Technology Scholarship Report 2014

Construction Of Skateboard Wheels and Slide Glove Pucks Using Recycled Plastic.

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Table Of Contents

Introduction

For my Technology Portfolio I was tasked with finding a client for whom I could create a technological outcome. My original idea was to find a musician and to create a dynamic and interactive website to help them generate a larger profile and there in turn reach a larger target audience. However, I had great difficultly in finding a local musician who would benefit from my expertise and skill. Many musicians I contacted did not even reply to my emails. As a result I had to broaden my search and find another client. In doing so I had to leave my comfort zone and attempt a project that both pushed and broadened my skills, knowledge, and expertise with not only digital technology, but also the engineering process, health and safety procedures, and product development. This resulted in the discovery of my main stakeholder, *The Paper Rain Project*.

The Paper Rain Project is a design company that originally specialised in custom painted longboards made from recycled water-skis. The Paper Rain Project have gone on to work with photography, graphic design, bamboo, maple, laser cutting, organic/fair trade apparel & other creative ventures. The Paper Rain Project aims to:

...combine sustainable living, and art with a local, environmentally friendly ethos that would make NZ proud.[1]

They also want to ensure their product is of a high quality using as many local, recycled or eco-friendly materials as possible whilst maintaining a strong sense of unique creativity.

After my initial meeting with my new stakeholder (The Paper Rain Project), and as a result of my open ended questions they concluded that as they currently do not stock plastic products, because they have not found an ethical alternative to the current polyurethane used, they would like me to design and test prototype wheels and slide glove pucks using recycled materials. Ideally, they would have the entire skateboard as close to 100% green as possible but the issues with the wheels and Slide Glove Pucks have thus far prevented this.

My initial research into the subject area showed me that effective recycling of products has become extremely important to business practise all over the world. Plastic products that are not recycled end up in a land fill and when they are not disposed of correctly can seriously harm wild life. Pictured opposite is a turtle which got caught in the plastic used to hold cans together. The turtle then grew, this has distorted its shape and seriously injured the poor animal. Sadly, this is one of many cases similar to this.
Whilst my project does not directly combat this issue I was pleased to know my work could potentially aid the environment and in the future it is my hope that technologists may find the solution for environmental pollution.

Figure. 1: Injured Turtle.

The research into the effect of non-recycled plastics was very enlightening. It had the effect of highlighting the issue and gave me the drive to pursue recycled skate products in-depth, as both the environment and skateboarding are very important to both myself and my stakeholder.

1. The Paper Rain Project Website, Home Page.

1: Technological Modelling - Initial Research

1.1: Contesting Factors

During my initial research into the creation of Skateboard Wheels and Slide Glove Pucks I discovered that skateboard wheels are either constructed with Polyurethane[2] or Polyethylene[3] and that Slide Glove Pucks are generally created using Polyethylene. This lead me to the first of my contestable factors: Polyethylene is a suitable material that fits with my stakeholders specifications, it is a thermoplastic which means it can be melted and remoulded. It is also used to create many common items, such as milk bottle lids. Milk bottle lids are not recycled in Marlborough thereby creating a surplus of product. The material is a perfect solution as the outcome (Wheels and Pucks) can be created locally by the Paper Rain Project using the lids that are not recycled by the Council. However, wheels of a higher quality are generally made of Polyurethane. This material is unfortunately non-recyclable, consequently I had to choose between the factors of:

Sustainable with Recycled Materials. (Polyethylene)	VS	Higher Quality but Single Use. (Polyurethane)

This issue comes down to the ethics of my stakeholder and the users of the final product. After a lengthy discussion with my stakeholder and interviews with a few local skateboarders,The Paper Rain Project decided upon the sustainable and recycled option. This was very important to their beliefs. The company design and create skateboards from recycled wine barrels with crushed recycled glass grip-tape, it is important my prototype fits in with the company's ethics. This means less materials will end up in the landfill and thereby protecting the environment. The product can be reused and remoulded. Keeping the development of the end product localised is also extremely important to the Paper Rain Project. The solution of this issue (contesting factors) resulted in my project being closer to meeting the final brief which was developed from my interactions with my stakeholder and wider stakeholders.

1.2: Budget

Another factor that arose during my initial Research was Budget.

I found the cost of a custom Skateboard mould was between $1000-$10 000, with wheels having custom graphics at the higher end of the spectrum.

I had a meeting with my stakeholder to discuss this issue and she concluded that this price range was too high for them to pay for a prototype investigation. After consulting with her business partner she decided I was to have a maximum budget of $1000 to create the prototype wheels and slide glove pucks.

This factor of budget was an extensive restraint that pushed me to consider new construction methods that would fit with in my budget and could still be used to make a prototype of high quality.

Figure. 2: Wheel Mould

This extensive research into construction methods led me to a page on *The Future of Prototyping* which discussed rapid prototyping using 3D Printing technologies. After some further research into 3D Printing and the innovative and amazing things they are being used for I concluded that this could perhaps be a possible way for me to create the prototype slide glove puck and wheels for my stakeholder. However, a brand new 3D printer in the current day and age costs thousands of dollars, and whilst they are slowly becoming cheaper and more accessible, purchasing a 3D printer would not allow me to fulfil the brief and thereby not meet the needs of my stakeholder.

2. Polyurethane is a thermosetting polymer composed of a chain of organic units joined by carbamate links.

3. Polyethylene or polythene is the most common plastic. The annual global production is approximately 80 million tonnes.

However, as I continued to research prototyping methods I consistently came back to 3D printing and became more and more certain that this technology would allow me to model and prototype not only a wheel and slide glove puck for my client but an almost limitless number of possible products. With this in mind I began to look into cheaper ways of assessing a 3D Printer for my stakeholder,and it was during this research that I came across the RepRap, an online community that offers free open source plans of many different 3D Printers.

The discovery of the RepRap lead me to an open source 3D Printer called the Eventorbot.

Specifications

- Printed Parts: 37
- Non-Printed Parts: 2.5” square steel frame (16 gauge/1.5mm/.0598” thick, cost: less then $20.00)
- Printing Size: 152 x 152 x 152 (mm)
- Material Cost: $300-$500 (DIY)
- Costs: $799 (assembled)
- Precision: 0.1mm-0.5mm nozzle

Figure. 3: The Eventorbot

The cost for me to build this 3D printer myself, $300-$500, is low enough that it is still well within budget and it would also allow me to purchase other Items I may need, it also allows me to create for my client not only the desired prototypes, but also a 3D printer.

This printer requires 37 parts to be created using a 3D printer, which appeared to be a constraint until my father heard about my project, he announced that he had a business partner who had built a 3D printer, Neil Stockbridge. Neil became an essential part of my project and a very useful outside technologist.

After I determined that the 3D printer would be an excellent solution to my budget constraint I wrote a proposal for my stakeholder outlining the uses and benefits of their own 3D printer. They would be able to prototype any product they are developing from a 3D model, rather than hiring someone else to print the model. They can also print multiple designs, trial and test them with the target audience. You can also use the same method to create many different items for their company such as y-tools, bushings and longboard wheels.

Once my stakeholders accepted my proposal, they were very interested in the possibilities of 3D Printing technology, I created a spreadsheet in OpenOffice to monitor any costs involved in the project.

3D Printer Part List				
Part	**Quantity**	**Source**	**Cost Including Postage (NZD)**	**Comment**

Total Additional Cost:
=SUM(D3:D5)
Total Cost (NZD) Of Project (Both Sheets Included):
=SUM(D3:D9,'3D Printer Cost'.D3:D3)

Figure. 4: Budget Table

This spreadsheet allowed me to keep track of my budget very efficiently. It also allowed me to make comments on each item I purchased, this can be used for future developments of the same project.

The comments allowed me to minimise the cost as I was able to find where the money was being spent the most, for instance ordering parts from America was a major expense that caused the 3D printer to cost more than intended. However, the use of the comment section allowed me to see this issue. The use of two separate sheets, 3D Printer Costs and Additional costs, allowed me to accurately keep track of each item purchased and allowed me to minimise my budget.

Another thing I needed to budget was my time. Time was an very important factor to my project. If I did not manage my time effectively I would not have met my deadlines and the product will not have been finished on time. This would has disappointed the stakeholder and be highly unprofessional. To monitor this issue I constructed a Gantt chart to keep track of important deadlines.

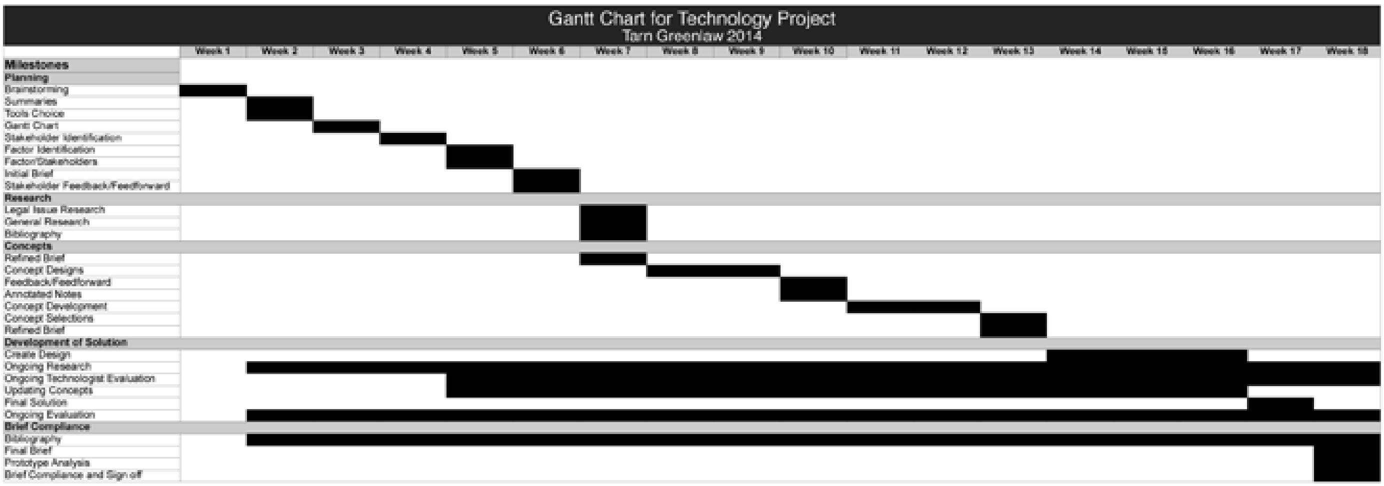


Figure. 5: Gantt Chart

This Gantt chart proved to be invaluable throughout my project as it allowed me to manage my time very effectively which was of paramount importance with constraints such as major sickness, family issues, after school work and the workload from other school subjects. It also allowed me to realise when I was spending too much time on a particular section; for instance I spent too much time on the initial research. The Gantt chart allowed me to realise this and make changes accordingly to ensure I met the deadlines, and thus continue to please my stakeholder.

1.3: Wheel Research

Researching into existing products gave me an understanding of how technologists who have already succeeded in the area have dealt with problems and how they have reached they maximum potential.

First this research showed me that the most common bearing size is the “608.” Characterized by an 8mm core, a 22mm outer diameter and a 7mm width, these bearings are the industry standard and match up with nearly every skate wheel out there. I factored this into the creation of my concepts designs.

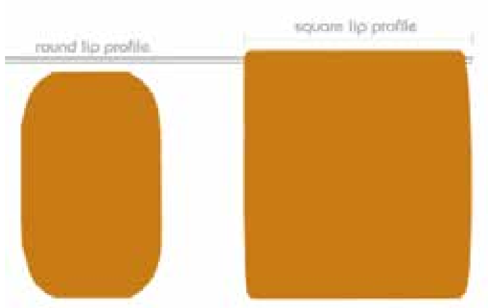


Figure. 6: Wheel Types

I also learnt from the skating industry that a wheels lip profile will determine how well your wheel grips the riding surface. A more ‘square’ lip profile will be more ‘grippy’ and provide more control at higher speeds. A ’round’ lip profile will provide less grip and perform better on slides. You’ll find different variations of ‘more round’ and ‘more square’ across different wheel models but most wheels fall toward one end of the spectrum or the other. This was an important factor that I included into my proposal to ensure my prototype wheel fits the needs and wants of my stakeholder.

