CUSTOMIZED FINISHING TECHNIQUES ON ENTRY LEVEL FDM 3D PRINTED ARTEFACTS IN VISUAL ARTS:

An explanatory sequential study.

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DECLARATION OF INDEPENDENT WORK

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I, SAREL PRETORIUS HAVENGA, identity number and student number , do hereby declare that this research project submitted to the Central University of Technology, Free State for the Degree MAGISTER TECHNOLOGIAE: DESIGN, is my own independent work; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State; and has not been submitted before to any institution by myself or any other person in fulfilment (or partial fulfilment) of the requirements for the attainment of any qualification.

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Summary

The aim of this study is to investigate ways to improve the quality of entry-level fused deposition modelling (ELFDM) produced artefacts, to make the technology more accessible to a wider range of prosumer and address the scale limitations of production components.

The development of entry-level 3D printed (EL3DP) technology enhances art and design by providing new techniques previously impossible; however limitations such as poor surface finish quality and size limitations are persistently observed. These limitations steer artists and designers away from utilizing this technology due to poor aesthetic value outputs. It was necessary to construct this study from within an explanatory sequential mixed method paradigm as both quantitative and qualitative data were needed to sketch a broad overview and analyse abstract concepts like aesthetic value.

Due to the lack of recorded academic information an experimental pilot study was first conducted to identify potential techniques, followed by quantitative (tensile tests and surface profile measurements) and qualitative (in depth interviews and online surveys) phases and lastly all the data was interpreted to cohesively substantiate the hypothesis.

The results show that the pre-experimental pilot study identified potential techniques that were investigated in the phases that followed. Clear evidence is shown to support the progression of ELFDM technique development by applying post-production finishing techniques (PPFTs). It also indicates that the aesthetic value of an artefact can be enhanced by applying surface finishing and assembly techniques.

This study enables a larger range of entry-level prosumer to utilize cheaper alternatives to Additive Manufacturing (AM) technologies which will lessen the gap between high-end and entry-level. Furthermore by affecting the strength and surface texture of ELFDM 3D prints it has a direct influence on the aesthetic value and functionality of EL3DP artefacts.

Glossary of terms

Keywords: Acetone, Acrylonitrile Butadiene Styrene, Artefacts, Fused Deposition Modelling, Post-production, Post-processing, Surface finish, Tensile strength, Post-production finishing techniques.

3D printing and Additive Manufacturing:

3D printing, a popular term for what is now known as **additive manufacturing** (**AM**), refers to various processes used to synthesize a three-dimensional object Available at https://en.wikipedia.org/wiki/3D_printing Accessed July 2016

Fused Deposition Modelling (FDM): is an additive manufacturing technology commonly used for modelling, prototyping, and production applications (Fernandez-Vicenti 2015)

Fused Filament Fabrication (FFF): FFF is a relatively new method of rapid prototyping (also known as FDM) which works by laying down consecutive layers of material at high temperatures, allowing the adjacent layers to cool and bond together before the next layer is deposited. Available at http://www.sd3d.com/fff-vs-sla-vs-sls/ Accessed on the 07/12/2016

Customization: to modify or build according to individual or personal specifications or preference. Available at http://www.dictionary.com/browse/customization Accessed on the 07/12/2016

Surface Finishing: The surface roughness of a component after final treatment, measured by a surface profile instrument (Davis 2004).

Assembly Techniques: Gluing or cementing of components or end items comprising of a number of parts or subassemblies put together to perform a specific function. Available at and adapted from: http://www.businessdictionary.com/definition/assembly.html Accessed on the 07/12/2016

Aesthetic value output: Aesthetic value is the value that an object, event or state of affairs (most paradigmatically an art work or the natural environment) possesses in virtue of its capacity to elicit pleasure (positive value) or displeasure (negative value) when appreciated or experienced aesthetically. Available at www.nottingham.ac.uk/humanities/ aesthetics/... /Aesthetic_value%20(1).doc Accessed on the 07/12/2016

Meaning-making: designates the process by which people interpret situations, events, objects, or discourses, in the light of their previous knowledge and experience. Available at http://link.springer.com/referenceworkentry/10.1007%2F978-1-4419-1428-6_1851#page-1 Accessed on the 07/12/2016

Vapor chamber: A vapor chamber is a high-end thermal management device that can rapidly spread heat from a small source to a large platform of area. It has a similar construction and mechanism as a heat pipe except that a heat pipe typically refers to a tube that transfers heat from one single point to another while a vapor chamber refers to a plate that spreads heat from one point to a two-dimensional area. Available at https://radianheatsinks.com/heatsink/vapor-chambers.html Accessed on the 07/12/2016

Heat sink: is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature at optimal levels. Available at https://en.wikipedia.org/wiki/Heat_sink Accessed on the 07/12/2016

Makerspaces: sometimes also referred to as hackerspaces, hackspaces, and fablabs are creative, DIY spaces where people can gather to create, invent, and learn. In libraries they often have 3D printers, software, electronics, craft and hardware supplies and tools. Available at http://oedb.org/ilibrarian/a-librarians-guide-to-makerspaces/ Accessed on the 07/12/2016

Consumer: An individual who buys products or services for personal use and not for manufacture or resale. A consumer is someone who can make the decision whether or not to purchase an item at the store, and someone who can be influenced by marketing and advertisements. Any time someone goes to a store and purchases a toy, shirt, beverage, or anything else, they are making that decision as a consumer. Available at http://www.investorwords.com/1055/consumer.html#ixzz4S9iZgbOa Accessed on the 07/12/2016

Prosumer: is a person who consumes and produces media. It is derived from ‘prosumption’, a dot-com era business term meaning ‘production by consumers’. Available at https://en.wikipedia.org/wiki/Prosumer Accessed on the 07/12/2016

Platform/ build plate: The build or deposition area where the 3D printed object is extruded on. May consist of Perspex glass, or various heat conductive perforated metal base plates.

3D maker: The maker movement is a cultural trend that places value on an individual's ability to be a creator of things as well as a consumer of things. In this culture, individuals who create things are called "makers. Available at http://searchmanufacturingerp.techtarget.com/definition/Maker-movement Accessed on the 07/12/2016

Extrusion: the act of extruding or the state of being extruded. Available at http://www.dictionary.com/browse/extrusion Accessed on the 07/12/2016

Resolution: Since components are printed in 3 dimensions, two points will have to be considered: the minimum feature size of the XY plane and the Z-axis resolution (layer height). The Z-axis resolution is easily determined and therefore widely reported even though it is less related to print quality. The more important XY resolution (minimum feature size) is measured via microscopic imaging and is therefore not always found in spec sheets. Available at https://formlabs.com/blog/resolution-meaning-3d-printing/ Accessed on the 07/12/2016

Warping: To become bent or twisted out of shape due to heat induction or removal in thermoplastics. Available at http://www.thefreedictionary.com/warping Accessed on the 07/12/2016

Step-layering: Visible deposition steps left by the nozzle on the surface profile of 3D printed objects. Also refer to layers left after support and raft has been removed from the 3D printed part.

Entry-level fused deposition modelling: FDM printers use a thermoplastic filament, which is heated to its melting point and then extruded, layer by layer, to create a three dimensional object. Available at http://www.livescience.com/39810-fused-deposition-modeling.html Accessed on the 07/12/2016.

