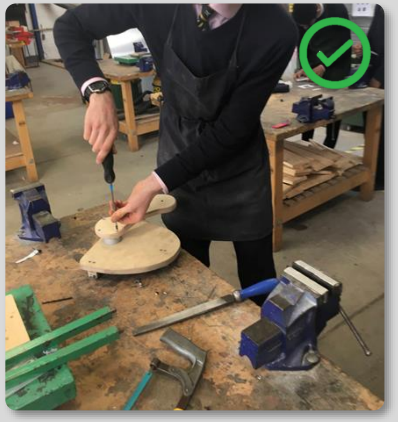
I applied the round-over effect with a router-table. This made use of a ¼" chamfering bit.



Timing: This took ~30 mins

E...G) Drilling ... Screwing ↓ →

I used some M4 * 35mm machine screws to attach the dogbone to the lower-arm plate, via the lockable articulating socket joint.



Health & Safety

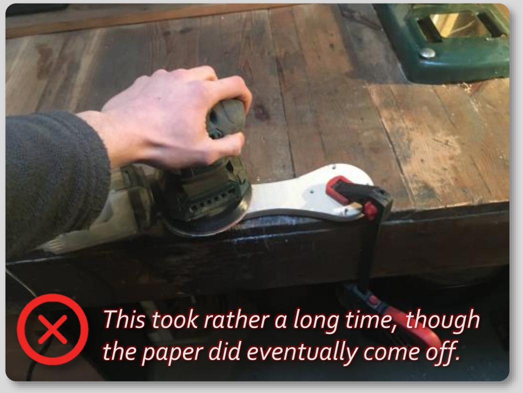
Whilst using the Jig-Saw, I ensured that the workpiece was clamped-down firmly. I used two F-Clamps to achieve this security. When rotating the workpiece – in order to cut the opposing side – I had to re-apply the clamps.

Critical Thinking

There were some Teflon pads on the ends of the clamps, which rather hindered the ability of the clamps to provide a high-friction gripping interface with the material. After a mild episode of frustration on account of this, I removed the pads in favor of a scrap shim of wood. This was necessary to prevent unsightly marking of the plywood being cut.

↓ Drilling the 4mm holes for the M4 bolts.

↓ Sanding off the paper template...



7) Final Sanding & Finishing

All that's left, is to give all the individual components a check-over and apply finishes, before assembly.

Timing: This took ~30 mins

A…B…C) Sanding … Beeswax Application … Spray Painting

I sanded the pieces with >=240 grit paper, in much the same way as before.

I then applied a series of different finishes to a piece of scrap plywood (the same birch sort from which my final product has been principally constructed). I asked the PU – Andrew P. – which of these finishes he took most favourably to, mentioning some of the technical and durability-related advantages of each finish…

Critical Thinking

↑ Beeswax and a synthetic alternative

PU Comments: Choosing a Finish

…Andrew responded thusly…

PU: "The Synthetic wax has an odd smell, and could have negative environmental implications. I'm not sure how many coats would be needed either."

PU: "The Beeswax seems to be more convenient with its shorter drying time, and I don't half mind the warmer colour."

… ↑ This feedback influenced ↓ …

I found that droplets of water formed beads when applied to the surface, after the coating had been applied. Therefore, it was successful in providing some protection to the wood underneath. Timing: This took ~10 mins

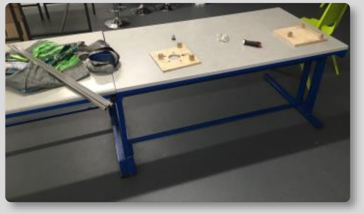
← I therefore proceeded to apply the beeswax, which didn't in-fact require any drying time; excess could be wiped off immediately with a rag. ↑ I also spray-painted the smartphone clamp, to prevent it from rusting. This was done with 3 coats of satin black spray paint, which most closely matches the colour of the cameras and smartphones it's designed to hold.