Taking into account the branding on different wheels also allowed me to deduce which are the most effective form of advertisement. I talked to several local skateboarders and asked them what they believed was the most effective branding they had seen on a wheel, they agreed that the most effective was a wheel with engraved logos as, through hard use, a printed design is removed. This then lead to update the specifications in my brief. Asking skateboarders was very beneficial to my technological project as it allowed me to gather the views and opinions of my target audience directly.

Figure. 7: Engraved Wheel

1.4: Slide Glove Puck Research

As I am an avid longboarder I already owned a pair of slide gloves. Owning a pair of these gloves gave me a perspective into slide gloves that I could not get though research. In using them my target audience (gathered from an interview[4]) and myself all agree that 3 pucks do not add to the gloves. Instead it reduces movement and stops you performing tricks involving board grabs.

Another thing I noticed is the branding on the pucks themselves, The word LOADED, is printed along the top puck. This branding was removed on first use, in literally minutes. This personal perspective allowed me to advise my stakeholder in its construction as once again I realised an engraved puck would allow for more effective advertising of my stakeholders business.

Figure. 8: Slide Glove

Figure. 9: Used Slide Glove

1.5: Colour Research

When HPDE (Polyethylene) is melted it retains its colour. This meant the colour of the Wheels/Pucks were limited to the colours milk bottle lids are created in. In New Zealand the majority of lids are blue, light blue, red and sometimes green. As these were the colours I had to use I began to research the meanings and emotions these colours represented. This would act to inform my stakeholder and allow them to make an informed decision in regards to their subject audience and the imagery.

- *Red Wheel: Youthful and bold. This is a great choice for younger boarders.*
- *Blue Wheel: Dependable and Strength. This is a good image for wheels to have, Strength is important in a wheel. Blue is also one of the most popular colours.*
- *Green Wheel: Growth and Health. The growth these wheels shall have undertaken will act as a great back-story, from milk bottle lids to a wheel on a recycled longboard. Green will also represent the company's 'Green' ethics.*

Figure. 10: Colour Emotion Guide

I then gave this information above and the *Colour Emotion Guide* to my stakeholder as part of my proposal. They were very interested in this aspect and decided that a mixture of the colours would allow for a wider target audience as there will be an option for different

4. Target Audience according to my stakeholder: *According to our Business Facebook insights, our target audience is 55% female, 44% male and range mainly from 15-39 in over 10 countries.*

peoples tastes and preferences. Reappraising at the proposal gave me the idea that it could open up a range of fantastic advertisement opportunities, for instance, I could brand each colour wheel in a way to show its history. The red wheel could be, Crème “Great with your morning coffee” (red milk bottle lids are for cream). Light blue could be, Trim (as light blue is trim milk), and so on.
The range of colours and the material choice combined could result in excellent branding for my stakeholder in the future.

2: Technological Modelling - Concept Designs

Concept designs are an excellent way to convey thoughts and Ideas to a client.

Initially I created a series of rough *Investigative/Ideation Sketches* to explore different shapes, and design of the slide glove pucks and wheels. I also created a series of designs for moulds that could be created using a 3D printer. These sketches were informed by my research into the subject area. This process worked very well for me as it allowed me to quickly record ideas as they came to me.

I then choose the designs I felt were most appealing and created digital *Persuasive Sketches* to show my client. This was done by scanning my technical drawings, and then rendering them in Adobe Photoshop. Examples of these designs are shown in Fig 12-13

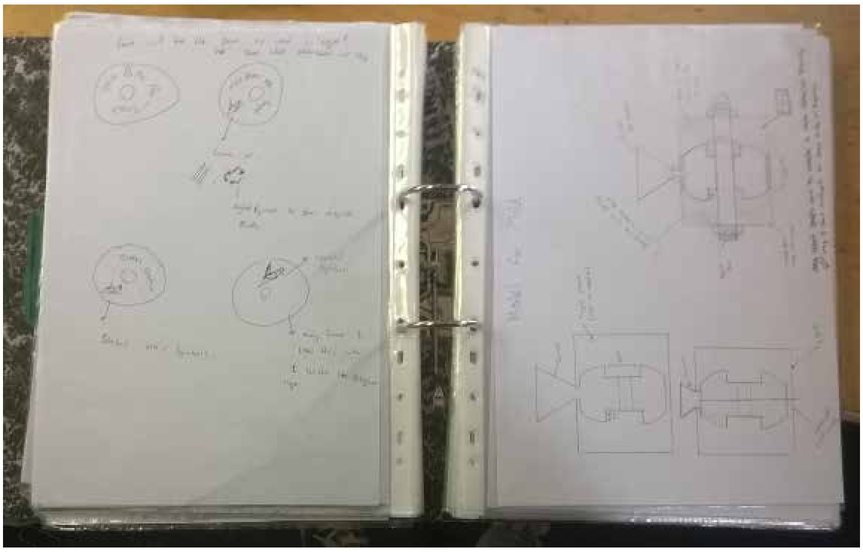
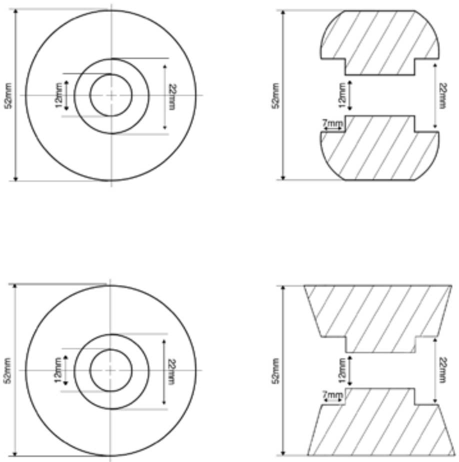


Figure. 11: Investigative/Ideation Sketches

Having a variety of designs to show my client offered them a broader spectrum of choice and ensured that my concept designs have the highest chance of meeting my clients needs and wants.



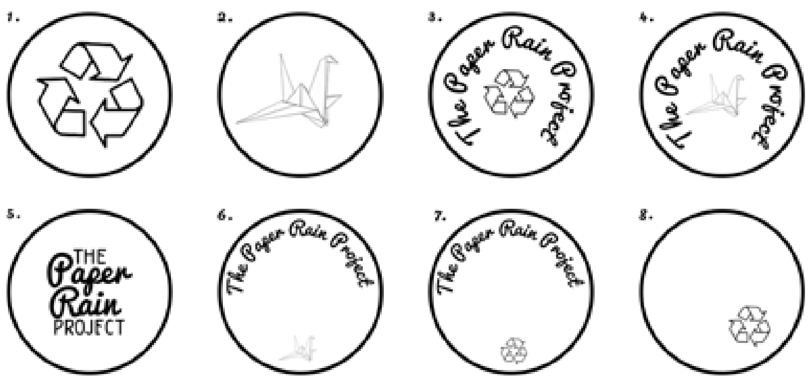


Figure. 12: Wheel Specifications Concepts ***Figure. 13:*** Slide Glove Puck Design Concept

2.1: Resources That Influenced My Concept Designs

Prior to this project I had no previous experience in Technical drawing. During the technological process I found this was a vital part of my project because I needed to show my stakeholder concept drawings and working drawings which would help to enlighten them as to what the end result was going to be.

I sought help from an outside technologist, my father, who was a Marine Engineer. This, combined with a book called *Technical Drawing For New Zealand Schools,* resulted in far more professional looking concept designs, which is an important factor when dealing with a client, as clear concept designs are needed to communicate ideas and thought processes.

To ensure my concept wheel production process (using a 3D printer to create moulds) would work effectively, I contacted a Product Development Engineer, Kris Lawry, who is currently working on a new form of nuclear reactor. I needed this technologist to aid me with the design of the moulds for the skateboard wheel to ensure that the process would work and deliver the outcome for my stakeholder. After sending him my initial concept designs for the wheel mould he reviewed them and pointed out a fatal flaw in my design; I did not include an air release. Without this, the wheel would be filled with air bubbles and would reduce the structural integrity of the end product.

This interaction potentially saved me hours of time prototyping and dollars spent on solving the problem. It also resulted in an updated final concept design for my wheel moulds (Fig. 14).

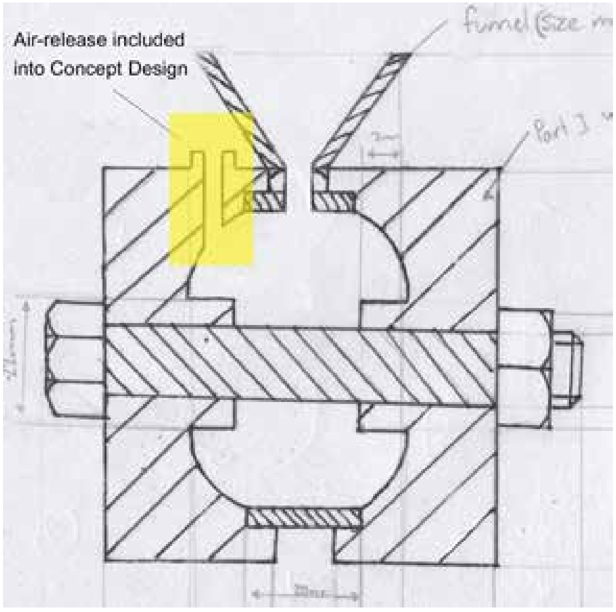


Figure. 14: Updated Mould Design

Research also played a large part in enhancing my concept designs. Researching existing products and production methods allowed me to gather ideas quickly and improve and change them rather than literally *reinventing the wheel.* It also allowed me to gather what my stakeholder's competition is producing to ensure that they can stay in a competitive market.

2.2: Stakeholder Consultation - Concept Designs

Once I had created my Persuasive Sketches, and met with an outside technologist to refine my production methods I created a proposal for my stakeholder that outlined my thoughts, ideas, and concept designs.

At this stage I was prepared to go back and update my concept designs according to my stakeholder specifications. However my stakeholder was, impressed with the range of designs I had created. They chose from the submitted concepts and asked that I continue on and create the Prototype for the wheel, slide glove puck, and begin construction on the 3D Printer.

My interactions with my main stakeholder and outside technologists were conducted in a professional manner. This is important when working with a client as it ensures that they are satisfied with the work done with/ for them. It also has the effect of ensuring that the client will be interested in working with you again, thus securing future work.

...Thank you very much for your proposal. We are continually impressed with the depth & quality of your ideas. We look forward to your correspondence, your work looks fantastic![5]

This quote from my stakeholder shows that the manner I conducted myself during interactions with them was pleasing and has ensured future work with the stakeholder. In fact, once I had completed this project they approached me to build them a laser engraving machine, further showing that in dealing with them in a professional manner I used correct technological practise and ensured myself future work.

2.3: Brief After Concept Designs

Once I had completed my initial research to gather a broader understanding into skateboarding, 3D printing, and construction of prototypes, as well as completing my concept designs, I added factors and new specifications to my initial brief. This brief, which was relativity sparse, developed with the additional factors which resulted from my stakeholder consultation. I learnt how valuable stakeholder feedback and feedforward is to a working document such as a brief for a client.

Conceptual Statement

A company, The Paper Rain Project, is a sustainable custom creative business; providing graphic design, photography, organic apparel and custom board art. They wish to create sustainable alternatives for popular related consumables such as skateboard wheel.

My stakeholder, Indigo Greenlaw, has requested I create a set of prototype wheels and slide glove pucks that shall be tested for use. Ideally, I would have the entire product as close to 100% green as possible. I shall build the Eventorbot printer, design and 3D model the wheels and slide glove pucks, print them, create a mould and finally test the product(s) with local skateboarders.