High-end production: The definition of high-end is something considered an expensive or extreme quality item. Available at http://www.yourdictionary.com/high-end Accessed on the 07/12/2016

Stereolithography: is a file format native to the stereolithography CAD software created by 3D Systems. STL has several after-the-fact backronyms such as "Standard Triangle Language" and "Standard Tessellation Language". This file format is supported by many other software packages; it is widely used for rapid prototyping, 3D printing and computer-aided manufacturing. Available at https://en.wikipedia.org/wiki/STL_(file_format) Accessed on the 08/12/2016

List of abbreviations:

HVF: Hot vapour fuming

CVF: Cold vapour fuming

ELFDM: Entry-level Fused deposition modelling

HE-FDM: High-end Fused deposition modelling

STL: Stereolithography

LS: Laser Sintering (ASTM F42 STANDARD: http://web.mit.edu/2.810/www/files/readings/AdditiveManufacturingTerminology.pdf)

GARPA: the Global Alliance of Rapid Prototyping Associations

RAPDASA: The Rapid Product Development Association of South Africa

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Chapter 1 Introduction

1.1 Background to the study

To form a cohesive understanding around the study of customized post-production finishing techniques (PPFTs) for entry-level fused deposition modelled (ELFDM) 3D printing, an overview of what FDM[4] is, should first be considered as well as the limitations that exist around it. Thereafter the context of fused deposition modelling through its trending developments as a contemporary medium for possible inclusion in the art and design world should be reflected on.

The author crossed over from the art to the technology world in 2012, generating an interest towards the development of ELFDM 3D printing. This raises the question whether the development of such an entry-level technology could cross the divide that exists between high-end and entry-level manufacturing processes. Could these technique developments eventually make entry-level produced 3D printing a feasible tool or medium for different industries alike?

To investigate such a notion the general opinion of ELFDM in the additive manufacturing sector should first be well-thought-through. FDM is defined as a common additive manufacturing form (Crump 1989). It is described as a medium used to build or grow artefacts by depositing a small bead of molten plastic through an extrusion head onto a build platform/buildplate.

Unfortunately, there is a stigma attached to so called “entry-level” produced FDM artefacts (Bual and Kumar 2014, Percoco, Lavecchia & Galantucci 2012), claiming that artefacts grown on ELFDM continues to suffer an inferior quality surface finish when compared to high-end FDM (HE-FDM) and other forms of additive manufacturing

[4] FDM is the process where a polymer filament is extruded through a heated nozzle head and deposits layer upon layer on a printing tray flatbed (Lady3D 2015). The process is started when a Computer Assisted Design file (Rouse, 2011), in Stereolithography (STL) format is sent to the printer software and converted into G-code (Benvin 2014 [7]), to be transferred to the FDM printer. The FDM printer then uses the G-code to print the specific Computer Assisted Design (CAD) model/component. The thermoplastic acrylonitrile-butadiene-styrene ABS (Lady3D 2015) used is heated beyond its Glass Transition Temperature during extrusion and cools down into a physically grown object or component.

(AM) (Bual and Kumar 2014). Another industry leader Mr Terry Wohlers from "Wohlers Associates" identifies ELFDM as low-end, inexpensive desktop printers with occasional questionable quality extrusion (Wohlers 2015).

This is a fast developing industry that was sparked out of the concept of Rapid prototyping. That is an almost 3rd industrial revolution of instant gratification. As this industry continues to develop it should be pointed out that the demand for improvements is inevitable. Therefore the demand to improve the surface quality of such artefacts would be imperative. This notion is supported by researchers (Brooks, Lupeanu & Piorkowski 2013).

Many improvements have been made to the hardware and software of ELFDM but very limited to no documented effort has been made academically to develop techniques that could improve this technology, specifically towards post-production finishing techniques. In recent years 3D makers and academia have attempted to explore post-production finishing but none of them attempted to address the quality of production from an aesthetic visual ideology within the artistic sphere (Hansen & Howard 2013, Brooks, Slater, Sofos & Whiteside 2015, Percoco, Lavecchia, & Galantucci 2012 & Galantucci, Lavecchia & Percoco 2010). Often their focus would be strictly directed at the tensile strength and functionality of 3D printed "objects" and they end up neglecting the aesthetic appeal and surface finishing from an artistic perspective. However indirectly some of these researchers like Brooks, without obvious direct intent, have addressed the matter when they identify that poor extrusion resolution (step-layering) hinders the visual appearance of the artefacts (Brooks et Al. 2013). This is corroborated by Campbell calling these drawbacks a common result in AM technologies where the surface roughness and heterogeneous mesostructure is more pronounced in FDM parts (Campbell, Martorelli & Lee 2002).

To address these shortfalls it was decided to follow a path of exploration that led to post-production finishing. That in essence, meant applying post-proccessing to artefacts after they have been designed in CAD format and produced on a 3D printer. Since the commencement of this study the researcher observed that academia and 3D makers alike have begun to include post-production methods as a viable option to improve artefact surface finishing as well as incorporating inproved assemblied components but with very limited exposure on ELFDM. Therefore to create a better understanding of the techniques employed to improve ELFDM printed artefacts, a short breakdown should first be considered to list the different techniques utilized.

Various methods of surface finishing and assembly techniques have been identified by authors like Galantucci for different industrial applications that were found promising for this study. Mainly there are four methods identified stemming from two production phases (Galantucci, Lavecchia & Percoco 2009) Three of the four methods are used in pre-production. They are "…the optimization of the build orientation, slicing strategies (layer thickness) settings and lastly fabrication parameters optimization". The fourth method includes post-treatment techniques which fall under the post-production phase and is the focus area for this research.

To cross over into the artistic sphere it is important to explain these finishing techniques and their place in visual art and design. It was necessary to jump between the traditional additive manufacturing intent of fused deposition modelling and a parallel in the art world. Even though it might be confusing at first the reader has to bear in mind that the research is produced from within an explanatory sequential mixed method research paradigm. Therefore seeing the concepts of FDM and finishing techniques from both perspectives in industry is pivotal. The one cannot exist without the other and that forms the basis of the argument. Although these concepts exist in unison there is a reluctance in utilizing these techniques especially in the art and design sectors because of stigmas surrounding the quality of ELFDM produced artefacts.

Visual art and design in its' contemporary form has evolved through advancing technologies. These technologies bring with them new techniques previously impossible for artists and designers. They include specialized finishing techniques for high-end production like Laser Sintering (LS) that emphasize artistic elements. These are the same techniques as identified in the additive manufacturing industries. "3D printing allows artists to manufacture forms and shapes that cannot be fabricated in any other way" (Franky 2010). However the use of these technologies stays limited to the high end spectrum of 3D printing, which is very costly and limited to a marginalized group of industry experts that leans more towards design in the Additive Manufacturing world than to visual art.

There are however platforms that wish to address the eradication of this marginalization. Innovation hubs such as the I2P (Wohlers 2012) laboratories have been created to start crossing the proverbial divide from the design/technology world into the visual art sector as discussed in previous publications (Havenga, de Beer & van Tonder 2014 & Havenga, de Beer & van Tonder 2015).

As the context of this study is written from within a South African setting, it makes sense to briefly explain 3D printing usage, Additive Manufacturing (AM) and its history. South African additive manufacturing started in 1994 (Campbell 2011). Between then and 2004 exponential growth took place where an increase of Rapid prototyping machines was seen in South Africa. One example of this were 3D printers. The Rapid Product Development Association of South Africa (RAPDASA) helped raise awareness to create links with GARPA (the Global Alliance of Rapid Prototyping Associations).

Potential problems like limitations on a variety of machines and materials as well as prolonged fabrication times, are identified (Campbell and de Beer, 2005).This falls in line with what can be observed earlier with similar limitations identified by Brooks and industry leaders like Wohlers and Crump.

A road-map was suggested in the paper “Rapid Prototyping in South Africa: Past, Present and Future” (Campbell and de Beer, 2005) which inevitably helped with the implementation of entry-level 3D printing at higher education institutions like the Vaal University of Technology through the form of the Idea 2 Product (I2P) labs.

These I2P labs encourage design and development across the spectrum of art and design.[5] It is through one of these I2P laboratories that the research was conducted.

[5] Inter-ARTES thematic network – from October 2004: Arts and science are both about perceiving the world and trying to understand it. Both include thought, intuition, imagination and research but find separate ways to translate, to visualise, to transform and to provide new meaning. The history of arts and science and technology is strongly interconnected.