8) Assembly

Timing: This took ~20 mins

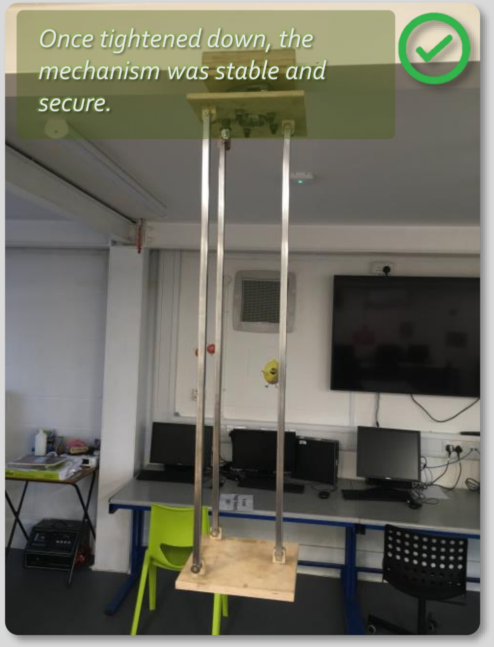
I can now endlich assemble the whole design for the first time, and ensure that all mechanical components work smoothly together.

← I laid out the components, and used a ratcheting T25 screwdriver, along with a spanner and socket set, to tighten the bars to the plates via the AABs. ↓



Quality Check!

Weight-tolerance check: The lower-arm plate must be able to safely hold 40 KG. I got a (disappointingly-easy-to-find) "*vertically-challenged*" year 7, to attest to the strength of the arm with part of his bodyweight. There were no signs of weakness or stress on the mechanism.



← Finally, I attached the bottom *dogbone* component, and mounted the smartphone clamp onto this, in readiness for the initial testing.

Timing: This took ~30 mins

← Next, the bearing-block was secured to the I-Beam, and the lower camera mount (inc. Dogbone) was affixed to the lower-arm plate, via the M4 mounting screws.

← On initially Tightening everything up, I found the arm to be somewhat stiff. Therefore, I had to replace the nuts with locking ones, to be able to safely loosen them.

Critical Thinking

Next Steps

I will now design the branding for the product, and then review it in more depth.

Brand Design

Introduction

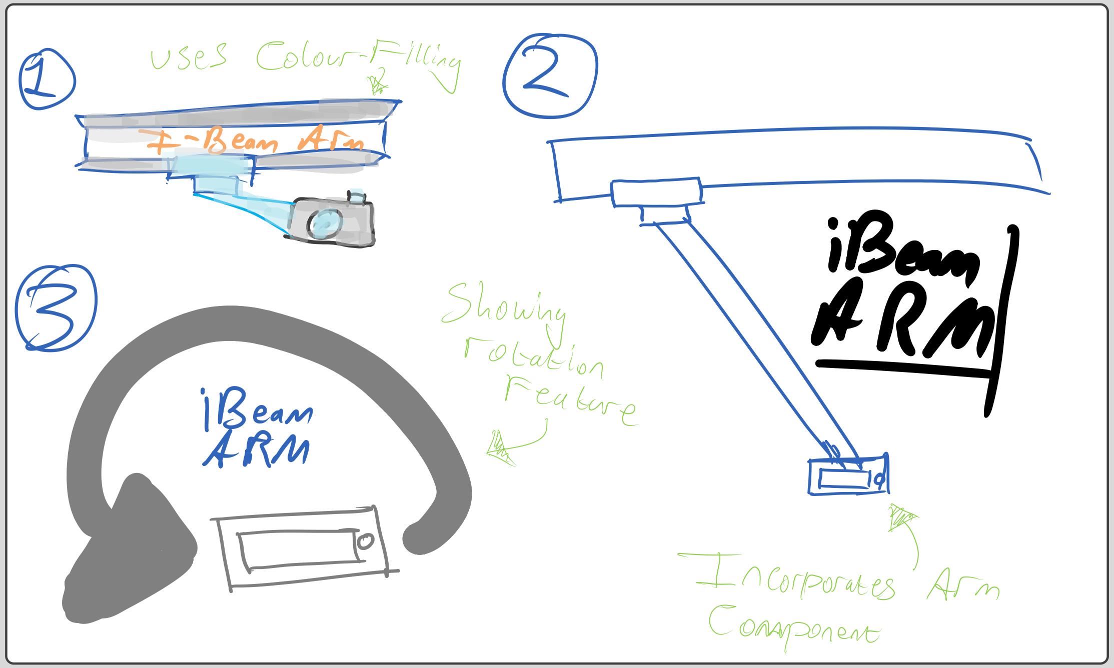
Here I design the branding the logos for the product. This is important, because the association of a memorable brand image or strapline is invariably linked with creating a successful product. The branding needs to represent the "*ethos*" of the product, which in this case could be summarised as:

- **Practical & Utilitarian –** Function follows form
- **Friendly –** The mechanism is designed to be easy and intuitive to use
- **Adaptable –** The arm can have a number of differing attachments fitted

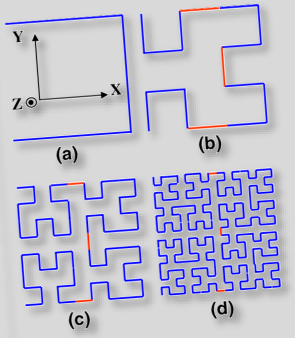
Because of these characteristics, I came up with the name "iBeamArm", as it is demonstrable, and follows the slightly optimistic and vivacious *i** branding, as used by Apple inc. for products such as the iPhone.

I used the font "Adobe Gothic Std B", because – to my eyes – it has a tenuously-grinning, marginally-hubristic sagacity, such as should be experienced by potential customers of the product.

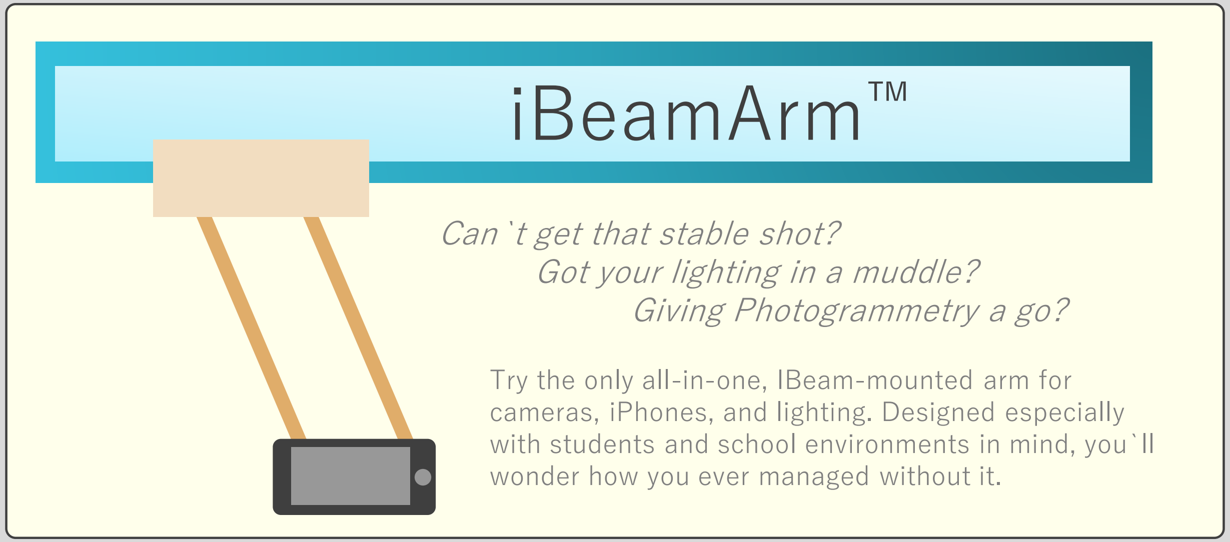
The next step was to sketch some potential logo designs. I wanted to incorporate the I-Beam and the Arm-mounted Camera, if possible.



