Overall grade: A

Performance Standards for Stage 2 Scientific Studies

	Investigation, Analysis, and Evaluation	Knowledge and Application
A	Critically deconstructs a problem and designs a logical and coherent scientific investigation with detailed justification. Obtains, records, and represents data, using appropriate procedures, conventions and formats accurately and highly effectively. Systematically analyses and interprets data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and their effect on data. Critically and perceptively evaluates the effectiveness of collaboration and its impact on results/outcomes.	Demonstrates deep and broad knowledge and understanding of a range of science inquiry skills and scientific concepts. Applies science inquiry skills and scientific concepts highly effectively in new and familiar contexts. Critically explores and understands in depth the interaction between science and society. Communicates knowledge and understanding of science concepts coherently, with highly effective use of appropriate terms, conventions, and representations.
B	Logically deconstructs a problem and designs a well-considered and clear scientific investigation with reasonable justification. Obtains, records, and represents data, using appropriate procedures, conventions and formats mostly accurately and effectively. Logically analyses and interprets data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effect on data. Critically evaluates the effectiveness of collaboration and its impact on results/outcomes.	Demonstrates some depth and breadth of knowledge and understanding of a range of science inquiry skills and scientific concepts. Applies science inquiry skills and scientific concepts mostly effectively in new and familiar contexts. Logically explores and understands in some depth the interaction between science and society. Communicates knowledge and understanding of science concepts with mostly coherent and effective use of appropriate terms, conventions, and representations.
C	Deconstructs a problem and designs a considered and generally clear scientific investigation with some justification. Obtains, records, and represents data, using generally appropriate procedures, conventions and formats with some errors but generally accurately and effectively. Undertakes some analysis and interpretation of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates procedures and some of their effect on data. Evaluates the effectiveness of collaboration and its impact on results/outcomes.	Demonstrates knowledge and understanding of a general range of science inquiry skills and scientific concepts. Applies science inquiry skills and scientific concepts generally effectively in new or familiar contexts. Explores and understands aspects of the interaction between science and society. Communicates knowledge and understanding of science concepts with generally effective use of appropriate terms, conventions, and representations.
D	Prepares a basic deconstruction of a problem and an outline of a scientific investigation. Obtains, records, and represents data, using procedures, conventions, and formats inconsistently, with occasional accuracy and effectiveness. Describes data and undertakes some basic interpretation to formulate a basic conclusion. Attempts to evaluate procedures or suggest an effect on data. Attempts to evaluate the effectiveness of collaboration and its impact on results/outcomes.	Demonstrates some basic knowledge and partial understanding of science inquiry skills and scientific concepts. Applies some science inquiry skills and scientific concepts in familiar contexts. Partially explores and recognises aspects of the interaction between science and society. Communicates basic scientific information, using some appropriate terms, conventions, and/or representations.
E	Attempts a simple deconstruction of a problem and a procedure for a scientific investigation. Attempts to use some procedures and record and represent some data, with limited accuracy or effectiveness. Attempts to describe results and/or interpret data to formulate a basic conclusion. Acknowledges that procedures affect data. Acknowledges the effectiveness of collaboration and its impact on results/outcomes.	Demonstrates limited recognition and awareness of science inquiry skills and/or scientific concepts. Attempts to apply science inquiry skills and/or scientific concepts in familiar contexts. Attempts to explore and identify an aspect of the interaction between science and society. Attempts to communicate information about science.

In the engineering process, data will be gathered differently. There will also be different ways to represent thoughts and processes. It is important that students and teachers feel empowered to follow ideas and present these ideas in a variety of ways. This student effectively demonstrated their processes mainly using pictures and annotations. This is appropriate for this task.

Background and context summarised according to Subject Outline

Problem Need or Opportunity:

Problem: Name removed for anonymity

Person X is double hand amputee as the result of severe burns. Therefore the problem is he can't use a toothbrush or pick up small objects.