Although the technology is readily available to artists and designers alike, some reluctance can still be seen in the art community when looking at the number of South African artists employing the technology at present (Agents of the 3D revolution, "Jansen van Vuuren" 2014). There is a handful of 3D printing artist specialists from around the world. As Maxey explains in this regard: "This motivates further investigation into 3D printing enabling more authentic exploration of objects that may not otherwise be readily available" (Maxey 2013). These I2P facilities allow support for visual arts by providing a platform to develop new techniques for artefact creation which influences the aesthetic value by using entry-level Fused Deposition Modelling (FDM) printers. As FDM entry-level 3D printers are becoming more popular as a cheaper alternative, visual art departments should be looking toward more cost-effective ways to create and provide accessibility of better designs as well as recognizing a niche market for customization of 3D printed artefacts. The same need can also be recognized in additive manufacturing and design institutions (Jones, Haufe, Sells, Iravani, Olliver, Palmer & Bowyer 2011).

This study does not focus further in depth on the I2P laboratories, the context from within which these artefacts were created had to be addressed to set some background. It clearly indicates the use and potential of artefact production from an entry-level perspective but with limitations that bring problematic areas to the front.

These developing technologies in artefact production lead to a need to examine a range of surface finishing and assembly techniques in order to improve the surface quality and alter the visual appearance of ELFDM printed artefacts. The understanding of what contemporary and aesthetic pleasing art is, influences the use and development of post-production techniques on 3D printed artefacts. These techniques help the art practitioner to question the nature and function of contemporary art and how new forms of art are produced and finished in post-production. "Art is a broad and dynamic field encompassing a wide range of approaches, technologies, contexts, theories, traditions and social functions …opening up new ways of understanding and producing meaning and knowledge" (Paradox 2015).

This study will present a range of tests conducted as individual surface experiments by applying various techniques that aim to improve the visual appearance, yet maintain the structural quality of the FDM printed ABS artefacts. Post-production finishing techniques are then applied to reduce the visible traces of step-layering, sometimes called stair stepping (Benvin 2014 & Benchoff 2013). Furthermore it also enhances the application of post-production surface bonding of multiple parts to create larger artefacts (Thellin. 2010).

All the components and artefacts that were tested were printed on UP MINI 3D printers. The UP Mini build size of 120mm x 120mm x 120mm, creates a limitation on this specific entry-level FDM printer. With this in mind, the areas that will be addressed are the investigation of Surface Finishing and Assembly Techniques to achieve improved entry-level 3D printed components.

This study will therefore argue that the strength and surface texture smoothness of entry level 3D printed artefacts have a direct correlation to the aesthetic value output and supply increased functionality of artefacts in visual arts; which when applied could narrow the gap between the entry-level and high-end production industries.

1.2 Problem Statement

Entry-level 3D printing technological expansion enhances visual art and design by making new techniques that did not exist previously possible, however there are limitations. They are identified as poor surface finish quality (step-layering) and the reduced strength of assembled parts (size limitations). These shortcomings steer artists and designers away from utilizing the technology as it inevitably leads to poor aesthetic value output. This is therefore identifying a clear gap between high-end and entry level users.

ELFDM 3D printing is a very cheap alternative for design and manufacturing. Overcoming size limitation and improving surface finishing can generate a new niche market in additive manufacturing, design and visual art. This will lead to higher quality artefacts on the one side but also create improved aesthetic value in the form of better surface finish and stronger bonds on assembled artefacts.

This study will impact on different industries by influencing advanced manufacturing, improving quality, size limitations, post-processing, design and costs incurred for artefact production. Industry stakeholders like Terry Wolhers maintains that rapid expansion within 3D printing industries is taking place. It is therefore important for academic institutions to stay on track with these developments.

The post-production finishing technique processes involved create improvements to the technology, but also empower the artists and designers alike with enhanced tools to obtain aesthetic value. Very little academic work has been done on these techniques. After searching reputable blog sites, many experimental techniques were identified and used during a pilot study phase of the research (Griffen 2014, Bowman 2012 & Benchoff, 2013). This led to the identification of specific techniques that can viably influence the inclusion of these techniques in the art world but also enhance aesthetic value outputs. Previously entry-level produced 3D printing was not seen as a viable aesthetic output because of the limitations it poses.

Different sectors make use of FDM printing technologies. It spans across industrial design, technology centres, visual arts, both private and government sectors. Entry-level FDM 3D printers like the UP Mini, with advanced software and limited micron printing size, makes it possible to start competing with larger printers like the FORTUS machines manufactured by Stratasys.

A further argument that validates the need to explore the surface finish and assembly techniques on entry-level FDM printers is the expansion in the additive manufacturing market leading to global companies for example HP[6] (2016) to engage with entry-level 3D printer designing. With the expiration of patent rights on the existing 3D printer designs, it has become an open market for developing new technologies that will improve entry-level FDM printing for the design and visual sectors alike.

[6] http://www8.hp.com/us/en/printers/3d-printers.html

1.3 Aims and objectives

The aim of this dissertation is to provide methods or techniques for the improved quality of ELFDM artefacts. How to make the technology more accessible to a larger number of users that will include, students, artists and engineers alike. Furthermore it should also address the scale of production for ELFDM. Can the expectations of ELFDM be adapted to the point where its' application will influence the aesthetic values of such artefacts?

The social impact of this study will then be able to identify cheaper alternatives for additive manufacturing production that will influence the aesthetic value outputs and quality of entry-level produced artefacts. Through addressing these technique developments it would demonstrate a reduction in waste material.

Lastly the study will aim to narrow the gap between the entry-level and high-end markets by recognising areas where 3D printing is not utilized by artists and designers in ELFDM.

All of the above is centred on the concept that chemical exposure provides improved surface finishing of ELFDM ABS artefacts and can be utilised to assemble smaller printed components into larger artefacts.

This study will argue that the strength and surface texture of entry-level FDM 3D printed artefacts also have a direct correlation to the aesthetic value output and supply increased functionality of artefacts in visual arts and design.

The objectives to achieve the above are as follows:

- Investigate post-production methods and techniques and observe how it can make the technology more accessible to a larger number of users.
- Investigate the success of fusing techniques to assemble artefacts.
- Determine by interviews/ surveys whether the application of ELFDM can influence the aesthetic value of artefacts.
- Lastly, identify through the investigation of mixed method research whether utilizing PPFTs could narrow the gap between entry-level and high-end markets.

Chapter 2: Literature review and theoretical framework of FDM 3D printing.

2.1 From RP to AM and the roadmap for South Africa (The impact on art, design and technology).

This research places the worlds of art, design and additive manufacturing on a colliding trajectory where the viewpoint on aesthetic-meaning-making is put to the test. By the introduction, experimentation and testing of new techniques innovative ways of artistic and manufacturing production are created. To grasp this ideology in its totality the background of additive manufacturing (AM) in South Africa should be reflected on.

Two very prominent figures in the design and additive manufacturing world according to the author is Professors Campbell and De Beer, due to their continued involvement with the development of additive manufacturing (AM) in S.A over the last 20 years as can be seen in publications such as (Campbell and de Beer, 2005). Due to this rapid and expanding growth the need for technique investigation can be argued for entry-level fused deposition modelling (ELFDM). This need is aggravated by a lack of introducing this technology at higher education, which in turn could be stated, influences the lack of artist and designers utilizing the technology at present (Campbell, de Beer & Pei 2011).

Very little is known about artistic usage and aesthetic value interpretation of 3D printed artefacts in South Africa and this study identifies a gap in the art and design industry. Campbell references that major industries in South Africa make use of 3D printing technology, including the art sector, but to what extent is still uncertain when looking at the small number of fine artists using 3D printing.

2.2 ELFDM in the education sector.

Improving 3D printing techniques (i.e. post-production finishing techniques), will assist artists and designers to access the technology on a more affordable level. A suggestion of Campbell and de Beer is to fast-track the technology at pre-university educational level, which in its current lacking state impairs creativity as well as artefact development. The introduction of this 3D printing technology on pre-university level and supplementing it with technique development goes hand in hand. Only when improved post-production finishing techniques have been developed in conjunction with awareness programs will artists be able to see the value of 3D printing technology. This in turn will lead to improved aesthetic value output in visual art and design.