I thought this a good opportunity to express my distaste for monochrome icons, so I spoke with the PU about the potential for some degree of colour in the logo. Much to my alarm, it was revealed that the PU was already rather intransigently besotted of silhouette-like icons, so we each had to capitulate and compromised on a flat-looking-yet-coloured style. I did also look at the possibility of encompassing some of the mathematical art styles that I had researched for the iterative development of initial idea 5, though it was agreed that attempting to force these into an otherwise focused design would be of little benefit.



This was the branding we came up with...

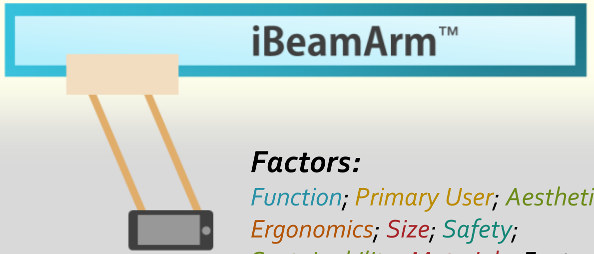


Next Steps

The next step is to collectively present the final prototype, and perform some initial tests with it.

Introduction

This is how the final prototype turned out.



Factors:

Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

I have indicated the PU's thoughts on each concept, by means of the ticks and crosses…

✗ Or ? Or ✓

Final Prototype

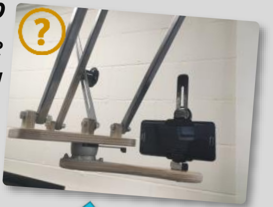
This is the resultant functional prototype, incorporating all iterations

Sizes and Dimensions

I re-measured all individual components, and the final design as a whole, and no parts were more than 3mm out-of-whack, which is within my tolerance of ±1.5%. The length of the middle arm-bar was 3mm shorter than was planned for, because of slightly too much corrective grinding.

Component: iPhone Clamp

This holds a smartphone onto the tripod-screw mount. The PU noted that it requires more long-term evaluation for ease-of-use. ?



↑ The CAD representation of the same part

↑ The same wheel bearing from initial idea 5, provides the smooth rotation here

Component: Bearing Block

This mounts the arm to an IBeam. It is the most robust component in the entire assembly. The Bearing also permits the arm to rotate. ✓

Test: Rotation Animation

This video shows a pan shot taken with the iBeamArm. The result was smooth. ✓

Click **here** to watch…

↑ Usually, a ring of this size would be required to produce this sort of shot

Test: Time-lapse Mode

One student took the opportunity to use the jig for filming a time-lapse of his own work. I hadn't even accounted for this use-case, but it worked well as a static mount too!

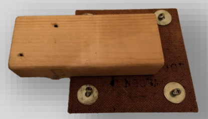
Component: Lower-arm Plate

This holds the dogbone camera mount, and is what the arm-bars bolt onto. ✓

Feature: Position-retention

This enables tightening of the arm at a certain height. ✓

The VESA-Mount I made earlier could equally be fitted to the end of the arm ↓



Next Steps

The next step is to begin the evaluation…

Evaluation: Viability

Introduction

I must now assess the *VIABILITY* of the final prototype. This means:

- **How closely does the final prototype meet the initial specification?**
- **How marketable is the product?**
- **What is the potential for expansion of the brand in the future?**

I have placed question marks next to some of the points which are met only tenuously, or because it cannot be known whether they are met due to time linearity e.g. the product has not been disposed-of yet.

Specification – Review

Am I meeting the non-technical requirements from the **wider stakeholders**?