Specifications

- *Time: The project must meet the deadline.*
- *Input/Output: I must take into account the quality input/output to the project.*
- *Monetary: I must not go over the budget given to me by The Paper Rain Project.*
- *Appeal: The product must appeal to the target audience. This is mainly young adults to mid-30s who are either students or in their first jobs out of university.*
- *Stakeholder Specifications: I must follow Stakeholder specifications.*
    These include:
    - A 52mm wheel made of blue milk bottle lid plastic.
    - Subtle branding & a reiteration of the fact that the wheels are recycled.
    - The Wheel with ratio of designs #4:#1.[6]
    - Subtle branding & a reiteration of the fact that the wheels are recycled.
    - A slide glove puck made of blue milk bottle lid.
    - The slide glove puck: design #8 [7]

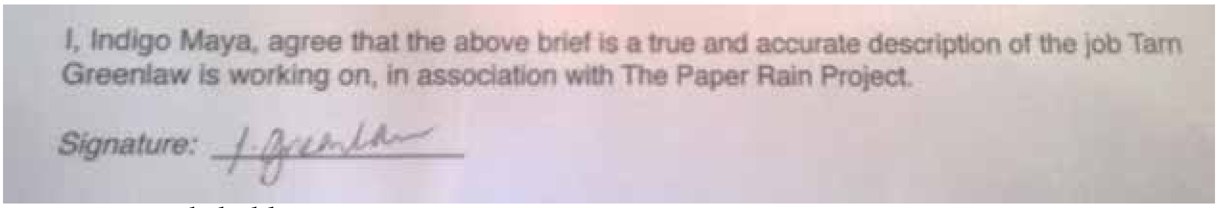
- *The outcome must comply to the New Zealand Copyright and Intellectual Property Acts.*
- *Environment: The product must be as close to 100% 'Green' as possible.*
- *I must be at forefront of sustainable & creative ingenuity; this means I need to research all methods involved in the creation of the skateboard wheels*
- *The wheels are to be made from recycled milk bottle lids (Polyethylene)*

5. Email from The Paper Rain Project.

6 & 7. Numbered designs given to my stakeholder included in my proposal.

Desired Outcome:
A fully functioning, fit for purpose and ascetically pleasing, set of skateboard wheels and slide glove pucks made from recycled plastics.

This brief allowed me to clearly describe a desired outcome that would meet a need and realise an opportunity. I used it to ensure I was fulfilling the needs and wants of my stakeholder. This was confirmed with her signature at the bottom of each brief, to ensure both parties were fully aware of the direction of the project.


I, Indigo Maya, agree that the above brief is a true and accurate description of the job Tam Greenlaw is working on, in association with The Paper Rain Project.

Signature:

Figure. 15: Stakeholder Signature

2.4: Final Concept Evaluation
Throughout this document I shall review whether or not my concept designs take into account the specifications and factors specified.

Budget:
The budget given to me by The Paper Rain Project was $1000. The concept designs I have developed and the process I plan to use, printing the moulds with a 3D printer that I shall build, will all fit within this budget.

Appeal:
I have created multiple designs that have been looked over by my stakeholder. They chose the one which they prefer and asked for no changes. This means my stakeholder thinks the concept designs are aesthetically pleasing. The size and the specifications of the wheels are also the averages for a skate wheel, this means it will appeal to a skateboarder.

Environment:
The process to create the wheels I have designed will use recycled plastic. The 3D printer prints in PLA filament can be substituted with recycled filament or recycled after its use and the parts of the printer can be melted down and recycled. This process is as close to 100% green as I can achieve within the deadline. This adheres to the specification given by my stakeholder.

Stakeholder Specifications:
Throughout the development of my concept designs I have constantly liaised with my stakeholder to achieve maximum satisfaction. *“Thank you for your prompt response & work for our concepts! I think we will definitely go ahead with the slide glove pucks!”* and *“We are continually impressed with the depth and the quality of your research ideas.”* These quotes from my emails with my stakeholder show she is happy with the concept designs and my work for her.

Sustainability:
The material I am to create the wheels from (Polyethylene) is completely recyclable and can be remoulded. This means the product can be melted and recreated. This will reduce environmental impact as it will not end up in a landfill.

Skill and expertise:
I have created the designs in a way that I should have the required skills and expertise to complete them. In areas my knowledge is lacking, such as engineering, I have contacted outside technologists, such as the Product Engineer Kris Lawry, to aid me in my creation process.

Legal:
All designs have been completed solely by me with no pre-existing designs incorporated into my work, aside from those given to me to use by The Paper Rain Project (My Stakeholder). This means I have not knowingly breached any Copyright or Intellectual Copyright Laws.

Equipment / Materials:
My concept designs should all be able to be completed using equipment I have access to locally. Material I shall use will be ordered online and brought locally wherever I can. I will also ensure they are as close to Green practise as possible.

Conclusion:
I feel that my concept designs are fit for purpose in the broadest sense as I have met the specifications of the brief provided to me by my client. Whilst undergoing the development of my concept designs I had to always consider the material composition of the outcome. This was to ensure that the stakeholder was aware of the implications of all decisions, keeping in mind the final outcome of the product.

3: Technological Modelling - Prototyping

Once my concept designs had been signed off by my stakeholder and my brief had been updated I was ready to continue on with Prototyping.

3.1: 3D Modelling

My first steps into Prototyping was to 3D model the wheels and slide glove pucks according to my stakeholder specifications. These 3D models can be used to consult with my stakeholder and ensure the project is developing according to her needs. They can also be 3D printed once I have completed my 3D printer build.

3.1a: 3D Modelling Constraints

After researching into multiple programs I chose to use Google Sketch-Up as a result of my budget, all other programs that were more suited to the task, such as Autodesk CAD or Solidworks, all cost far too much. This proved to be a critical review point and I had to consider what free 3D Modelling software was available to me. Google Sketch-up 8, is available on my school computers. However there were minor constraints that arose during the 3D modelling stages due to a lack of functions in this program.

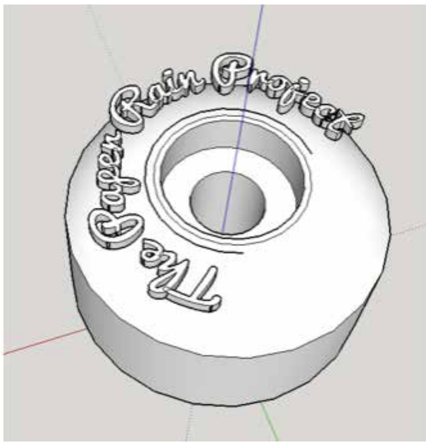


Figure. 16: Curved Text

First I created the wheel, to the correct size specifications, this was a simple task. However once I began to apply the intended graphics to the wheel I ran into my first constraint: The program would not allow me to bend the text into a circle. This was when I learnt the importance of ongoing research. After searching forum after forum, I discovered a plug-in developed just for this purpose, and was able to bend the text around the intended path (Fig 16).

The next constraint that I came across sadly could not be fixed with plug-ins or further research. When it came time to intersect the intended designs into the wheel the graphic became broken and jagged. This was due to Sketch-Up's inability to handle curved faces (Fig 17). This constraint became prevalent yet again when it became time to extrude the faces downwards to create the desired engraved effect (Fig 18).

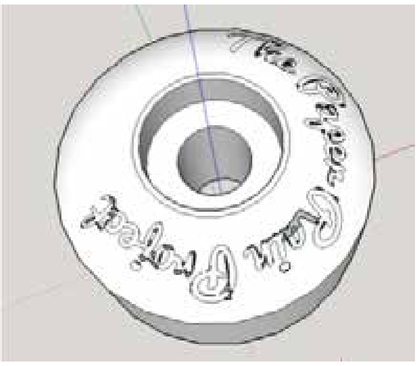


Figure. 17: intersecting Error

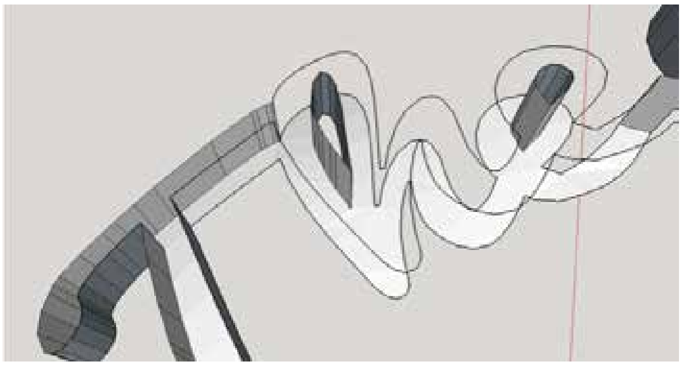


Figure. 18: Engraving Process

I overcame both problems by manually adding faces to the object until the design was completed. However, this was an extreme waste of time that could have potentially pushed me past the deadline of my project, and thereby disappointing my stakeholder. I gained new knowledge from this unfortunate turn of events: When dealing with a project sometimes two contesting factors must be addressed in a way that does not completely neutralise one or the other. In this case *time* was severely constricted due to my *budget.* I had to use a limited program (Google Sketch-up), that used a lot of my time, to allow me to stay within budget. This taught me to both mange my time more effectively (Using the Gantt discussed in Article 1.2), and to prioritise my factors to ensure I stay within the parameters of my brief.

_3.1b_ Final 3D Models

Once I had completed my 3D models I met with my stakeholder for feedback/feedforward and to ensure they were pleased with the progress I had made. They were very happy with the 3D models and requested I continue and create the physical prototype. This meant my brief did not change at this point and I did not need to update my concept designs.

The final concept designs of my Wheels, Slide Glove Puck and moulds (Fig. 19 - 26) are as follows:

Figure. 19: Wheel Design #1, Angle #1

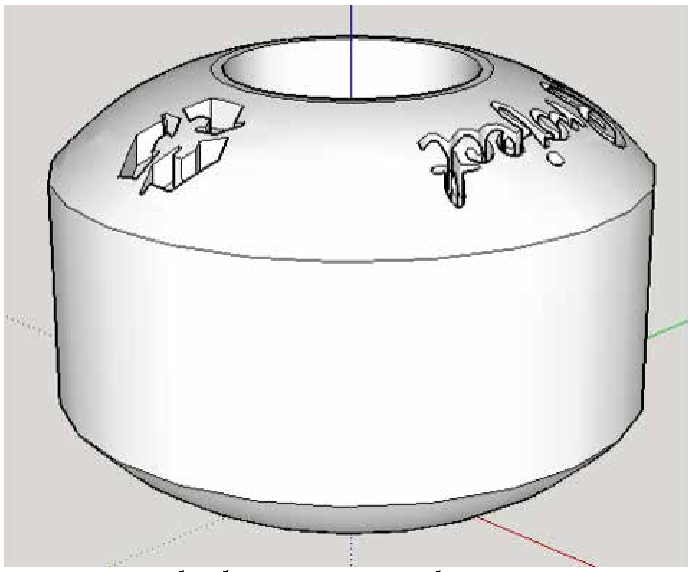


Figure. 20: Wheel Design #1, Angle #2

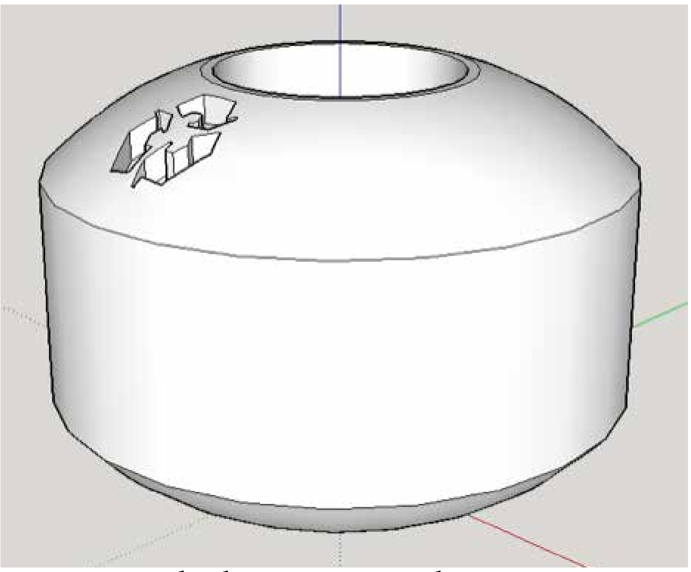


Figure. 21: Wheel Design #2, Angle #2

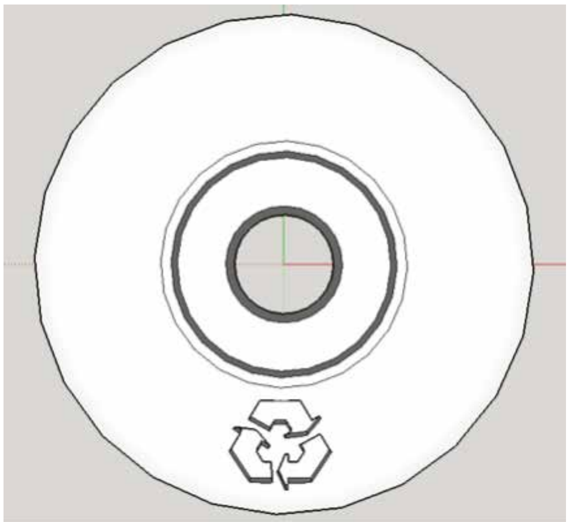


Figure. 22: Wheel Design #2, Angle #1

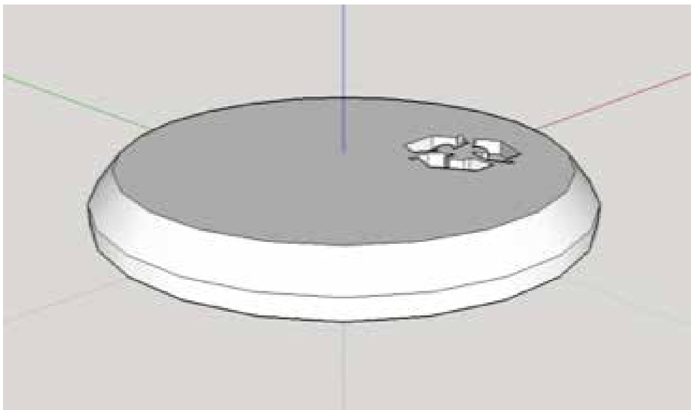


Figure. 23: Slide Glove Puck Design, Angle #1

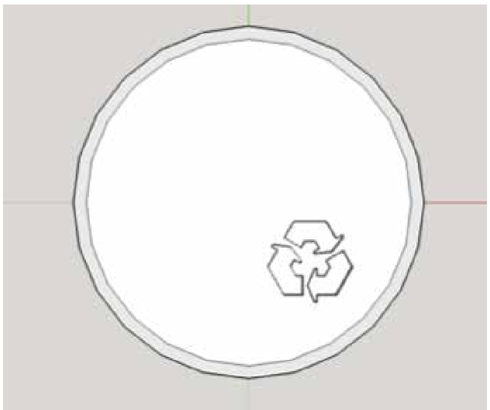


Figure. 24: Slide Glove Puck Design, Angle #2

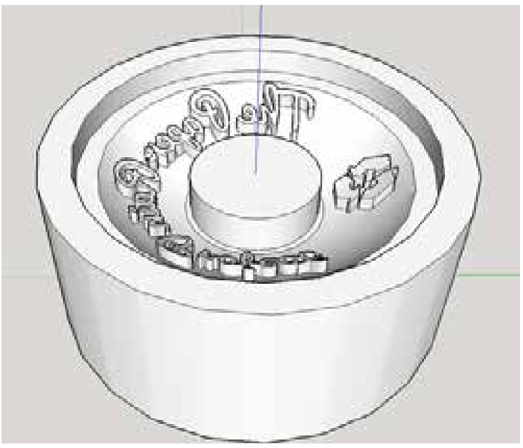


Figure. 25: Mould Design #1

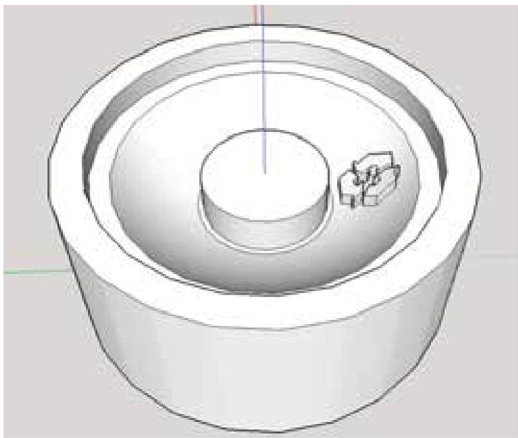


Figure. 26: Mould Design #2

3.2: 3D Printer Build

The process of building the 3D printer, The Eventorbot, was a long process that, to begin with, I did not imagine would require such time and effort. This almost pushed me past my deadline. In addition to the unexpected time required to construct the printer I was effected by severe sickness that took two weeks over the holiday period out of my schedule, which was when I planned to do the bulk of the construction of the 3D Printer. As a result, I had to request an extension from both my school and my stakeholder. Fortunately both agreed and I was granted an extra 4 weeks to continue work on my project. This extension allowed me to finish the project and the planning documentation at a much higher standard than I could have achieved otherwise. It also showed me that during a technological project unexpected factors such as sickness can arise that cannot be planned for ahead of time.

As a result of this extension I updated my Gantt chart, previously mentioned in Article 1.2, to account for the additional time. Once again this resource allowed me to manage my time effectively.

3.2a Resources That Influenced My 3D Printer Build

• The 3D printer build would not have been possible without an outside technologist I contacted, Neil Stockbridge. Initially Neil provided me with the 3D printed plastic parts needed to create the printer. These parts were downloaded from the Rep Rap website.

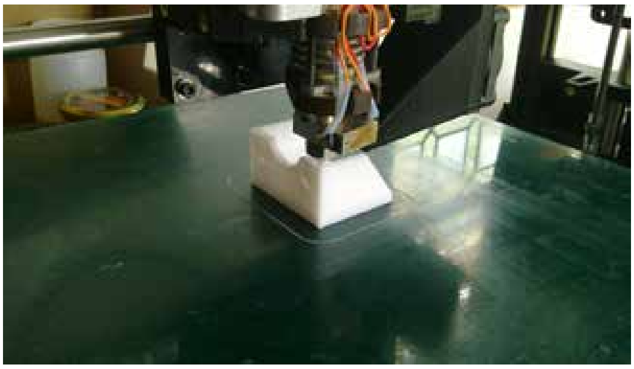


Figure. 27: Motor Mount Printing On Neil's 3D Printer

Neil also offered me extremely useful advice and insight into building the Printer, for instance he provided me with a list of the programs used in the pipeline required to 3D print an object. This gave my research focus and allowed me to gather a perspective into the industry standard for 3D printing.

Neil also contributed as a technical consultant, aiding me when constraints arose during the implementation of the hardware, firmware, and software aspects of the project.

Without Neil Stockbridge acting as an outside technologist this project would likely not have progressed beyond the theoretical stage.

• My father once again aided my project. He was able to provide me with his decades of engineering knowledge and expertise to advise the mechanical build of my printer. He was able to help when my expertise was lacking in the field of Engineering & Software. This was especially useful as prior to this project my technological knowledge was mainly computer based. Having him around day and night was a fantastic resource to my project.

• The local engineering workshop, Gregory Engineering, was also a very valuable resource. They were able to complete jobs such as welding (Fig. 28) that I could not attempt myself, as well as help me to find the correct parts to complete my build such as steel rod, nuts and bolts.

Figure. 28: Frame cut and welded by Gregory Engineering

• Finally the creator of the Eventorbot, Duy Dang. Without him I would not have been able to remix the design to create the printer for my stakeholder. He also provided me with a hot-end[8] when I could not locate one elsewhere.

8. A Hot-end is the part of a 3D printer that heats up and extrudes the melted plastic.

All of these outside technologists contributed to my 3D printer build. This technological project taught me the importance of outside technologists, they are an amazing source of knowledge and expertise and are direct stakeholders as their knowledge has an influence, not only on how the project is developed, but also adds to my technological knowledge and practise.

3.2b 3D Printer Hardware Build Constraints

The first set of constraints arose during the purchase of the 3D Printer parts.

The part list for this project was supplied on the Eventorbot RepRap web page, this list was created by an American. Therefore all of the measurements and bolt sizes were in the Imperial System. This caused multiple constraints for me. Firstly I was unable to purchase the required 2.5" square steel frame. Instead I had to substitute it with a 66mm version and as a result I had to resize parts that were related to the size of the frame (Fig 29).

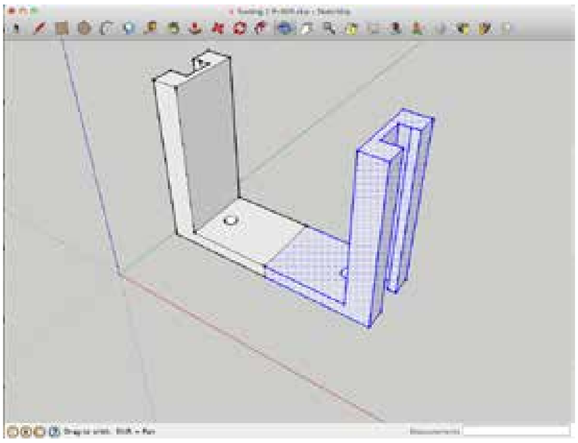


Figure. 29: Resizing Footing Piece

The Imperial measurements also meant I had to order a lot of parts from America such as motors, bolts and the hotend. This resulted in my budget being slightly higher than previously expected due to shipping costs. Fortunately I was able to keep track of this using my budget table (previously mentioned in Article 1.2) and the budget my stakeholder set me was more than enough to complete my project despite this minor increase in spending.

Another constraint that arose during the hardware construction stage was that the files provided for the printed parts were created with the exact sizes needed. This caused problems when they were printed as 3D printers have a margin of error, in the case of Neil's printer this margin of error is about 0.3mm. Therefore pieces that were required to fit together tightly had to be resized, tested, and reprinted, consuming valuable plastic and the time of both myself and my outside technologist. I fixed this constraint using three different methods:

1. Firstly, I digitally resized and tested pieces, such as the printing bed, to ensure they fitted correctly. I edited the file so Neil only needed to print the end pieces that fitted together to test them (Fig.30). This saved time and plastic.
2. I resized already printed parts using a drill and sandpaper (Fig.31).
3. I also created some pieces out of wood using the school's Woodwork Department (Fig.32). This was done to save time trialling and testing plastic pieces.

In doing so I ensured I would stay within the parameters of my brief and please my main stakeholder.

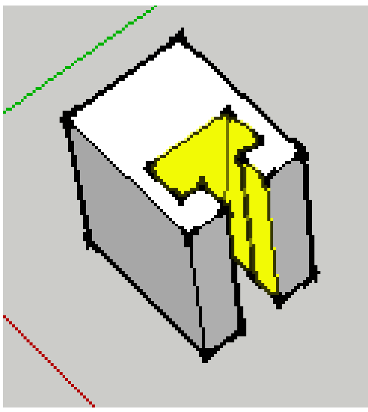


Figure. 30: Resized Piece

Figure. 31: Manually Resize Pieces

Figure. 32: Wooden Footing Pieces

The steel box section that I purchased was a off-cut from another project, this saved me money. However it also meant that it was covered in rust. To combat this issue I sanded the frame down and painted it with primer and then paint to prevent the steel from oxidizing (Fig. 33 - 35). This will ensure the longevity and sustainability of the product for my client.

Figure. 33: Priming 3D Printer Frame

Figure. 34: Sanding 3D Printer Frame

Figure. 35: Painting 3D Printer Frame

To ensure my health and safety I performed the painting in an outdoor environment to allow the fumes to disperse. To keep with in COPS (Codes Of Practise) I wore a face mask to protect my lungs.

The final constraint that arose during my hardware build was that I could not find an assembled motherboard to drive the Printer. As a result, I had to purchase a kit-set that required me to solder each component into the motherboard (Fig. 36). This was a very interesting experience for me as at the beginning of the year I did not expect taking digital technology would result in me doing anything remotely like this Printer build. However, it was an experience that was very beneficial to my skill set.