To introduce the technology de Beer makes use of the Idea 2 Product labs® (I2P), which were launched by himself in the middle of 2011 at the Vaal University of Technology. This is the ideal platform for technique development as the labs provide an affordable alternative to 3D printing technology. It further offers opportunities to cross-reference artefact-aesthetics from design, art and additive manufacturing viewpoints. That said, this study's main focus originally was technique development for future artists and designers, not aesthetic interpretation of artefacts. However since the qualitative interpretation on the value of the artefacts became pivotal, an explanatory sequential research methodology was adopted. The study therefore focuses on technique development and its influence on aesthetic value.

2.3 Specific technology used at the I2P

Some explanation of the 3D printers used by the I2P is necessary so as to not to confuse it with other layered additive manufacturing processes. Although this explanation might seem very technical and removed from a strict artistic sense, it is important so as to understand the production process of 3D printing better. By understanding the production process, it helps identify the need for post-production finishing techniques and its possible aesthetic output. The I2P utilizes TIERTIME UP Mini Fused Deposition Modelling (FDM) printers. It was said as early back as 1994 that FDM technology would accelerate production and improve artefact quality (Comb, Priedeman & Turley 1994). Twenty years later the technology has improved through software, material and hardware development; however post-production finishing is still needed, because of warping distortions and/or step-layer effects on entry-level 3D printing. In visual art these deviations can be overcome by incorporated them into the design of the artefact pending the desired visual or aesthetic outcome. The debate of whether this can be seen as viable will be discussed in detail in Chapters 5 and 6.

Some transformation can be observed but too much focus is still placed on high-end FDM processes limiting the exposure and exploration of entry-level 3D printing. Improved techniques, software and hardware are pushing the technology towards cheaper alternatives of production that inevitably will create a niche-market for a new 3D printing artist and designer user. (Davidson 2013).

2.4 Surface finishing and assembly techniques:

Two techniques for post-production finishing (surface finishing and assembly techniques), can be identified as promising. In Griffins' article it is said that although the shape and fit are valued higher than surface treatment in 3D printing, treatment is worthy of overall judgement (Griffin 2014). A well-finished artefact can be judged to be of higher value and standard depending on the aesthetic appeal it raises. This point is very clearly raised in Chapter 5 and most of the respondents had a favourable view to this hypothesis. In support to Griffin's' argument researchers like Galantucci et al. (2009) have employed chemical post-production treatments to enhance surface finishing of ABS FDM specimens. The favourable results indicated improvements in the roughness reduction of the specimen surfaces.

Researchers Fernandez-Vicente, Canyada and Conejero (2015) corroborate this notion by arguing that the technology has restrictions for example, the print orientation which influences the overall visual aesthetic of the artefact. In their recent paper "Identifying limitations for design for manufacturing", he raised this problematic area and focused on resolving surface finishing limitations via the print orientation. They therefore proposes a solution based on the pre- and during the production phase. This research study however does not deal with experimenting with the print orientation except where it was used as a control method under which all specimens and artefacts were exposed.

Early examples of experimentation suggest the technical aspects of the techniques outlining the four steps to increase the quality of entry-level artefacts (Bowman 2012). The use of acetone cement as an assembly technique and acetone glossing as a surface-finish technique are identified. These techniques are not new but little to no scientific data has been collected inside the visual art and design worlds. Visible step-layers will always be present, making post-production finishing necessary (Benchoff 2013). He does however warn that acetone overexposure may have negative implications which should be studied.

2.5 Research methods

This is an explanatory sequential mixed method research study, but additional “non-traditional” ideologies are included as seen through Sullivan’s pragmatic ideas that support the inclusion of blogs, data collection and interviews (Sullivan 2005). This study leans on empirical quantitative data, followed up with qualitative interviews supported by online documentation.

It is disconcerting that Sullivan postulates that to borrow research methods from other fields of study could deny art practice of intellectual maturity and making it incapable of raising valid questions for cultural and educational ideas. Making such a bold statement goes both ways for this research. Firstly the research leans substantially on empirical quantitative data but is followed up and completed with qualitative interviews where opinions and possibilities matter. Incorporating Sullivan’s theories is therefore good and bad for this study and caution is kept in mind. Sullivan argues that although quantitative research is based on occurrences, and findings from qualitative inquiries are assessed by relevant outcomes, imaginative insight is still lacking. Focus should move from probability to possibility, which strengthens the use of mixed method research as both feed off each other to interpret the data. The outcome is centred on the acquisition of new or existing techniques to use in visual art to attain improved aesthetical value outputs for future artists.

Sullivan continues to say that artists and designers do not confine their practices to one style anymore, corroborating the need to merge art and technology. However, why do South African artists and designers not readily use the technology of 3D printing? Why does each stay marginalised to their own fields, indicating the lack of knowledge in technology availability and improving techniques for 3D printed artefacts.

2.6 Art and online specific theory

Art has its own rules on data validity and caution should be taken between aesthetic value and technique development. As no sound scientific data in an artistic setting can be found on these techniques the referencing to blog-sites in the maker-space is validated. This is supported by Robert Runte argument on using blogs in his New Media Blog chapter in (Knowles and Cole 2008). He argues blogs offer valid source material through three sections he calls: Blogs as Source Material, Ethical Issues and Blogs as Research Tools.

Under source material he explains, rapid spread of information, data availability, date stamping, archive referencing and search engine usage as ways to define target sampling. (Which in fact is exactly how the researcher methodically researched his target group for the qualitative phase in Chapter 5). Runte continues by saying bloggers create cross-referencing through related topics and also encourage commenting.

“Blog based research does not come under purview of review committees because blogs constitute ‘published material’, according to Runte and is supported by the bloggers anonymity, privacy level, syndication and registering of indexing service choices (Knowles & Cole 2008, p 320).

As a research tool blogs were used to support the interviews for this study. This pragmatic qualitative approach allowed the researcher to go back to the initial interpretations of the participants but also to corroborate and encourage further responses (re-interpretations) during the open ended online SKYPE interviews. Furthermore colleague and teamwork collaborations via blog can identify and eliminate confabulations, selective recall or manifestations of false consciousness, making the study more valid. This further also creates an exchange called “non-intrusive emergent collaboration” (Knowles & Cole 2008: p320).

2.7 ELFDM in art and industry

However the visual aesthetic perspectives and different value outputs of art, design and additive manufacturing 3D printed artefacts should be linked and it would be more appropriate to look at 3D printing from an artistic perspective. Dr Lise Jakobsen's[7] work makes for a good study to formulate a background setting for artistic opinions in this regard.

It is of particular concern that the divide between the individual industries that make use of ELFDM as well as the lack of implementation in industries like art and design that can benefit from its inclusion. Jakobsen in her current post doctorate research stipulates"…"amidst the technology excitement there is a lack of knowledge about what we print and what kind of aesthetic issues are associated with this particular access to translate two-dimensional images into three-dimensional objects". Her work (Print a thing! Analysis of the aesthetic meaning of 3D printing with emphasis) examines how artists and designers alike use 3D printing and how they observe these artefacts aesthetically.

Her argument for aesthetic value is derived from the perspective that the 3D print can be likened to the two-dimensional digital image. For her, aesthetics does not arrive from improving technique development or inadequate post-production finishing as the researcher proposes, but rather that certain artists make use of this medium as a sense of letting "something unsettling" into this world. She makes reference to the Danish artists, Martin Erik Anderson and Rene Schmidt and calls this 'unsettled imagery'. Two and three-dimensional imagery becomes embedded into each other that cancels our notions of surface and space.

It was clear that the grounding theory for aesthetic value should be based on more tangible empirical evidence followed by interpretation otherwise the divide between the industries will never be illuminated.