Wider Stakeholder Requirements

{Many of the PU Requirements, and…}

For Students, Staff, and Institutions:

	Met?
✓ The product should be relatively **affordable (Less Than £100)** (bearing in mind that non-profit institutions such as schools are a primary target market)	✓
✓ *[!Important]* The product should be **easy-to-use** for students; it must not be overly complicated, and should have a self-evident (ideally entirely axiomatic) function	✓
✓ The product should not be able to be stolen easily	✓
✓ The product does not block out so much **natural light** as to obstruct the operator taking a photograph	✓
✓ If the product holds a camera, it must keep this **camera stable**, and allow steady photographs to be produced. It should also offer a reasonable degree of protection to that camera, and prevent it from being easily damaged	✓
✓ The product should be **principally self-integrated**, and not have a large number of losable components	✓
✓ *[!Important]* Should any **assembly** of the product be required, this should be **simple and approachable** for a relatively inexperienced adult. The focus on simplistic assembly is not, however, so paramount as to take precedence over making the product strong and robust	?
✓ If the product is **mounted to a wall, ceiling**, or other pre-existent structure in the room, this structure should not be permanently and irreversibly damaged	✓
✓ Where possible and appropriate, the product should ideally comply with existing standards (e.g. VESA or the standardised camera-to-tripod screw thread size)	✓
✓ The product should attempt to avoid implementing any needlessly-frustrating procedures	✓

For the Retail Stakeholders: …

	Met?
✓ The product should be easily **packageable** and able to be shipped or transported	?
✓ At the end of its service life, the product – and its packaging – must be **disposable by commonplace recycling services**. (E.g. Could use *biodegradable* packaging)	?

The question marks indicate points where I cannot unimpugnably say that I have met them. For example, I have not created any packaging, and therefore haven't been able to test for how said packaging might be disposed of, or biodegrade. ←

Specification – Review

Am I meeting the non-technical requirements from the **PU**?

PU Non-Technical Requirements

General:

	Met?
✓ *[!Important]* The product **assists design students** in the process of documenting their projects photographically	✓
✓ The product should be **extensible** and **adaptable** to different use cases within the photographic process (e.g. holds either a camera, *OR* a light…)	✓
✓ The product is suited to, and can be used by, a range of **different ages** of student (e.g. by being height-adjustable)	✓
✓ *[!Important]* The product must **not consume too much space** (anything more than ~ ½ M³)	✓
✓ The product should have an **aesthetically unobjectionable** (tolerable; utilitarian) design – possibly complementing other items in the 6th form design studio where the product is to be used. In other words, its visual appeal isn't the top priority, but ought to be nevertheless inoffensive and almost innocuous	?
✓ *[!Important]* The product should be made from **materials which are *known* to be durable** and long-lasting; the product must withstand the environment of a secondary school, wherein there are –from time to time – bouts of boisterous juvenile behaviour.	✓

Sustainability:

	Met?
✓ Where possible and appropriate, the product should me made from **recycled, partially-recycled**, or otherwise sustainably-sourced materials. The usage of sustainable materials should not, however, compromise the durability or robustness of the product	✓
✓ *[!Important]* Any Plywood should be sourced from an **FSC-certified** supplier	✓
✓ When disposed of, the product should not have any deleterious effects on the environment	?

Anthropometrics:

	Met?
✓ Any **openings or pockets** in the product ought to be at least 13cm wide, and 5cm deep (from the front to back edge)	✓
✓ Any **handles or grip points** should have a ~2.5cm bulge and be ~10cm in length (See forthcoming Ergonomics Research Slide…)	✓
✓ *[!Important]* **Corners should be rounded**, sanded, or chamfered, in order to make the product comfortable to hold and to avoid potentially-dangerous sharp edges	✓
✓ The product should not be intolerably heavy, should it need to be lifted (less than ~30 KG)	✓

Next Steps

The next step is to assess the feasibility. This will involve some physical testing, as well as PU input.