Figure. 36: Soldering Motherboard

Figure. 37: Completed 3D Printer

Once these issues had been solved I was able to complete the hardware build of my 3D Printer. This took slightly longer than anticipated, but I was still able to complete in the required time frame.

When I had completed the hardware build of my 3D Printer it was time to load the firmware onto the motherboard and calibrate the Printers movements. Unfortunately this step was not without its issues.

3.2c: 3D Printer Software and Firmware Issues

During this stage in the 3D Printing build I constructed a table to monitor my trialling and testing.

Testing Of The 3D Printer				
Date	Details	Expectation	Result	Next Steps
28/06/14	At this point I believe I have completed the build of the 3D Printer. I am now ready to connect the 3D printer to my computer. I have downloaded Slicer and Printrun in preparation of this moment as a result of Neil Stockbridge's (Outside Technologist) advice.	I hope to connect to the computer using a USB cord. I will then use Printrun to move the motors and heat the hotend to the correct temperature.	The program Printrun could not communicate with the printer. It would not connect.	I must use the internet and consult with my outside technologists to find the solution to this issue.
29/06/14	I found the correct driver on an Eventorbot forum. I am now ready to reconnect the 3D Printer to my computer.	I hope to connect to the computer using a USB cord. I will then use Printrun to move the motors and heat the hotend to the correct temperature.	The 3D printer connected to the computer as expected. However I was only able to heat the hotend (To the correct temperature of 230º), I was unable to move the motors.	I must use the internet and consult with my outside technologists to find the solution to this issue.
06/07/14	The Polous Drivers have arrive and I have soldered them on.	I hope to connect to the computer using a USB cord. I will then use Printrun to move the motors.	The 3D printer connected to the computer and I am able to move the axises. However they only move in a positive direction.	I must use the internet and consult with my outside technologists to find the solution to this issue.
21/07/14	The USBasp programmer arrived.	I hope to be able to move the motors in both directions.	The Axises all move in both directions.	I must now calibrate the Printer.

Figure. 38: Trailing and Testing

This table allowed me to problem solve constraints as they occurred. An example of this being the constraint that arose on the 28/06/14 in Fig. 38. Once Neil reviewed the information in the table he was able to point me to the solution: the driver I installed was incorrect.
Each of these issues listed in the aforementioned table was solved between Neil and I using the information recorded. I found it was a very effective way to trial and test software as recording all of the information in one place can help to find reoccurring patterns, such as the inability to connect or load firmware to the motherboard. This enables me to find the relevant solution, in the case of the example previously given: Purchasing a USBasp programmer.

I also used online forums to find solutions to my various issues. This was at times helpful and at others frustrating. When it comes to open source projects, such as the Eventorbot, they are remixed and changed so often that a solution that works for one version does nothing for another. This meant that it took a long time for me to find the relevant solution to each problem.

After many hours and late nights of debugging and changing code in the firmware (such as Fig. 39 which allowed the axis to move both directions) I was able to get to the stage where I was ready to calibrate the printer. However due to the multiple unexpected errors I experienced my final deadline was almost upon me.

```
// The pullups are needed if you dir
//If your axes are only moving in on
//If your axes move in one direction
const bool X_ENDSTOP_INVERT = true;
const bool Y_ENDSTOP_INVERT = true;
const bool Z_ENDSTOP_INVERT = true;

// This determines the communication
#define BAUDRATE 115200
//#define BAUDRATE 250000
```

Figure. 39: Changes In Code, End Stop Invert = true

According to Neil a printer takes weeks of adjustments to calibrate so we came up with a solution, Neil 3D prints the wheel moulds and I finish the calibrations at a later date. This will allow me to continue on and create the slide glove pucks and wheels for my stakeholder. I had a meeting to discuss this major constraint with my stakeholder and she agreed that this would be the best course of action. She was also extremely happy with the work I had created for her thus far.
This is yet another example of balancing factors to provide the best possible outcome for my

stakeholder. If I had completely calibrated the 3D printer I would have been unable to create the wheels and slide glove pucks for my stakeholder. As this is the desired outcome of the brief I had to postpone the calibration of the 3D printer for a later date. This was agreed with and signed off by my stakeholder.

3.2d: Health And Safety

During the trialling and testing phase of my 3D printer build I tested the hot-end to ensure it reached the required temperature, 230º. I realised that this temperature could easily cause injury and the hot-end is very exposed. After researching the correct method of dealing with this issue I created a sign to place on the printer to warn people, and protect them. This adheres to the Health and Safety guidelines.

Figure. 40: Warning Sticker

Figure. 41: Warning Sticker In-Situ

3.3: Wheel Mould Creation

Once the 3D printed parts of my mould designs and slide glove puck arrived (Fig 42 - 44) I had the task of recreating them from a different material. This was because PLA, the material used to 3D Print, has a lower melting point than Polyethylene. This meant that should I have attempted to use them the plastic of the mould would have been destroyed.

Figure. 42: Slide Glove Puck

Figure. 43: Mould Design #1

Figure. 44: Mould Design #2

3.3a: Silicone Moulds

After some extensive research into various replacement materials I decided upon resin as it has a much higher melting point than Polyethylene and it is a epoxy, meaning I do not have to melt the material. (An epoxy is a two part mixture that uses a chemical reaction to harden).
To accomplish this I needed to first create a silicone mould of the wheel mould. I found some cheap moulding silicone at an online store located in New Zealand and, following the instructions provided I mixed the silicone with the catalyst provided (Fig 45- 47).

Figure. 45: Mixing Silicone

Figure. 46: Pouring Silicone

Figure. 47: Final Silicone Moulds

The creation of the silicone moulds was completed without any issues.

Silicone was the perfect material for the job. It is flexible, strong (Fig. 48) and can withstand high temperatures. This means that I can use it to create multiple moulds for my stakeholder, allowing me to trial and test them until I create one that works the best and thereby please my stakeholder. This process, once perfected, can also be used to create an almost limitless number of prototypes for my stakeholder.

Figure. 48: Strength Test

3.3b: Resin Moulds

Once the silicone moulds were completed I was able to fill these with a two part resin that would withstand the heat of the melted Polyethylene.

This mixture is very harmful when it comes in contact with your skin so I wore protective gloves to prevent this. However I wore a very nice shirt which I ruined completely when I accidentally put my elbow in the mixture. This taught me to wear protective overalls during future projects.

Unfortunately the resin did not harden correctly (Fig. 51). I attempted to fix this issue with hardening powder in a secondary mixture, this time wearing overalls and a breathing mask to prevent me from breathing in the powder (Fig. 52), a necessary Health and Safety precaution.

Figure. 49: Mixing Resin

Figure. 50: Pouring Resin

Figure. 51: Incorrect Mixture

Figure. 52: Remixing Resin

Figure. 53: Final Resin Moulds

3.3c: Final Wheel Mould

Once the Resin moulds were completed they needed minor adjustments to allow for the 12mm bar to fit though the centre (Fig.54). This was done using a drill.

I had to purchase the centre steel pipe that is used to create the contact patch of the wheel from the local engineering store, Gregory Engineering. I cut this pipe in half to create the two different wheel designs (Fig. 55), both branding and recycled symbol designs as per my concept.

The steel pipe availability caused me to resize the wheel as I could not find the correct size, 52mm, I had to resize my concept designs accordingly. This was cleared with my stakeholder prior to the adjustments. We concluded that 58mm would still work as an effective skateboard wheel. It even has its own benefits, this size can be used on both skateboard *and* longboards. I learnt from this experience that sometimes changes must be made to a concept design because of material choice and availability.

Figure. 54: Centre Bar Through Resin Mould

Figure. 55: Cutting Steel Pipe

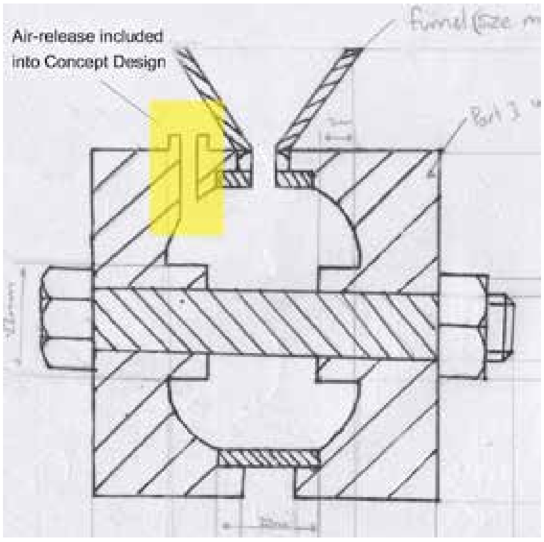


Figure. 56: Mould Concept Design

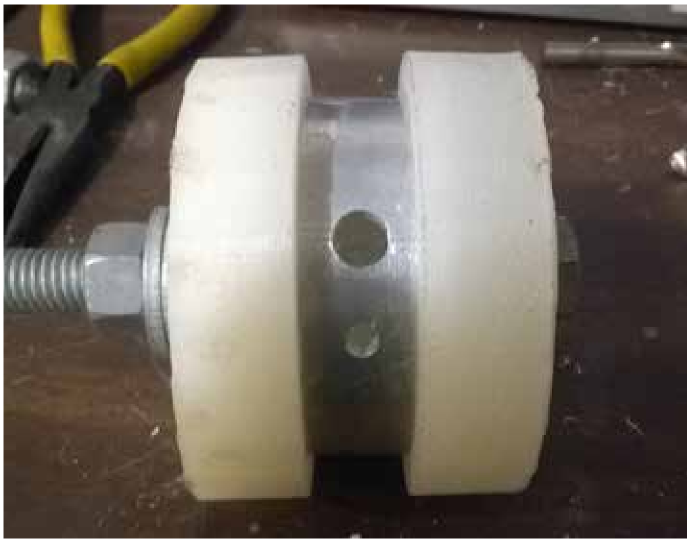


Figure. 57: Final Mould

Comparison

The finalised mould is very similar to the concept, the only changes made are as follows:

- Instead of using a funnel I have decided to pour the plastic in the hole straight from the container.
- The air release is not in the plastic part, instead it is also drilled into the metal pipe.
- The dimensions changed. This was the result of availability of nominal sizing and imperial sizers

These differences are all a result of the technological modelling process of trailing and testing as well as stakeholder feedback/feedforward. They have all been made to better the design of the wheel, for example: Allowing the air release to be in the steel pipe rather than the 3D printed parts means that any blemishes will not be seen once the contact patch had been used or sanded down to provide better grip. This is an example of Prototyping in the broadest sense, by improving a design though trialling and testing.

In regards to the slide glove puck mould. I decided upon the silicone mould as it will withstand the heat.

This method of creating a wheel mould can be personalised and changed with ease to suit the needs and wants of my stakeholder. This is why a 3D printer is such an effective method of prototyping. It can be used to rapidly produce prototypes with graphics and dimensions that can be changed to suit the specifications of the given brief.

3.4: Prototype Creation #1

Once the moulds were ready to be filled with molten plastic I prepared them using a release agent. This was to ensure the mould could be taken apart after the plastic solidifies.

Figure. 58: Moulds Ready To Fill

Once I was ready I prepared the Physics Department's fumigation cupboard and Bunsen Burner to melt the milk bottle lids I had collected from Outward Bound (Fig. 59), a local Adventure Guide course. Collecting the lids from a local company ensures that the prototype is created using locally sourced materials, a very important factor to my stakeholder. It also ensures that these milk bottle lids will not end up in a landfill, in keeping with the clean green image of the Paper Rain Project.

The fumigation cupboard was also a necessary Health and Safety precaution. Melting plastic gives off fumes that are harmful.

Figure. 59: Milk Bottle Lids

Figure. 60: Milk Bottle Lids On Bunsen Burner

Figure. 61: Melting Milk Bottle Lids

The melting process took a long time, almost 2 complete school periods, to get the Polyethylene to the state suitable for moulding. Even when it had reached this point it was still too thick to pour into the wheel mould. I concluded that I needed to heat the plastic to a higher temperature to reach this state. However I was able to pour the molten plastic into the slide glove puck mould as this did not have a small opening. This mixture was very thick and many air bubbles were caught in the plastic as it hardened (Fig.63). This was yet another reason the plastic needed to have a lower viscosity, it will allow air bubbles to escape.