[7] http://pure.au.dk/portal/en/projects/print-a-thing-analysis-of-the-aesthetic-meaning-of-3d-printing-with-emphasis-on-how-artists-designers-and-architects-currently-use-3dprinters(ac61d5e3-34e2-43f5-b180-22a983b7ffe3).html

In yet another article (Jakobsen 2015), *Holding Your Scream in Your Hand. 3D Printing as Inter-Dimensional Experience in Contemporary Artworks by Alicia Framis, Martin Erik Andersen and Hito Steyerl 2015*[8], Jakobsen comments: "…not much has been written about the aesthetic aspects of this new possibility of transferring bits to atoms".

She continues with a very valid point. The technology is new. So new that there is a knowledge gap about what the status is of the artefact being produced and which aesthetic problems will come with the process of turning a digital data piece into a tangible artefact. This statement rings very true for the researcher as each industry has its own reserved opinions about the artefacts status and value which in part at least can argue why the divide persists between the art, design and additive manufacturing sectors. It therefore behoves the researcher to ask whether technique development that will be employed on entry-level produced artefacts could essentially then narrow this gap between the industries.

Jakobsen then points towards (Mitchell 2010) that technical innovation and new media typically gives rise to a so called "image crises", because people perceive new image types to be potentially dangerous and invasive. It cannot be helped but to ask, could this also influence the aesthetic value output then of entry-level produced artefacts?

She further adopted an analytical approach to examine inter-spatiality and inter-dimensionality of artefacts from specific artists to effectively move the shift on 3D printing away from a technological production perspective towards an aesthetical viewpoint. An exhibition during 2013 titled '3D – Dreidimensionale Dinge Drucken (In 3 Dimensions: Printing Objects' examined the relation between artefacts produced for designers, architects, engineers, medical doctors and biologists.

The curator, Spanish architect and 3D printing scientist Marta Malé-Alemany summarized the risk and potential as: "…the materialization of the digital world made possible by new fabrication tools will have a significant number of economic and social-cultural effects: we are all of us potential fabricators, we can fabricate anywhere

[8] Holding Your Scream in Your Hand. 3D Printing as Inter-Dimensional Experience in Contemporary Artworks by Alicia Framis, Martin Erik Andersen and Hito Steyerl. ACTA UNIV. SAPIENTIAE, FILM AND MEDIA STUDIES, 10 (2015) 25–45/ DOI: 10.1515/ausfm-2015-0002. Aarhus University (Denmark)

– meaning that production is completely delocalized – and carry out our own customized fabrication".

2.8 The use of aesthetics in 3D printing

The above illustrates the current trends surrounding the visual aesthetics of the 3D printed artefact in general. This study however did not deal with these ideologies as it aims to provide evidence for post-process development for entry-level produced artefacts instead of seeking ideologies on meaning-making from an artistic perspective.

Another argument was observed in "An aspect of undoing aesthetics" where reference was made to the researcher Wolfgang Welchs' debate about whether sport can be seen from an aesthetic pleasing viewpoint in art (Satoshi 2009). Although this argument has no relevance to 3D printing per se, it does convey value in how people observe aesthetic value subjectively. Welch failed to conclude why sport cannot be seen as art from an aesthetic viewpoint. Satoshi argues this can be seen as an indication of how precarious our common sense in understanding aesthetics has become.

Our viewpoints on aesthetics are driven on historical conventions of what aesthetic values are to the individual. It is for this reason that the researcher needed to observe the opinions of individual experts in the field of art, design and additive manufacturing to create a world view perspective of sorts. Aesthetics as subject matter will differ in value and opinion for each of the above mentioned.

As previously stated the researcher does not wish to go down the art aesthetical route, where the philosophical viewpoint becomes a focus. This study is purely set around the development of creative post-production finishing techniques that will assist in developing the entry-level fused deposition modelled artefact and narrow the gaps between high-end and entry-level production.

For this reason the focus falls more in line with views from the additive manufacturing world. An example of this can be seen in "Enhancing the surface finish of FDM parts using vapor treatments" (Brooks et al. 2015). Here the main disadvantage of layer based extrusion as well defined layers that negatively impact the aesthetics of parts are listed. Furthermore these limitations are a serious barrier for the adoption of the technology.

Aesthetics here is seen purely from a physical viewpoint that can be investigated empirically by set measures and standards. With this in mind the reader should take caution when interpreting the use of the word aesthetics in this research study even though it can be superimposed over ideologies of an artistic nature as seen with Jakobsen above.

The following chapter will discuss the methods used to gather data as well as explain in further detail why it was necessary to implement a mixed method research study which corroborates the successful bridging between the above stated industries that employ entry-level fused deposition modelling.

Chapter 3: Research Methodology

3.1. Identifying the gaps in knowledge

3.1.1 Not enough academic knowledge on the topic (Emerging ideologies)

As was earlier discussed in Chapter 2, there exists limited knowledge with regard to post-production surface finishing techniques when looking at studies from researchers like (Brooks et al. 2015). Although a substantial amount of research has been done in the last couple of years, the resulting work focused mainly on the viewpoint and implementation of surface finishing for industrial applications. No academic work in the field of arts has been done directed towards material and technique development when it gets to entry-level fused deposition modelling 3D printed artefacts.

The very limited knowledge and academic research that does exist from an artistic perspective (Jakobsen 2015) focused mainly on the philosophical interpretation of 3D printing itself as a tool for the artist. As the reader by now knows this study focus mainly on the identification, implementation and scrutiny of post-production finishing techniques. This brings the researcher to the point of identifying the shortcomings.

3.1.2 Shortcoming in technique development

This beckons the question then why there are shortcomings in technique development. What could hinder the development? For the researcher this mainly lies in the fact that all the different industries have different opinions about the output values of entry-level 3D printers. Limitations have been identified but when the researcher look at present literature indicating solutions to these limitations the focus never falls on a post-processing resolve. In Chapter 5 and 6 it is argued that it is pivotal for the hardware/software developments to evolve with the introduction of skills development for post-production finishing.

3.1.3 Entry-level end users lack accessibility to 3DP due to limitations of technology

Furthermore there is a lack of accessibility to 3D printing exposure for users on the entry-level spectrum due to quality and cost constraints. It is therefore important for this study to identify alternatives to address accessibility caused by limitations. If alternatives can be identified then it will open the way for more end users to have access to the technology.

3.1.4 Art and design entry-level end users not targeted

The majority art and design users steer away from employing entry-level fused deposition modelling in their arsenal. There is a very clearly identified gap of users who make use of high-end FDM processes that can be viewed in the results and discussion of Chapter 5 and 6. A clearer understanding of why industry feels this way is also under debate in these chapters. The researcher believes that making use of post-production finishing techniques to enhance the quality and aesthetic output of entry-level produced artefacts will help identify solutions to these problematic areas.

3.2. Research questions

As this study is making use of an explanatory sequential mixed method research study the quantitative strand is followed up with a qualitative strand and then interpreted to establish the success of utilizing finishing techniques on entry-level FDM produced artefacts.

It is of utmost importance to superimpose the quantitative strand with the qualitative strand as this study implies new and/or adapted techniques that can be used in visual art, design and additive manufacturing. It is for this reason that each of the phases has therefore a set of complementary questions that derive from their respective paradigms. Below will firstly be found the main research question followed up with a table showing the layout of the sub-questions.

The main research question states: “How can post-production finishing and assembly techniques influence entry-level FDM 3D printed artefacts and thereby create meaning-making to attain improved aesthetic value in visual arts as well as narrow the gap between art and additive manufacturing industries?”

In Table 1 below the different sub questions that were used for each phase from within a quantitative and qualitative viewpoint are indicated.