Evaluation: Feasibility

Introduction

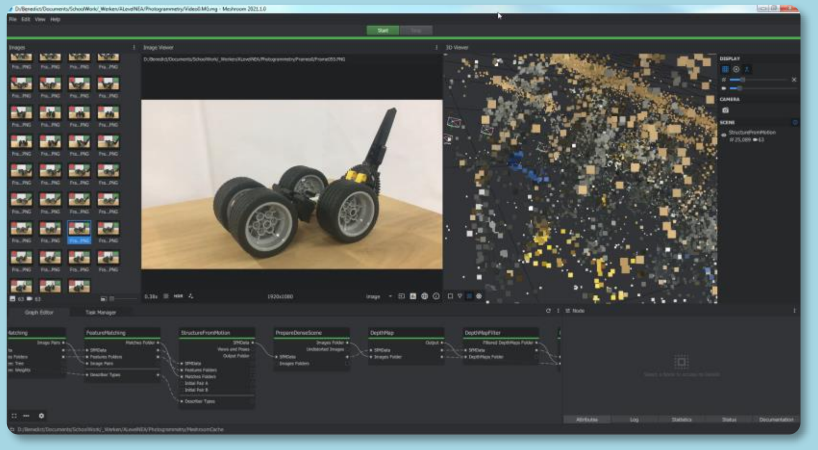
I must now assess the ***FEASIBILITY*** of the final prototype. This means:

- **How well does the final prototype perform in testing?**
- **What are the PU's views on the final prototype?**

Scenario-based Testing: Photogrammetry

One of the abilities of the product that most excited the PU had been the Photogrammetry feature; the ability for the product to automate the process of taking many shots of an object from different angles, and combining them in computer software to create a 3D Model file, such as `*.obj`.

To do this, I mounted an iPhone in the clamp, started video recording, and slowly and steadily moved the arm around the object. I then adjected the arm height using what I could only describe an eximiously well-designed position-retention knob, and took another video at this new height. I took a total of three videos in this manner.



Then, I used a program called `FFMPEG.EXE` to extract PNGs from the MOV video file at regular intervals. I used the following form of command-line invocation:

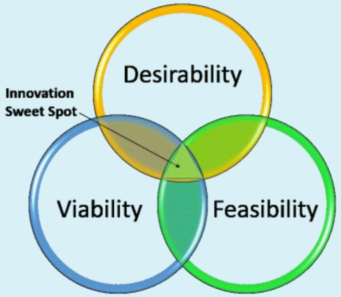
```
.\FFMPEG.EXE -i Video0.Mov -r 3 "Frames0\Frame%03d.PNG“
```

These PNGs were then dragged-and-dropped into a piece of software called Meshroom, which took several hours to produce a **depth map** and render a .OBJ 3D-object file. This looked a little rough, so I used another software package called MeshMixer to clean it up, leaving me with an acceptable result.

Physical Testing

Strength Test: To attest to the strength of the arm, I hung three rucksacks from it an once. This is more than the weight it should reasonably encounter during normal use. It held this weight flawlessly.

Consistency Test: To give credence to the claim that the product is geometrically accurate, I used a dial indicator to set a datum reference point, and then swung the arm around by 360*. It returned to within 1 mm of the same depth point, meaning that it is of sufficient accuracy.



← An angle of 15 set →*

Moisture Test: To prove that that the beeswax coating provided a sufficient level of protection against water, I put some droplets of moisture from a damp cloth on the surface, and observed as they formed beads instead of infiltrating into the wood. Success.

Ergonomics Test: To demonstrate the comfort of the knobs, I asked the PU to grip and test them.

PU Remarks:  ***"The bearing-block knob is easy-to-reach, and comfortable to hold. The position-retention knob is similarly lovely."***

Motion Test: To ensure that the motion of the arm remained smooth over time, I left the arm installed on the I-Beam for 5 weeks, and returned several days later, to check that it was still operating smoothly and without a high-friction or grit-like feel.