Figure. 62: Mould Prepared For Filling

Figure. 63: Molten Plastic In Mould

Figure. 64: Prototype Top View

Figure. 65: Prototype Bottom View

This Prototype was just that, a Prototype. It was far from perfect as it is filled with air bubbles and bumps. However it still can be used to trial and test the Polyethylene material once I attached it to the gloves. Before doing this, however, I cleaned the puck up using sandpaper. I did this so that when I tested it with the target audience they would not be put off by the look of the pucks (Fig.66). I then attached the slide glove puck to my pair of slide gloves using Velcro (Fig. 67) to test the prototype with the target audience.

This process worked very effectively to Prototype a design. However, as the plastic took so long to melt, I decided to test another method of melting plastic before I began trialling and testing the Puck.

Figure. 66: Final Prototype Slide Glove Puck

Figure. 67: Velcro Attached To Puck

Figure. 68: Slide Glove With Puck

3.5: Prototype Creation #2

The previous melting method took too long to get the plastic to a usable state and once it reached this, it was still too thick to pour into the wheel mould I had created. As a result, I decided to try another method of melting the plastic.

I contacted the Head of the Queen Charlotte College Art Department, Ms Somers. She was able to supply me with a small kiln used to melt glass. I set this kiln up outside to prevent breathing in fumes, I also wore a breathing mask.

Figure. 69: Kiln Set Up Outside

I chose the kiln as it reaches much higher temperatures compared to a Bunsen Burner. It also does this far quicker. However, after placing the milk bottle lids into the kiln I had less than favourable results:

• Firstly the plastic did not melt quickly, instead it caught fire (Fig.70). This has a negative effect on both the environment and my prototype development. To solve this issue I heated the plastic with the door of the kiln open.

• Once the plastic began to melt it did not reach a favourable state. It was too thick to pour into both the wheel mould and the slide glove puck mould. It stuck to everything *except* the mould, similar to melted sugar (Fig.71).

The end result of this experiment was not a pleasing one. The plastic refused to flow into the mould, instead forming a ball around the mixing stick (Fig. 72).

Figure. 70: Flaming Plastic

Figure. 71: Melted Sugar Like Consistency

Figure. 72: End Result

This failure led me to a disheartening conclusion. Polyethylene's viscosity is too high for me to mould using my planned methods. This discovery resulted in further research into the moulding methods required to create products using Polyethylene.

3.6: Updated Concept Designs

During my further research into recycled Polyethylene I came across a process called injection moulding. This process uses pressure to force the molten plastic into the mould, removing all air bubbles and filling all extremities, a prominent example of this construction method being Lego blocks (Fig. 73).

Figure. 73: Lego injection Mould

This process would allow me to fill the wheel and slide glove puck mould to create smooth blemish free versions of my designs. Injection moulding is the perfect way for my stakeholder to create the final wheels and slide glove pucks.

Once I determined that this was the solution to my problems I redrew my concept designs to show my stakeholder.

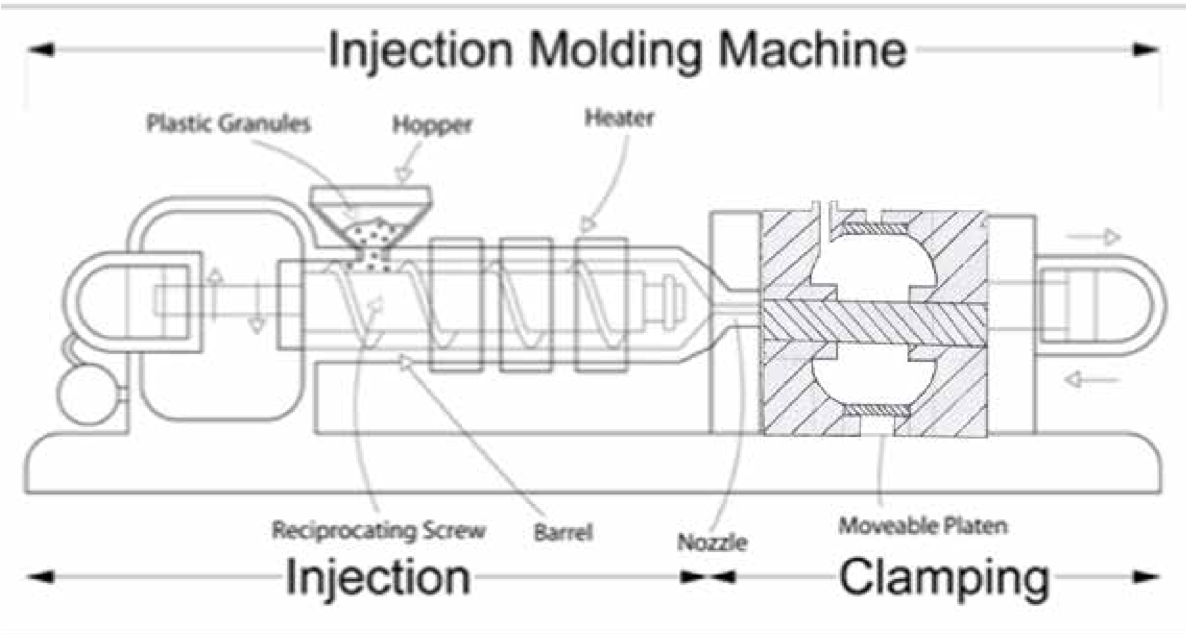


Figure. 74: Updated Mould Concept #2

This concept design uses an injection moulding machine to fill the mould. The air release allows the excess air to escape, as per the instructions of my outside technologist Kris Lawry.

This process can be used to create prototype designs using the mould I have already created. However it is primarily used to create final products. The plastic is injected into a metal mould. This shall be the next step for my stakeholder once they are happy with the design of the wheel.

Due to the viscosity of Polyethylene, I updated my concept designs and concluded that injection moulding was to be the way forward. I had a meeting with my stakeholder to discuss the matter. The resultant discussion led us to the conclusion that we did not have access to an injection moulding machine. This meant I was unable to trial and test the wheel designs I had created. However, we decided that despite this major constraint, I had created a usable slide glove puck. This meant I could test the slide glove puck with local long boarders to see if the puck and the material would withstand usage. I learnt a lot from this setback, equipment and materials are key factors in a technological project. When I was unable to access an injection moulding machine a good portion of my project

reached a dead end. The wheels I designed could not be created due to this extremely substantial constraint. I also learnt that at times constraints are sometimes so great that they prevent an idea from becoming more than theoretical.

Whilst my stakeholder was disheartened by this setback she, as a technologist, understands that when prototyping, things rarely go to plan. Our final meeting to discuss the fate of my wheel design ended with her assuring me that once we have access to an injection moulding machine, the wheel prototyping would continue.

3.7: Trialling and Testing Of The Prototype
Trialling and testing a prototype is essential to ensure it fits the needs of any given stakeholder. In terms of the prototype Slide Glove Puck I developed I needed to ensure that the prototype performed well in-situ, that the branding remained, and that it appealed to the target audience.

To do this, I contacted a local skateboarder, Caspian Harvey, to test the Prototype vigorously to ensure it is suitable for its location and use.

Figure. 75: Caspian Harvey Using The Prototype

Figure 75 shows screen-shots taken from a video I took of Caspian Harvey using the slide glove pucks. After his usage he is recorded saying “They slide like butter.”, which is exactly how a slide glove is supposed to perform. It is supposed to slide across the ground with minimal resistance. I filmed him performing multiple slides with the gloves. After this was completed the pucks were not damaged at all.

I then left the Gloves with Caspian to use them as much as he could for a week, then I re-evaluated the prototype.

Figure. 76: Prototype After One Week Of Heavy Use

After a week of usage Caspian was very pleased with the performance of the slide gloves. He commented that they worked just as well as his professional pair. This comment helps to show that

the Slide Glove Pucks are up to standard and are fit for purpose.

As for how the Polyethylene handled (which was a specifications to my brief): After a week of heavy usage the pucks only shows slight wear (Fig.76).

In regards to the branding, the logo on the puck is hardly worn. This lasted far better than the professional pucks that I own.

Figure. 77: Loaded Branding Before Use

Figure. 78: Loaded Branding After Use

The ‘Loaded’ branding on the pair of professional pucks I own was removed very quickly (Fig.77-78), almost straight away in-fact, as it was just printed onto the puck. This helped to prove my hypothesis that engraved design will last much longer.

The fact that the plastic is hardly worn leads me to believe that the the material would be suitable for the skateboard wheel. In the future, it would be possible to create the wheel using injection moulding into the mould I created. Once the design is finalised the mould would be reproduced in metal and mass produced.

Caspian, who trailed and tested my puck, also shared the puck among other boarders. They liked the aesthetics of the puck as well as its usability. “Wow that is awesome” and “Can I have one!” show that it appeals to the target audience.

My Stakeholder was very pleased with the result of my trialling and testing. The puck performed well in the intended environment, the material withstood usage and it appealed to the target audience.

4: Technological Modelling - Evaluation

Evaluating a technological journey is a very important step in the technological process. Evaluations help us to learn, what worked and what didn’t, how we can repeat the successes, minimise the mistakes, and whether or not the project is sustainable.

4.1: Brief Compliance

I developed my outcome according to the brief that was generated as a result of feedback/feedforward with my stakeholder, The Paper Rain Project.

Desired Outcome:

A fully functioning, fit for purpose and ascetically pleasing, set of skateboard wheels and slide glove pucks made from recycled plastics

I have not met the desired outcome in its entirety. I have created a working and usable Slide Glove

puck that has been tested and is fit for purpose. However, due to the lack of an injection moulding machine I was unable to complete the wheels. The wheels however, are very close to completion. I have complete a working mould that can be used in an injection moulding machine. This mould fits my stakeholder's specifications and can be used to create a prototype in the future.

The Slide Glove Puck is indeed made from recycled plastic and can be recycled over and over again. Its use has also proven that the plastic could withstand the wear that a wheel would go through as the puck goes through a similar usage.

My stakeholder is satisfied with the work I have undergone and agrees that despite the wheel not meeting the brief I have proved it can be done once I find the correct equipment. I shall complete this at a later date.

I have met the following specifications of the brief:

• *Time: The project must meet the deadline.*

I have met the deadline set to me by the school. This deadline was moved back due to sickness.

• *Input/Output: I must take into account the quality input/output to the project*

The quality of the Slide Glove Puck, the 3D printer and its production was at a high enough standard to ensure that it is fit for purpose.

• *Monetary: I must not go over the budget given to me by The Paper Rain Project*

I did not go over the budget of $1000. The total project cost was $863. This included the creation of the mould and the 3D printer.

• *Appeal: The product must appeal to the target audience. This is mainly young adults to mid-30s who are either students or in their first jobs.*

The design was chosen by my stakeholder. It was also trailed and tested by local skateboarders who were pleased with the product.

• *Stakeholder Specifications: I must follow Stakeholder specifications.*
These include:

- *A 52mm wheel. (Updated to 58mm)*
- *Subtle branding & a reiteration of the fact that the wheels are recycled.*
- *The Wheel with ratio of designs #4:#1.*
- *Subtle branding & a reiteration of the fact that the wheels are recycled.*
- *A slide glove puck made of blue milk bottle lid.*
- *The slide glove puck: design #8*

My design/3D model fits these specifications to the letter.

• *The outcome must comply to the New Zealand Copyright and Intellectual Property Acts.*

All work has been created and designed by me. Any advice given to me has been used with the technologists permission. This complies with the aforementioned Acts.

• *Environment: The product must be as close to 100% 'Green' as possible.*

The product is created from recycled plastic. The plastic components of the printer are constructed with plastic that can be recycled and in the future the 3D printer can print with recycled plastics. The steel frame is also recycled.