Partial image only, to prevent identification

His current prosthetic is too heavy to be supported by the stabilizing muscles that contribute to abduction/ adduction of the shoulder joint and is too expensive to manufacture and modify as it requires specialist knowledge and specialist parts.

Opportunity Aim:
To create a solution to replace the function of hands, inexpensively, light weight and that are adaptable.

Need:
To develop or modify an open source light weight prosthetic that can be modified with relatively low cost and accessible components.

The opportunity is to source, develop or modify and build a 3D Printed prosthetic hand.

In the USA, a single prosthetic can cost up to $90,000. Despite insurance, they may still pay 90% of the cost. In Australia, limbs are wholly funded by Medicare. Therefore, producing cheaper prosthetics could benefit people in both countries. With replacements and care, the lifetime costs for someone needing a prosthetic can be up to $1.4 million[1], so it is beneficial to produce a cheaper alternative.

Limitations:
Most commercial prosthetics are between $6000-$90,000 and are made of carbon fibre. This is going to make it difficult to create a durable prosthetic as we cannot source carbon fibre.

Criteria for success:

1. Be able to hold a toothbrush while brushing teeth for 30 seconds.
2. To print in under 24 hours.

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[1] "Cost of a Prosthetic Limb". *Cost Helper Health*. Retrieved 13 April 2015.

Research summary:
The following websites were used to conduct research into why the current prosthetic was incapable of completing certain daily tasks (e.g. brushing teeth) and appropriate materials to use with a 3D printer.

3D universe[2]	Thingy verse[3]	YouTube videos[4]
Enable.org[5]	Limbitless[6]	

Specialists at a 3D printing business were consulted with weekly for advice on solving problems and making improvements as well as the engineering and tech teacher.

Proposal:
The design is an elbow driven device that uses an elbow that bends to force the fingers closed on the hand.

The first prototype will need further iterations, but the aim is to develop a functioning prototype from which the next can be fully customized. This device was created for those with a functional elbow and considerable amount of forearm but no wrist or not enough wrist/palm to power a wrist driven design.

Plan – proposed solution and specific requirements:
To build and iterate the open source file allows a unique combination of components to meet the design brief of the client's needs. Each design decision, challenges, testing and iterations will be journaled under the following:

Filament type	Printing Density	File type
Colour	Supports	Printing size
3D Printer equipment	Customizer software	Measurements of the client

IAE3 - Analysis of materials and design, with justifications for decision making are provided in the following sections.

Design the model or prototype:

Filament type: PLA Pro. Some of the filament types that were considered were Carbon Fibre because it is strong, light weight but it was too expensive. The reason as to why I choose the filament type PLA is because it melts easier to mould into a prosthetic hand. (Figure 15)

Printing Density: in testing different densities it was found that 40 was optimum. The reason I chose 40 was because if its less the 40 it will lose strength. However, if you use anymore than 40 then the cost will be more, and it will weigh more. Weight is an important consideration given the clients injuries.

File type:
The file type used was called a STL File. Before I put the file into the cutter called Z suite which meant it changed the file to a z code, made be able to start the 3D print. The reason this software was used because our Zortrax printers are compatible.

Colour: The colour that was chosen is PLA Black as this was readily available and suitable for a prototype. The final product will use *Person X's* colour preference.

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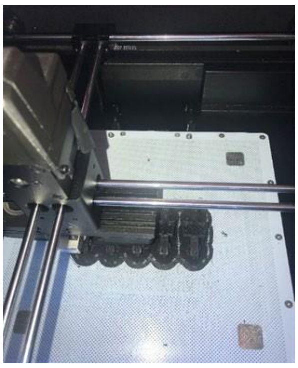
[2] https://shop3duniverse.com/collections/3d-printable-kits/products/phoenix-hand-by-e-nable-assembly- materials-kit
[3] https://www.thingiverse.com
[4] https://youtu.be/369PX9LzUPs
[5] http://enablingthefuture.org/
[6] https://limbitless-solutions.org/

IAE3 - links with data and evidence to analyse results and form conclusions and the next steps.