←The product in use by a student in school. He was able to move it about easily.

Next Steps

The next step is to assess strengths & weaknesses.

Evaluation: Positives and Negatives

Introduction

I will now assess the positives, negatives, potential modifications, and design-optimisation techniques, which are or relevance to my final prototype and product branding.

Mid-Fabrication Interview

Recorded about half-way through the making process

↑ Click here to Listen ↑

Summarised Responses:

- *I like the many points of articulation; that enables a wide variety of different shots and pans. This is particularly useful for the animation and photogrammetry functionality.*
- *I think that the dogbone component is very ergonomic, however the adjustable tightenable knob can a little difficult to reach sometimes. (We agreed that this was actually only occasionally an issue)*
- *Concerning the robustness, the bolts do contribute not only to veritable robustness, but also to a robust aesthetic.*
- *There is some chip-out with the plywood, which isn't a major issue, though it is unsightly.*

Factors:

Function; Primary User; Aesthetics; Ergonomics; Size; Safety; Sustainability; Materials; Features; Lifespan & Maintenance; Manufacture; Storage; Commercial Opportunity; Transportation

Design Optimisation: Adapting for Commercial Manufacturing Processes

Had I the resources to manufacture this design at a more industrial scale, then I would consider the following:

- The steel arm bars would be cut on a horizontal metal band saw, and the ends tidied-up with a linisher, instead of the bench grinder I was using.
- The plywood sheet components would be cut out of sheets and more densely packed together, for even less wastage. This would be possible because a CNC router could be used to cut out the correct curved shape, first-time-round, instead of my current method which necessitates post-table-saw Jigsawing to produce the complex Beziers.
- A lighter – but reinforced – material such as aluminium would most likely be used for the metal arm bars, because the lighter they are, the less dangerous the overhead assembly is. In addition, aluminium is less expensive than the mild steel.
- The design could possibly include clips and spacers, so that it would be disassembled into a flat-packed form, for more convenient transportation.
- There are a number of off-the-shelf components, which make commercial manufacturing easier.

The product would be batch produced, instead of mass produced.

Next Steps

There are no more next steps! Yippee!

Final Interview

Finished Final Prototype Feedback

↑ *Click Here to Listen* ↑

Summarised Transcript

Gist: The PU likes the design, including the space-consumption, materials, and durability.

The following criticisms were made however, which would need to be improved were the product to be sold commercially

- The design does rely on access to an I-Beam
- The brass knob is a little small and is too high-up
- The positioning knob does slip from time to time. This can be solved by simply tightening it more, but this is not a particularly easy process.

Marketability Criteria:

I discussed the following marketability points with the PU...

Functionality: A tripod should be able to hold a camera steady and provide a range of height and angle adjustments to suit different shooting scenarios. It should also be easy to set up and use, and durable enough to withstand frequent use and transportation.

Versatility: A tripod should be able to support a range of different camera types and weights, from lightweight point-and-shoot models to heavier DSLRs and video cameras. It should also be able to adapt to different shooting environments, such as uneven terrain or low-light conditions.

Brand Reputation: A reputable brand with a proven track record of producing high-quality, reliable products is more likely to be successful in the market. Customers are more likely to trust a well-known brand over an unknown brand.

Price: A tripod should be competitively priced relative to other products in the market. However, customers are often willing to pay more for a product that offers superior quality, durability, and features.

Marketing and Advertising: Effective marketing and advertising can greatly increase a product's visibility and attract new customers. Effective product descriptions, attractive packaging, and positive reviews can also boost sales.

We concluded that product meets these criteria rather well, and would as such have at least some chance of commercial success.

Sources

Contexts & Initial Research

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Researching Existing Products & Initial Ideas

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Initial Idea Development & Final Design

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