- *I must be at the forefront of sustainable & creative ingenuity; this means I need to research all methods involved in the creation of the skateboard wheels.*

The process I used to create the wheels is new and, as the 3D printer industry is growing steadily, it is very sustainable.

- *The wheels are to be made from recycled milk bottle lids (Polyethylene).*

The wheel is created from Recycled milk bottle lids collected from Outward Bound and the teachers at school.

Constraints I have managed:
- *Time: I must meet all deadlines I am given.*

Solution: I used effective time management to complete the project on time. I used my Gantt Chart, my Critical Review Point progress reports and constructed personalized check-lists to manage my time effectively.

- *Skill level: The concept designs and product can only be created if I have the skill level to complete them to the standard that is required.*

Solution: I did not plan anything too ambitious. I knew my own skill level and I planned my designs around it. I also contacted outside technologists to aid me with areas in which my knowledge is lacking.

- *Workload from other subjects: I am now aware of the extent of this project and a large amount of credits are tied into to it. However this project is of similar importance to my other classes and I have been neglecting them.*

Solution: I used effective time management to complete the project on time. I used my Gantt Chart, my Critical Review Point progress reports and constructed personalized check-lists to manage my time effectively and allow me to handle the workload from other subjects.

- *Sickness: This constraint has prevented me from meeting the initial deadline.*

Solution: I used the extension given to me to effectively finish my project.

Constraints I have not managed:

- *Equipment: I am unable to access the required Equipment.*

As I was unable to create the wheel due to this constraint I had to test the plastic I intend to use in other means to determine its usability for my stakeholder.

Evaluation:
I believe that my 3D printer, ready for calibration, and my slide glove puck are fit for purpose. I have met the majority of the stakeholder specifications and as a result of testing and feedback I am

satisfied that my final designs are suited to the target audience and fit for purpose. This brief compliance was signed off by my stakeholder (Refer to Figure 15).

4.2: Evaluation Of Resources Used

4.2a: Programs Used Evaluation

Program Used	How I Used It	How this Improved My Outcome
Google Sketch-up	I used this program to 3D model the wheels, slide gloves and moulds for my project. I also used it to edit the 3D files that were printed to create the 3D printer.	This program performed well for the majority of my 3D modelling needs. However, whilst engraving text into the wheel I came across a multitude of problems. This software does not work well with curved surfaces. However, there is a large community that develop plug-ins for the program. These helped me on many occasions. In the end I was satisfied with the programs performance but in the future I may invest in a program such as Solidworks, which does not have these issues, unfortunately other programs are quite expensive. This was the main reason I choose Sketch up in the first place.
Printrun	I used this program to drive the Printer. This included testing its axis and heating the extruder.	Printrun is a user-friendly program that makes operating a 3D printer a lot easier. It is simple to use and it has all of the features I required, such as a simple way to move each axis to test them individually. This proved very beneficial as it allowed me to trouble shoot effectively. Its ease of use was the main reason I chose it over the other programs I researched.
Slic3r	This program was used to turn the STL files into G-code for Printrun to drive. I used this for the 3D printer parts.	Slicer provided me with a very comprehensive set of tools that allowed me to change the settings of each file to print perfectly. Its only downside is that it has a very complex user interface and does not explain its settings. You have to understand 3D printing to use it. Fortunately I had Neil to advice me. I chose this program as is the industry standard.
Open Office	I used Open Office for all of my word processing.	Open Office is a useful program for word processing. However it handles images very poorly when compared to a word processing programs such as Pages. I chose this program as our teacher Ms Winter wanted a windows friendly program, which this is. However, we still needed to save them in a Microsoft Word file type, which changed the formatting. In the future I would either use Pages or invest in Word.

Program Used	**How I Used It**	**How this Improved My Outcome**
Safari	I used Safari for the majority of my research.	This program worked exactly how it should. It has a user friendly interface that I was familiar with. I would continue to use this program in the future.
Arudino	I used this program to edit the firmware that is uploaded to the 3D printer.	Initially Ardunio appeared to be very complicated and would not work. However this was an issue with the bootloader on my motherboard. Once I had solved this issue Arudino performed as it should and was easy to use. In the future I will continue to use this program to calibrate the 3D printer.

***4.2b:* Outside Technologists Who Influenced My Project Evaluation**

Resource	How They Influenced My Project	How this Improved My Outcome
Ms Winter	Ms Winter is the HOD Technology and Digital HOD. She has given me lots of advice and knowledge in the field of technological practise and planning. She has also supplied resource material to help my planning.	Her knowledge and expertise allowed me to complete my planning and prototyping to a much higher standard than I would have otherwise have managed.
The Paper Rain Project	As my main stakeholder they directed my project, research, concepts and the development of the final outcome. All key decisions were cleared with or made by them.	Their input into the project allowed my final outcome to fit the final brief to the highest possible standard.
Neil Stockbridge	Neil provided me with his knowledge and expertise in regards to the construction and running of a 3D printer. He also 3D printed the parts required to build my printer.	Neil was invaluable to my project. He provided me with essential knowledge regarding my 3D printer. He also printed the parts for my printer. Without these I could not construct the 3D printer for my stakeholder. Without the advice and aid from this outside technologist I could not have met the brief.
Kris Lawry	Kris Lawry is a product development engineer currently working on a new form of nuclear reactor. He advised me in the creation of a mould.	Whilst I was unable to test the mould, his advice allowed me to create a mould that I am sure will work. Without him the mould I created would not be up to standard or fit for purpose.

Resource	How They Influenced My Project	How this Improved My Outcome
Duy Dang	This man is the creator of the plans for Eventorbot, the 3D printer I built.	Without these plans I would be unable to build the 3D printer and, therefore, not be able to met the brief.
Caspian Harvey	Caspian, a local skateboarder, tested my slide glove puck.	Through his testing I was able to determine that my slide glove pucks were fit for purpose.
Mouli Greenlaw	My father aided me with the engineering knowledge required to build the 3D printer.	His advice and input allowed me to ensure the printer was fit for purpose. He has extensive knowledge in this type of work and he was extremely useful.
Online Forums	I used these whenever the above resources could not aid me.	The online community is filled with knowledgeable people. Their advice allowed me to fix many issues during my project that would have otherwise been the end of my project.

All of these outside technologists contributed to my technological project. Outside technologists are an amazing source of knowledge and expertise and are direct stakeholders as their knowledge has an influence, not only on how the project is developed, but also adds to my technological knowledge and practise.

4.2c: Evaluation Of Tools Used To Benefit My Project

Brainstorms:

As a class we brainstormed what is involved in the making/running of a business (Fig. 79). I needed to consider all of the resulting ideas when creating a prototype/product to ensure it is fit for purpose and can be effectively integrated into any business I am working for.

This method of generating ideas is used to work through ideas to find a solution to a problem or situation. It is a powerful way to generate, share and maximize new ideas. Brainstorming provides many advantages to the process of sorting through problems.

Figure. 79: Business Brainstorm

I found brainstorming especially useful when trying to decide between project ideas and expand on ideas. I used it on multiple different occasions as seeing my ideas on a page helps me to work through them.

Gantt Chart:

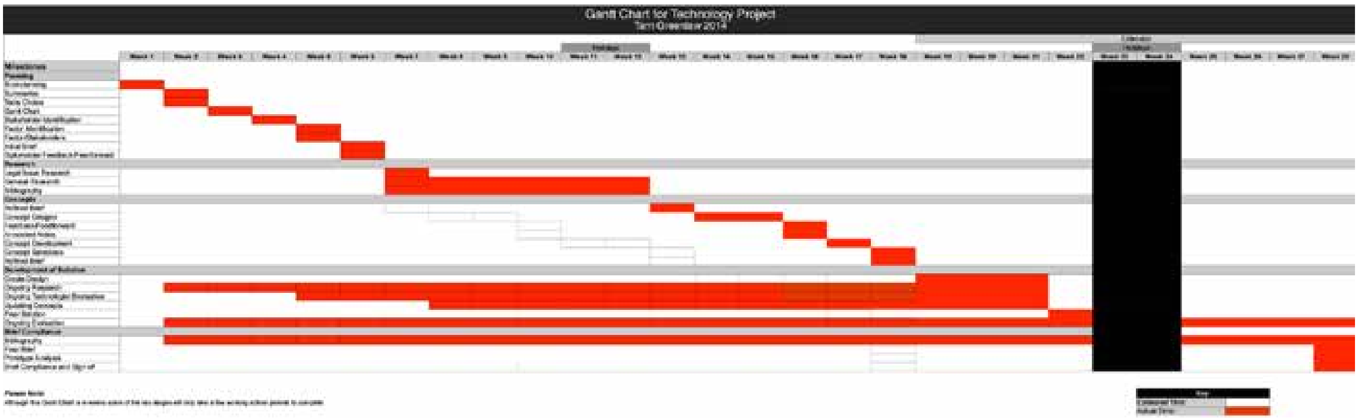


Figure. 80: Final Gantt Chart

I constructed a Gantt chart to keep track of important deadlines. This Gantt chart proved to be invaluable throughout my project as it allowed me to manage my time very effectively which was of paramount importance with constraints such as major sickness, family issues, after school work and the workload from other school subjects. I changed and updated the Gantt chart with my extension and kept track of time taken on each step of my project.

They're also helpful for managing the dependencies between tasks, for instance I needed to finish my initial research before I was able to continue onto the concept design stage. As you can see from Figure. 80 I spent far too long on the research stage and, as Concept designs were reliant on this, I could not continue onwards.

The Gantt chart was an extremely useful resource that allowed me to effectively manage my time and deadlines.

Critical Review Points:

Throughout my project I kept track of each constraint, progress, and changes through the use of a template I constructed (Fig. 81).

This system allowed me to manage each update as I was able to record constraints, solutions, resources, and my stakeholders feedback involved. I was able to show these reports to my stakeholder to demonstrate my process, it simplified my technological journey so that I could easily explain to outside technologist and people who were interested in my project. They were also a useful method of managing my time.

I found my critical review point system to be a very valuable asset to my project.

12/03/2014

Mile Stone: Research

Critical Review Point: In the process of the research I have found that that custom skateboard moulds are very expensive, ranging from $1000 – $10, 000 a piece.

Next Steps: My next steps are to research possible alternatives to this.

Constraints:
1. Work Load: The work load from other subjects is a constraint I must manage.
2. Time: I must complete my research in the given time.
3. Budget: I must ensure I keep to the budget provided to me by the Paper Rain Project.

Solutions:
1. Work Load: I must effectively manage my time.
2. Time: I must use effective time management to complete my research in the given time. This includes use of check lists and the Gantt Chart I created.
3. Budget: To ensure I stick to my budget I must research another possible way of creating moulds for the skateboard wheels I am to design.

Resource
- Word Processing
- Internet
- Books
- Community

Stakeholder Feedback:
My stakeholder agrees that if possible she would prefer to spend less on the prototype.

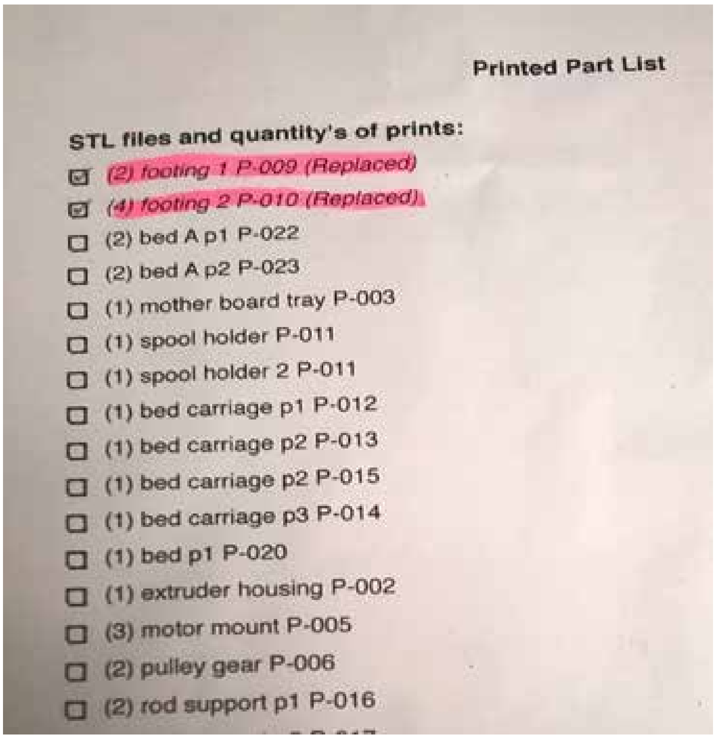
Figure. 81: Critical Review Point

Checklists:

The use of checklists allowed me to keep track of various aspects of my project, such as the arrival of parts (both printed and hardware) and my daily to-do lists.