Supports: Research showed that prints often need supports when there are large spaces or tunnels. Supports are removeable sections that are needed during the print to help mould the print into shape and protect any areas from getting damaged. The challenges of having these supports was the level of difficulty to get them out, when the supports went in it went into tiny little holes which meant I had to use a drill to get them out. The was challenging and started to cause damage to the print. I decided to use no supports in the final print which could have ben good or bad, as the print could collapse. Another option (which can be pursued in further tests) is to use partial supports on the big spaces and no supports on the little spaces.

IAE4 - student identified challenges and then problem solved solutions to this. Evidence of procedure evaluation and creative thinking.

Using supports is only needed for the print to succeed. Dissolvable supports were a design option that were discovered after the prototype. Dissolvable supports use a water-soluble print which when immersed in water dissolve, however the print process time is increased by 30-50%.

Because putting the print in hot water to dissolve the filament, the filament also takes some time to come out of the print. On the next product I will use this for the whole print. The longer print time is more than compensated for by the saving of time trying to clean out supports and the protection of the product. The final product utilised the dissolvable supports to prevent damage to the prosthesis components.

Printing Time

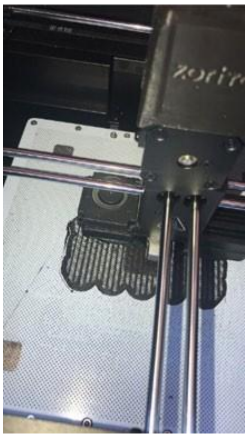
	Prototype	Final Product
Time to print whole prosthetic (hours and minutes)	18 hours	26.25 hours
Comment	Print time was under 24 hours, although there were significant issues with build integrity.	Integrity was appropriate for required task, but print time was over success criteria.

Length of time the tooth brush could be held for

	Prototype	Final Product
Time to hold tooth brush (minutes)	>5	>5
Comment	Print successfully held toothbrush for well over 5 minutes. Stopped recording at 5 minutes as recommended time to brush teeth is 2 minutes. Taking into account limited movement and range this is why the time was recorded until 5 minutes.	

IAE2 and 3 - Print times and analysis of product recorded in context of success criteria.

Printing size: Decisions were made about print time.

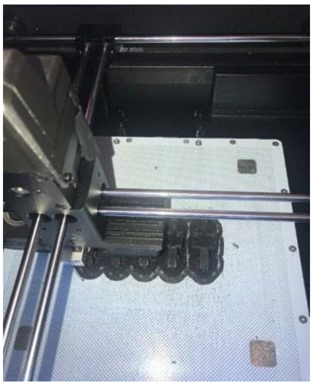


Economies of Scale tries to increase the number of print items on one print plate. However, if an error occurs there is impact on the print job. I chose not to overload the components on the plate to reduce risk of loss due to print failure, but gives a reasonable print time. The components that were too big were out sourced to a company locally, called '3D Solutions'. This was done because the plate on the school printer is only 25cm the forearm was 27cm.

3D Printer equipment: the printers used are the Zortrax the benefits and features accessible through the school there are 3 printers enables multiple prints longer prints I had to work around other users eg weekends. The limitations are the bed size, this was a limitation because the bed size which is the base plate was too small for the forearm.

KA4 - use of terminology and its understanding communicated effectively as part of engineering design

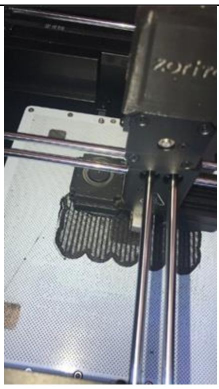
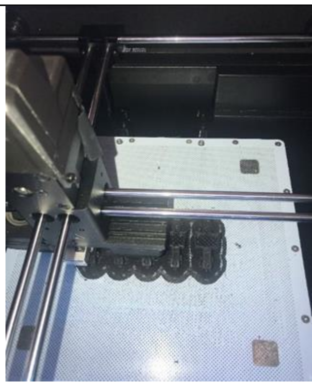
IAE4 - evidence of ongoing evaluation of the process and decision making.