Table 1 Research sub-questions

Quantitative	Phases	Qualitative
Which techniques and how can they be applied to Post-production surface finishing?	Pre experimental pilot study	Why would PPSFT influence aesthetic output of artefact and lead to gap between EL3DP and art?
What are the requirements for apparatus that can be constructed to assist surface prep and customization?	Phase one, Stage one: Apparatus design	What improvements must be made to entry level 3DP tech to enhance aesthetic value in VA?
Which tech and standards are best suited to test strength & surface texture roughness? What are typical values of surface finish, etc. that can be achieved?	Phase one, Stage two: Test strip samples	What PPSFT's can be implemented to improve the surface fin of entry level 3DP in VA?
To what extent can finishing techniques successfully be implemented in visual art?	Phase two: In depth interviews	What determines the Aesthetic value of surface fin tech on entry level 3D P in visual art?

3.3. Research methods. Mixed method research

Due to this research moving across multiple disciplines to make sense of the different possible uses of finishing techniques and the varied use of the aesthetic value concept, it was important to implement an explanatory sequential mixed method research study. It moved from a quantitative paradigm to a qualitative paradigm. (Creswell & Plano Clark 2011, Crossman 2015). A sequential form of data collection where one type of data provides a basis for collection of another type of data (Mertens 2005).

Although the research was conducted sequentially it was not linear and allowed for emergent themes to develop which enabled the most appropriate method for progressing in the research to be chosen (Neuman 2006). A visual representation of this can be seen in 3.4 under the basic layout of the research structure showing how the path of enquiry was non-linear due to the influence of the different research questions. Neuman continues: "Rather than moving in a straight line, a nonlinear research path makes successive passes through steps, sometimes moving backward and sideways before moving on … It can be highly effective for creating a feeling for the whole, for grasping subtle shades of meaning, for pulling together divergent information, and for switching perspectives". This is clearly reflected in the hypothesis later in 3.4.

The mixed method model design allowed for the research questions of the second phase to emerge from the inferences of the first phase (Teddlie & Tashakkori 2003). The first phase was exploratory and data collection, analysis and inferences were seen as a collective, from there the study took a quantitative approach after the pre-experimental pilot study. The second phase was confirmatory with new data, analysis and inferences from a qualitative approach (Teddlie & Tashakkori 2003). Inferences, as used in mixed methods research, refer to the inferences made from what is studied, as opposed to only the results of a study. Mixed methods lead to multiple inferences that can either complement or confirm each other and become very evident in the qualitative phase. Then it is finally reflected back upon during the Meta-inference (Figure1).

The two-phase design did not in itself present any major issues. In fact, it allowed for a much needed theoretical framework for the organisation and flow of the research processes. The results or inference of the first phase would, to a large degree, determine the research activities and directions that would follow into the second phase. This is not to say that the research design was retrofitted to the study, but that the ultimate research design was not fully known until part of the way through the research process. Any number of directions could have been employed depending on the results of the first phase.

In terms of data alignment and display issues the second phase of the study provided some challenges. The second phase involved the testing of the developed artefacts in the field and its evaluation utilising a combined process evaluation design (interviews and surveys).

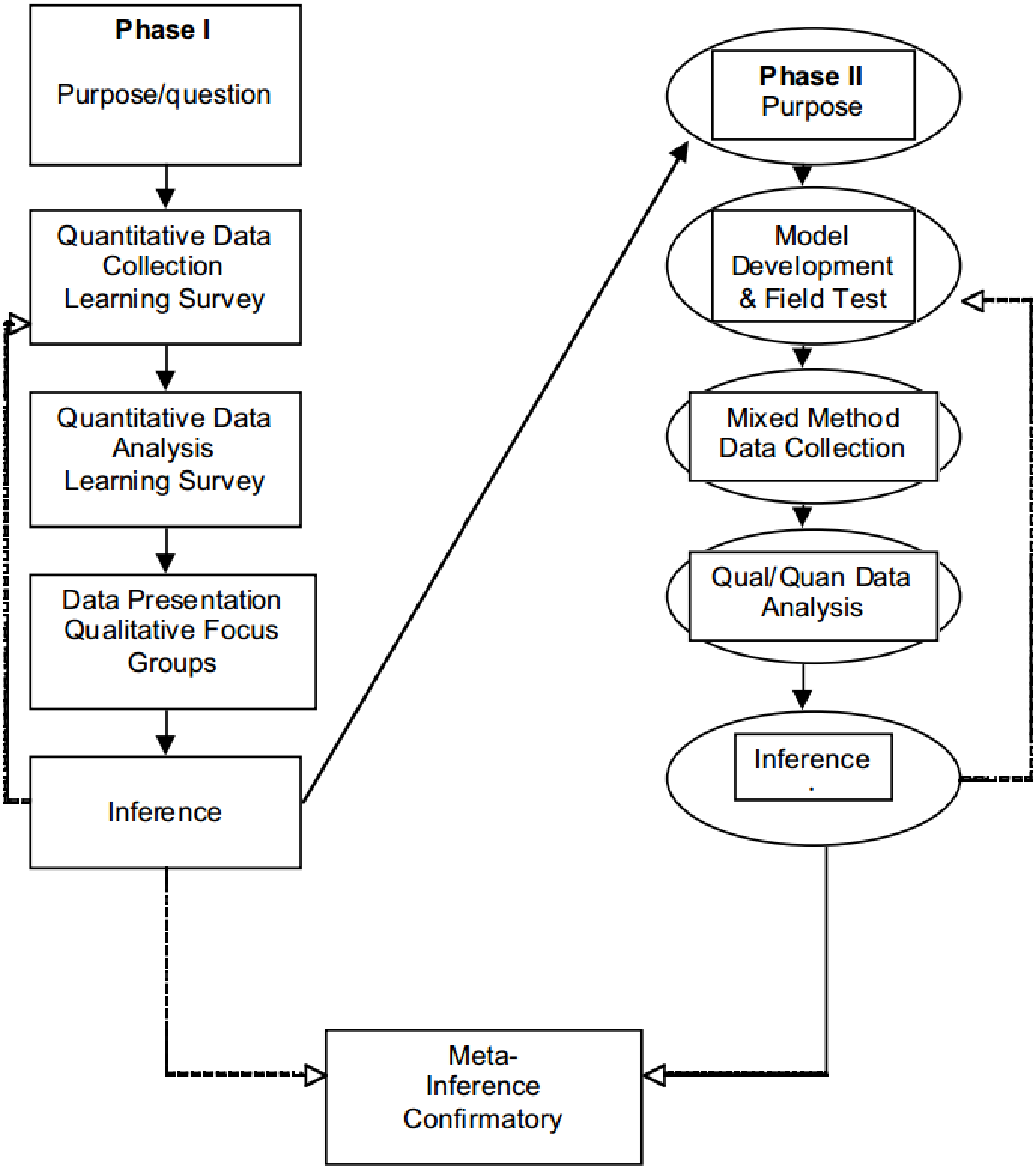

Figure 1: Sequential mixed method design (Adapted from Teddlie & Tashakkori 2003: 688)

What resulted was a complex blend of mixed methods data collection across three data collection points. These three points were the fields of study (Art, design and Additive manufacturing) as well as the stages (pre-experimental pilot study, quantitative phase one and qualitative phase two).

Data triangulation was attained through the mixed method data collection techniques from each phase of the research (Zohrabi 2013) Investigator triangulation was achieved through the use of both internal and external evaluators in the formative evaluation of the model in the field. Various analyses were used through the researcher in the pilot study followed by internal and external investigators for both quantitative and qualitative phases.

During the first phase, quantitative data were obtained through closed-ended questions and the qualitative data through open-ended questionnaires, interviews and surveys. The points of the questionnaires were mainly developed by being based on the research objectives, research questions and qualitative assumptions made by the researcher.

Closed-ended questions from the pilot study provided the researcher with quantitative enquiries that led to numerical data collection in the first phase and was concluded with open-ended questionnaires for the qualitative second phase. When the researcher looked at Blaxters' division of questionnaires into "seven basic question types: quantity or information, category, list or multiple choice, scale, ranking, complex grid or table, and open-ended", it confirmed the use of quantitative enquiry as well as open-ended questions (Blaxter, Hughes and Tight 2006). It is important to remember that open-ended questions will accurately reflect what the respondents want to say, therefore it is important to include both closed- and open-ended questions in an interview (Nunan 1999). The researcher saw the importance of this and adapted the questionnaires and surveys to reflect this.