They helped to manage my time as they prioritised jobs I needed to perform. I also used them to help remember tasks, as sometimes when my teacher suggested a small correction to my planning it could slip my mind. My daily checklist system fixed this issue.

The checklist system was also very useful when used to keep track of parts arriving. As I was receiving packages almost everyday with new parts for my printer build It was at times hard to determined what had yet to arrive. This system solved this issue.



Printed Part List

STL files and quantity's of prints:

- ☑ (2) footing 1 P-009 (Replaced)
- ☑ (4) footing 2 P-010 (Replaced)
- ☐ (2) bed A p1 P-022
- ☐ (2) bed A p2 P-023
- ☐ (1) mother board tray P-003
- ☐ (1) spool holder P-011
- ☐ (1) spool holder 2 P-011
- ☐ (1) bed carriage p1 P-012
- ☐ (1) bed carriage p2 P-013
- ☐ (1) bed carriage p2 P-015
- ☐ (1) bed carriage p3 P-014
- ☐ (1) bed p1 P-020
- ☐ (1) extruder housing P-002
- ☐ (3) motor mount P-005
- ☐ (2) pulley gear P-006
- ☐ (2) rod support p1 P-016

Figure. 82: Checklist

Budget Table:

My budget table, previously mentioned in Article 1.2, was an invaluable resource which I used to keep track of all of my spendings throughout the project. It ensured I stayed within my budget and was used to show my stakeholder exactly where and how much of their money was being spent on this prototyping journey.

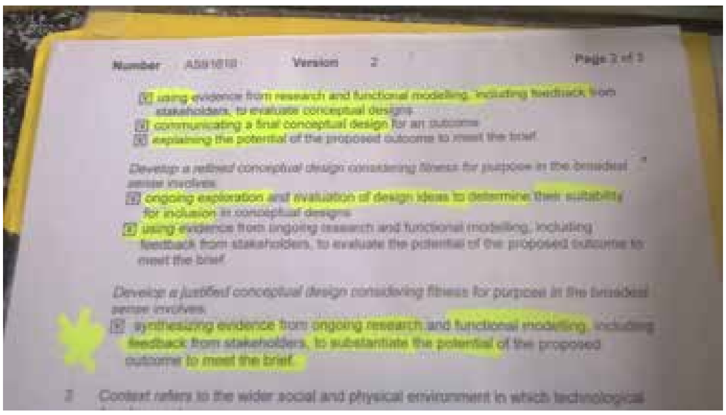
It also allowed me to notice themes and patterns that saved me money, for instance, the table showed me that I was spending a great deal on postage and this allowed me to minimise spending and benefit the local economy by purchasing as many parts as possible in Marlborough or New Zealand.

Standards and Assessment Schedules:

As my project was to be as assessed according to NZQA guidelines I had to tailor my planning and technological journey to suit their marking schedule.

To do this I used Standards, Assessment Schedules, and Exemplars to inform my work and to see what is needed to maximise my success.

Highlighting relevant information was an extremely useful technique as it brought important information to the forefront of my attention.



Number Version 2 Page 2 of 3

- ☒ using evidence from research and functional modelling, including feedback from stakeholders, to evaluate conceptual designs
- ☒ communicating a final conceptual design for an outcome
- ☒ explaining the potential of the proposed outcome to meet the brief.

Develop a refined conceptual design considering fitness for purpose in the broadest sense involves:

- ☒ ongoing exploration and evaluation of design ideas to determine their suitability for inclusion in conceptual designs
- ☒ using evidence from ongoing research and functional modelling, including feedback from stakeholders, to evaluate the potential of the proposed outcome to meet the brief.

Develop a justified conceptual design considering fitness for purpose in the broadest sense involves:

- ☒ synthesizing evidence from ongoing research and functional modelling, including feedback from stakeholders, to substantiate the potential of the proposed outcome to meet the brief.

2 Context refers to the wider social and physical environment in which technological

Figure. 83: Highlighted Achievement Standard

Reflection:
In the future I will use all of the aforementioned tools, processes and templates again as they all worked very effectively to maximise the success of my technological project.

4.3: Sustainability
Longevity and sustainability is an important part of a technological project.

Material Choice:
The plastic and development method that I used are both very sustainable. The plastic/material I used can be reused and recycled over and over again. This is very good for the environment.
As for the production method: 3D printing is just beginning to show its potential with plans to 3D print shelters on Mars and Doctors already 3D printing replacement bones and organs. It is a very sustainable method of production.

Backup:
I needed to ensure that I have a back up of all of my work. This will help protect my Intellectual Property as well as displaying good practice with Digital Information and Media. Thus, I have kept a constant incremental backup throughout the project using Time Machine. This is an application that is inbuilt into the Mac computer system. However, I need to think about off site back ups, so I have backed up on an external hard drive and Dropbox which is a web based application program. I did consider the Cloud but I needed to think about my own Intellectual Property and Copyright.

Using the information I received from, http://www.backup4all.com/kb/backup-types-115.html, I will ensure in the future that I will use the knowledge gained to safe proof any future digital outcomes that I create for future stakeholders.

Sustainability of My Designs:
My technological journey taught me how important Sustainability is for a business. A product must be at the forefront of sustainable & creative ingenuity and withstand usage to be worth the investment and cost of prototyping for a business. An example of this that became relevant to me was the engraved logos, I used this concept in my puck and wheel designs. Throughout usage the brand stayed visible, and branding is a very important factor to a business. This was a very sustainable process as it lasted far longer than its printed counterpart. This practise has been adopted by many businesses over the years, the most common example being engraved engine components that withstand extremely heavy usage. When you lift the bonnet it is still obvious which company created them.

Ongoing Maintenance:
Maintenance of machinery can be a very substantial on-going cost for a business. The Paper Rain Project are now in full ownership of the 3D Printer and this printer will require maintenance in the future. However, as the printer is an open source design there are multiple online forums which can help with any issues. Should my stakeholder be too busy or lack the required skills the design is simple enough that any person with knowledge in 3D printing or engineering can aid The Paper Rain Project. Maintenance and specialised knowledge also helps to keep a technologist in business.

I also took multiple steps to ensure the Printer would run with minimal maintenance issues such as: Creating the printer in a thick metal frame and, recording each step I took and issues/solution I had already faced in a journal. This means that should my stakeholder need to make adjustments or fix issues they have a guide to follow, ensuring the sustainability of the printer I provided them with.

Patents

A patent is a set of exclusive rights granted by a sovereign state to an inventor or assignee for a limited period of time in exchange for detailed public disclosure of an invention. A patent is a very important tool that enables inventors to prevent other people from making use of their ideas.
As I, on my stakeholders behalf, investigated new methods of prototyping and wheel designs, I recommended my stakeholder look into Patents. However, as they are quite costly she opted to wait to follow this path. Patents are an option for my stakeholder in the future.

4.4: Health And Safety Evaluation

During my project I encountered many situations where I had to consider Health and Safety.

• During the build of the 3D printer I took multiple steps towards ensuring my Health and Safety. Such as, wearing eye protection during drilling. I believe that to further my protection I would have completed the build in a workshop, rather that my bedroom. I did not have access to this. However, In the future I will take this into account.

• Once the 3D printer was completed I looked into health and safety and took a step recommended by work place health and safety websites, I added a warning sticker to the extruder. This was needed as it reaches 230ºc.

• During the mould pouring stage I wore the recommended rubber gloves and a breathing mask. This protected my skin and lungs from damage.

Whilst melting plastic I wore gloves and mask. I also used a fume cupboard and had a fire extinguisher close at hand. This was a necessary step as dealing with molten plastic can be very dangerous.

Conclusion:

As a student working on this project I had no insurance of my work place covering me. This meant I had to take every step I could to ensure my safety. I believe I have done this effectively.

4.5: Procedure Evaluation

Procedure:

3D Model -> 3D Printer -> Printed Mould -> Silicone Inverse Mould -> Resin Mould (Resin Copy Of Printed Mould) -> Prototype.

Conclusion:

I created this method of creating the prototype wheel to diminish the cost of the process. This I accomplished. I took the price of a prototype wheel down from $1000 - $10000 down to $863. The 3D printer I created was included in this final cost.

The process is a long one that was riddled with problems. However, this was my first attempt at something like this. I believe that each time I run through the procedure the errors would be minimalism and the process would be quicker. This is how prototyping works, with each failure I learnt how to produce a better product.

As a result I feel that this procedure was a success and I would use it to create prototypes again. A very useful feature of this prototyping method is that it is very customizable and allows for complete personalization as it starts from a very accurate 3D model.

4.6: Future Ideas For The Project

Wheel

• I plan to find an injection moulding machine to fill the moulds and create the prototype wheels. This will mean I can test it and properly prototype my wheel design.

Slide Glove Pucks

• Creating the slide glove pucks with an injection moulding machine will ensure a even result and will result in a much higher quality product.
• I will then attach these pucks to the gloves The Paper Rain Project are developing.
• I will also experiment with multiple colours. This could result in a rainbow coloured puck and pucks of different colours. This could also be used in the Wheel design.

3D Printer

• I plan on experimenting with existing recycled filament extruders to develop a version that can create filament straight from milk bottle lids. I believe I could create a injection moulder that works as both. I would simply need to turn the heat up and attach a mould to the end of it and it would work as an injection moulder. Turn it down and add a extruder end and it could create filament.
• I may also replace the steel frame with one of wood. Possibly bamboo. This will further the Paper Rain Project's goal of 100% green. I can also recycle the parts of the printer once they break or I upgrade them
• I have found plans for a duel extruder, an LCD screen and a heated bed. I shall include these into the 3D printer design.

Additional

• I have been asked to create a laser engraver for the Paper Rain Project during the summer. This works in similar fashion to a 3D printer as it is a 3 axis positioning system. It could be possible to make a duel machine that runs both. I shall research into this possibility further.

• The 3D printer itself is a very useful tool for my stakeholder. It is used to rapidly create the plastic copies of 3D models. This means my stakeholder can use it to produce any number of prototypes to expand her business. It is an extremely versatile tool that is only just beginning to show its potential.

Conclusion & Final Outcome:

Reflection:

In the beginning of this technological journey I had very limited knowledge of engineering, and the technological process of planning. When I first undertook this project I had no idea that I was going to create a functioning 3D printer. Looking back this was a huge accomplishment and it benefited my skill set with the growth of engineering skills that I can apply elsewhere.

Figure. 84: My Technological Project

During my learning journey I developed new knowledge and skills which enabled me to understand not only the technological process of planning but also a given understanding of business, how it works, and the manufacturing process of product design. Through working with my stakeholder and outside technologists I was able to glean an understanding of their technological practise and how it had benefited their respective

businesses. This new knowledge not only helped me to complete my project to a higher level than I previously could but it will also help me in the transference of my new skills and knowledge to benefit other learning in my future career path, for example, the use of the Gantt chart for time management purposes.

Although I faced many constraints throughout my project I learnt a multitude of new technological processes and techniques that will aid me in the future.

This project has been extremely beneficial to me. It has taught me some of the necessary skills I will required in the future and I have produced a technological outcome that both myself and my stakeholder are very satisfied with.

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Community

• Ms Winter, HOD Technology Faculty.

• Mouli Greenlaw provided me with knowledge in engineering and electronics.

• Neil Stockbridge provided me with knowledge and expertise concerning the construction of the 3D printer.

• Caspian Harvey tested and rode my 3D printed wheels.

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