Customizer software: the Slicing Software was called Z Suite. The role of using Z Suite was to convert the STL file into a Z Code file which means it could communicate with the printer. The slicer slices the print in sections, so the printer duplicates these layers in the print. The benefits of using this would mean I would get a better-quality print. The challenges I had with the slicer was sometimes it did not open and would not respond set back with printing because I always had to fix that issue.

Measurements of the Client: To build an arm proportional sizes are needed by the printer. As there is a relationship between foot length and forearm size, the length of his foot was used to determine probable forearm length. Also, height and average hand sizes relationships were used as *Person X* has neither which can be used to compare.

KA1 - throughout. Evidence of scientific inquiry skills and science concepts.

 Figure 1: Finger tips completed on the 3D Printer	 Figure 2: Reverse view of Figure 1
 Figure 3: Fingers starting on the Zortrax Printer.	 Figure 4: Shows the layers being done.
 Figure 5: Broken fingertip – wrong density and layer, weakness.	 Figure 6: Side View of the Fingers

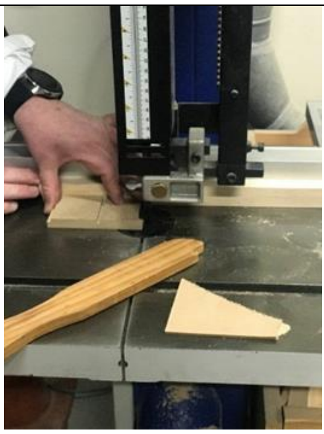


Figure 7: Cutting plastic off so special bits can go into the final.

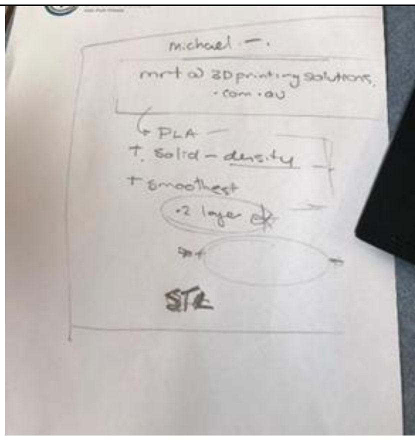


Figure 8: Shows printing settings and company that were used.

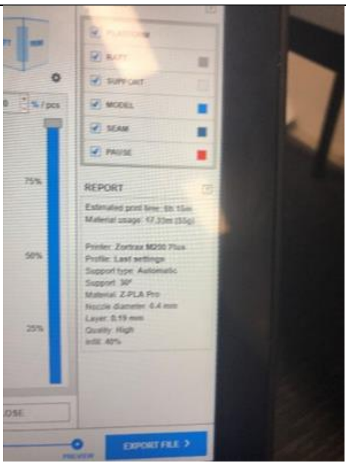
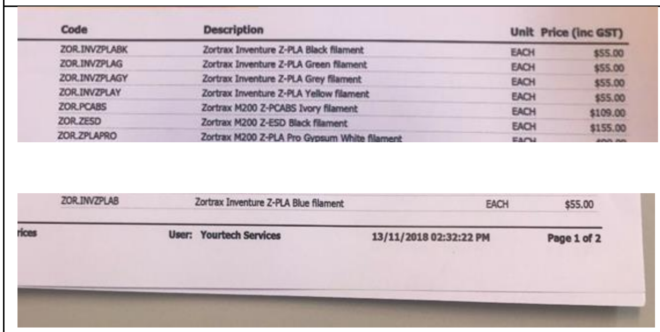


Figure 9: The settings used when converting the files into Z code.

Figure 10: Softening cuff with hot water to mould it. Possible due to PLA filament choice.