After the questionnaires were constructed the researcher had to reflect on the interviews that would take place. To investigate this the researcher looked at Merriam that says the inquirer intends to obtain a special kind of information and investigates for him/herself what is going on in the mind of the respondents (Merriam 1998). The researcher cannot observe the informants feelings and thinking, therefore interviewing is a key to understand what and how people perceive and "interpret the world around them". Or the purpose of the interview can be interpreted so as to reveal existing knowledge in a way that can be expressed in the form of answers and so become accessible to interpretation (Flick 2006).

Interviews can be divided into four major type's namely, informal conversation interviews, interview guide approach, structured open-ended interviews and closed, fixed response interviews (Patton 1990).

The informal conversational interview was a likely choice for the researcher as it poses the freedom of the information to flow naturally. It is very exploratory in nature but might steer in a direction that does not address the research problems identified for this study. So the researcher focused on the other side of the spectrum towards a structured open-ended interview format. The questions are predetermined, with a fixed order. However caution was noted that it can become very rigid and may not allow access to participants' real perspectives and understanding of the topic (Merriam, 1998).

The researcher decided on a semi-structured guided interview approach in the end where the topics and questions were specified but they could be reworded in any sequence based on the situation. One of the advantages of the interview guide approach is that the collected information "can later be compared and contrasted" (Fraenkel & Wallen 2003). In this approach data collection is rather systematic and conversational. This type of interview is flexible and allows the interviewee to provide more information than other formats. This form of interview is neither too rigid nor too open. It is a moderate form in which a great amount of data can be elicited from the interviewee.

The following guidelines were made use of to structure the interviews that were conducted through SKYPE (Merriam 1998; Fraenkel & Wallen 2003; Johnson & Turner 2003; Flick 2006):

- The respondents should be provided with scope to express their opinions.

- The researcher should be non-judgmental and neutral during the interview.

- The researcher should be respectful, natural and nonthreatening.

- The researcher should create rapport.

- The researcher should not interrupt.

Now that the theory premise behind the study has been explained the phases can be described conclusively as follows:

- Pilot study

Initial pre-experimentation tests were done during 2014 as a pilot study to determine post-production surface-finishing techniques. The collection of data from the pre-experimentation pilot study, allowed crucial assumptions to be made towards artistic/aesthetic finishing methods for 3D printed artefacts, which led to the two specific phases namely surface finishing and assembly techniques.

- 1st Quantitative research questions

The first phase consisted of two stages, namely the development and construction of a surface-preparation apparatus (Acetone Vapour Chamber "AVC"), which was then supposed[9] to be accompanied by an extensive quantitative testing stage of tensile strength samples. These samples determined the effect of acetone alteration and identified controls. They formed the basis for the study's known variables and consisted of a large sample of numerical data tested on standard instruments. The instruments that were used are an Acetone Vapour Chamber, W-type tensometer, INSTRON tensometer, a MTS tensometer, a SJ210 Mitutoyo surface tester and a Dobamoni DR-432B Surface Profile gauge tester. (Creswell & Plano Clark 2007).

- 2nd Qualitative research questions, followed by interpretation

The results were then analysed by deductive reasoning and compared to a complementary qualitative comparison in phase two. The main objective in phase two was to conduct in-depth interviews with participants to retrieve their subjective viewpoints on the topic of successful surface finish and assembly technique application on specific 3D printed physical artefacts. The main drive behind this was because of the dualistic epistemological nature of the artefact. The object out there and idea in the mind are two different things (Neville, Willis & Edwards (eds) 1994 Caulley), there is a post-positivist interpretive form of inquiry.

[9] The design of an elaborate vapour chamber was decided against as the researcher could obtain the exact same results by establishing controls and parameters under strict conditions with a makeshift design. This design was also a saver ethical option that will be discussed in more detail in Chapter 4.

This second phase consisted of subjective unknown variables which was collected in the form of textual data and imagery. This small sample groups' information was gathered by means of a loosely structured observation. By way of subjective meaning and inductive reasoning the researcher formed viewpoints of the participants' expert opinions of the aesthetic output and its validity of these techniques.

- Traceability Matrix method explanation of research questions

Below is a Traceability Matrix (Table 2) that explained the implementation of the research questions on the different phases. The traceability matrix indicates the implementation of the research questions and its' loadbearing impact on the study. More detail about the research questions can be reflected back on in point 3.2 above. Furthermore it can be said that the quantitative phase made use of quasi-experimental sampling consisting of controls and manipulations but not randomization whereas the qualitative second phase employed pragmatism. Using both spectrums of subjective and objective natures of visual aesthetics supplied sound triangulation to demonstrate the qualitative nature of this research study which is supported by underlying quantitative theory and data (Greene, Caracelli & Graham 1989).

Table 2 Traceability Matrix method explanation of research questions.

Traceability Matrix						
	Research Methods					
Research Question	Literature Review	Pre-prod pilot study	Apparatus Design	Data Production	Blogs	Interviews
Which techniques and application?	X	X				
What are the Apparatus requirements?	X		X			
Surface finish requirements and ISO 527-2: 2012 standard?	X			X		
Successful implementation in art/design/engineering?	X			X	X	X
Why would PPSFT influence aesthetic value?	X	X		X	X	X
What improvements can be made to enhance aesthetic value?	X	X	X	X	X	X
What determines aesthetic value of 3DP artefacts?	X	X		X	X	X

It can be argued that the strength and surface texture of entry-level 3D printed artefacts have a direct correlation to the aesthetic value and functionality of artefacts in visual arts and design. This study makes use of a component design form, namely triangulation: Different methods are used to assess the same phenomenon toward convergence and increased validity (Caracelli & Greene 1997).

3.4. Diagram of dissertation structure:

Mixed method research theory can become somewhat cumbersome at times due to the merging of different worlds. Below is a completed illustration of the layout of the research design to give a better understanding to the reader of the methods used to systematically address the research problem. This was discussed in the second paragraph of 3.3 above and reflects the non-linear approach that the mixed method research adopted.