Code	Description	Unit	Price (inc GST)
ZOR.INVZPLABK	Zortrax Inventure Z-PLA Black filament	EACH	$55.00
ZOR.INVZPLAG	Zortrax Inventure Z-PLA Green filament	EACH	$55.00
ZOR.INVZPLAGY	Zortrax Inventure Z-PLA Grey filament	EACH	$55.00
ZOR.INVZPLAY	Zortrax Inventure Z-PLA Yellow filament	EACH	$55.00
ZOR.PCABS	Zortrax M200 Z-PCABS Ivory filament	EACH	$109.00
ZOR.ZESD	Zortrax M200 Z-ESD Black filament	EACH	$155.00
ZOR.ZPLAPRO	Zortrax M200 Z-PLA Pro Gypsum White filament	EACH	[illegible]
ZOR.INVZPLAB	Zortrax Inventure Z-PLA Blue filament	EACH	$55.00

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Figure 11: Filament prices

Figure 12: The Phalanx which joins to the fingers

Figure 13: This is the prototype being complete.

Figure 14: Rubber Bands act as joints for fingers

IAE2 - over past 3 pages, detailed observations recorded including steps taken, materials used, programming and print settings. Student also provided costing of project. In an engineering project this is sufficient evidence to demonstrate practical application and progress. The student also detailed the prototype and then at the end of this document, the final project all in journal picture form.

Figure 15: Screws for changing the tension.

Figure 16: Finger grips for the fingers

Figure 17: Velcro strap to hold it to *Person X's* stump

Figure 18: String used for the tendons

In summary, the design did not meet one of the success criteria (24hr printing) because with short print time the manual cleaning and polishing took too long to make it commercially viable. The man hours to do this would have been cost prohibitive. In future prints further refining of the STL file will enable more efficient print times.

The other criteria, to hold the tooth brush for 30 seconds, was achieved in both prints.

IAE4 - Critically evaluates aspects of the product to ensure a comfortable fit that is fit for purpose, which also includes feedback from the user.

Reflection

During assembly, creativity and inventiveness enabled overcoming of challenges.

For example, the plastics needed to be soften to fit to shape. This was achieved by using a hair dryer to customise the shape. As everyone has different length fingers. This meant that the tension adjustors needed to be custom length as well. The tendon attachment knots (specific to personal length) required a precising gluing technique to fix the knot due to the size of the area that was available as well as to reduce friction or imposing on the stump space.

In the creation processes pieces that were created for the "testing phase" ended up being recycled in the finished product to reduce waste. For example a test knuckle was able to be used to replace a finger piece in the final product.

The prototype outcome exceeded expectations in grip, and whilst it wouldn't be suitable for heavy weights, it would more than cope with remotes, toothbrushes, bowls, keys etc. The grip thimbles installed improved the friction on the fingertips resulting in greater capacity than was originally intended.

A meeting with person x resulted in feedback. This enabled further customisation of finger control, tension and

KA4 - student communicated with various parties to achieve end product. Communication was coherent throughout. Effective use of scientific terms and conventions.

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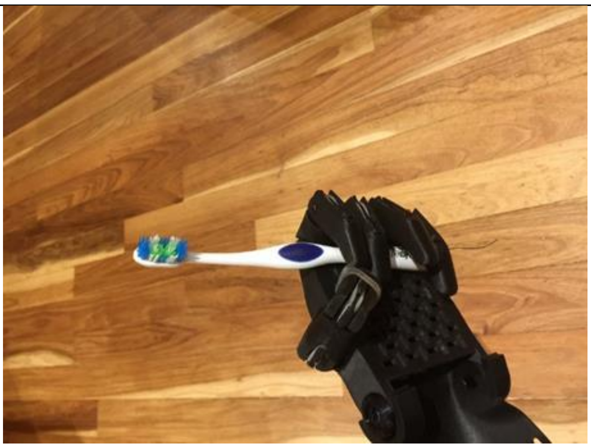
adjustments from which a new arm will be printed in the colour of his choice. A successful outcome is the ability to replacement modified component parts and do reprints inexpensively creating the opportunity for a continuous progressive design process.

IAE4 - Critically evaluates aspects of the product to ensure a comfortable fit that is fit for purpose, which also includes feedback from the user.

Final Prototype



Testing with toothbrush