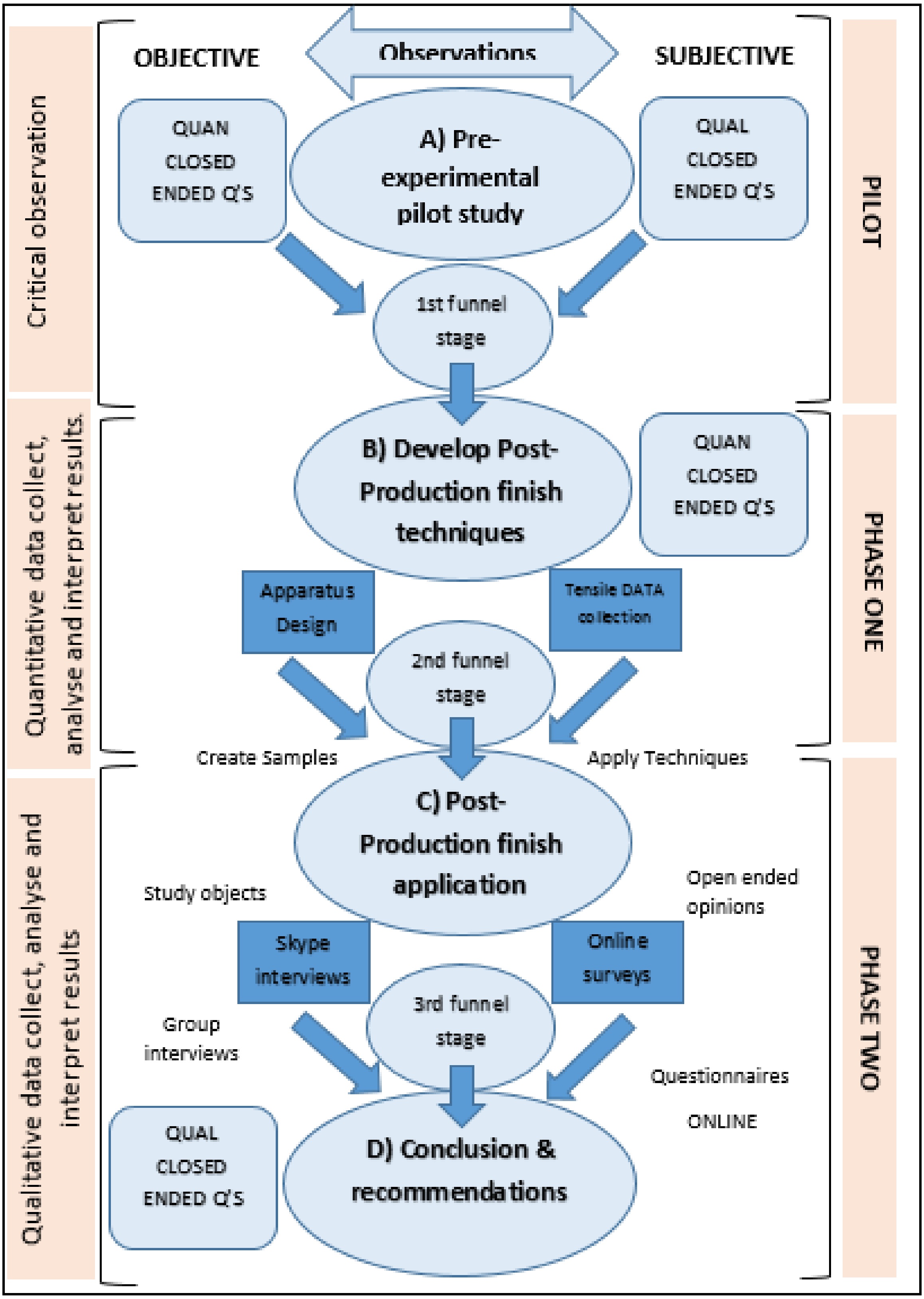

Figure 2 Basic layout of Explanatory Sequential Research design

3.5 Steps to collect data

These steps below reflect the stages of collecting data and are reflective of the research layout on the previous page:

Table 3 Sequential steps for collecting data

	Steps on how data was collected:	Stages
1	Observe trends in Additive manufacturing, design and art through blogs	A – Pilot
2	Reflect objectively on types of techniques existing in the maker-space	A – Pilot
3	Formulate quantitative closed ended questions	A – Pilot
4	Reflect subjectively on types of techniques existing in the maker-space	A – Pilot
5	Formulate qualitative open-ended questions	A – Pilot
6	Structure types of techniques to experiment with in pilot phase	A – Pilot
7	Create prototypes with possible finishing technique	A – Pilot
8	Identify the most successful techniques	A – Pilot
9	Reflect on pre-experimental pilot study by form of research output	A – Pilot
10	Research quantitative data collection for available equipment	B – Phase 1
11	Conduct experiments and collect data for stage 1 of phase 1	B – Phase 1
12	Reflect on quantitative data, adapt ISO standard and deliver research output	B – Phase 1
13	Create new specimens (ISO) and test extensively through collaborations	B – Phase 1
14	Collect all specimens from Loughborough, VUT and CUT (Established research partnerships and specimen availability)	B – Phase 1
15	Analyse quantitative data	B – Phase 1
16	Formulate questions from the findings	C – Phase 2
17	Identify population group	C – Phase 2
18	Decide on questionnaire and survey types	C – Phase 2
19	Make contact with possible respondents	C – Phase 2
20	Confirm respondents and setup up paper trail correspondence	C – Phase 2
21	Collect biographical information from respondents	C – Phase 2
22	Send & receive NON-DISCLOSURE AGREEMENT for ethical consideration	C – Phase 2

23	Receive STL files to be printed	C – Phase 2
24	Reproduce all the artefacts	C – Phase 2
25	Create print documentation that shows print fails, hours, reprints and grams	C – Phase 2
26	Complete surface finishing on all artefacts	C – Phase 2
27	Document during and after surface finishing	C – Phase 2
28	Send artefacts to each respondent (UK, BFN, PTA, VRNG VNDB, JHB)	C – Phase 2
29	Set interview dates	C – Phase 2
30	Conduct Interviews and online surveys	C – Phase 2
31	Write up transcriptions of interviews	C – Phase 2
32	Send transcripts to respondents to corroborate their opinions	C – Phase 2
33	Analyse and present data internally at CUT	C – Phase 2
34	Write dissertation	D – Phase 2
35	Post all findings and bios for supervisors in website for reflection	D – Phase 2
36	Analyse if follow up sessions or interviews are needed	D – Phase 2
37	Publish dissertation	D – Phase 2

3.6 Scope of the research

The pre-experimental pilot study did not have any delimitation pertaining to the materials and techniques used in ELFDM. A wide range of materials and techniques were experimented with to establish potential candidate materials and techniques for surface finishing and assembly techniques. That said there was a delimitation towards the type of FDM processes used for production. The study focused exclusively on entry-level fused deposition modelling.

From the pilot study was established that Phase 1 should consist of two stages. The first stage consists of the construction of a surface preparation apparatus (Acetone vapour chamber) but it was later adapted to a makeshift ready-made chamber. This chamber was used during Phase 1 to manipulate the surface texture and influence the integrity of dog bone test strips.

The second stage consisted of testing dog-bone test strip samples following the ISO 527-2: 2012 Standard. It was recommended that delimitation took place to focus the research from a design towards art perspective. For assembly techniques tensile pull testing was used. For the Surface Texture Evaluation two sets of surface profile testers were used to determine the surface smoothness. So although numerous techniques of measurement exist, only two types were used as the results reflected adequately and the process adhered to time constraints.

The second phase focused on limiting the population sample to three groups of industry specific practitioners and the impact these techniques would have on entry-level FDM during the post-production as well as the aesthetic quality of the artefacts. Various artists and designers locally and abroad were selected to participate and substantiate the concept and validity of the study. There were two people chosen from additive manufacturing, two from the design sector and lastly two from the fine art world. The reader should bear in mind that these respondents were selected in their sectors for the contributions they have made in their respective fields. However they might not only function from within the field they were identified In, for example one respondent might have been chosen as an expert in the art field, however they work from within a design field and vice versa. This grouping provided a very clear understanding on 3D printing from their respective industries to create a holistic overview.

The case studies consisted of in-debt interviews to establish the successful application of surface finishing and assembly techniques and how these techniques influence our understanding of what an aesthetically pleasing object is.

3.7 Significance of the research

The study signified that a gap has been identified in entry-level FDM 3D printing. More industries are looking towards cheaper alternatives for production and aesthetic value meaning-making by introducing technologically advanced techniques. This research study created such a platform for artists and designers alike to be able to use enhanced techniques with improved quality and physical appearance for 3D printed artefacts. As (Merriam 1998, p. 202) states in qualitative research: “reality is holistic, multidimensional and ever-changing”. Therefore, it is up to the researcher and research participants who attempt to build validity into the different phases of the research from data collection through to data analysis and interpretation. Therefore, validity is concerned with whether our research is believable and true and whether it is evaluating what it is supposed or purports to evaluate.

3.8 Expected outcomes and contribution of the research

The research provides guidelines to achieve the improved quality of ELFDM 3D printed artefacts, which will make the technology more accessible to a wider variety of students, clients and artists in various industries. Furthermore larger artefacts will be able to be produced, changing the outcome and expectations of ELFDM 3D printed artefacts and its application from an aesthetical viewpoint. New techniques for artistic use are postulated to fill a gap where 3D printing was not utilized in the entry-level sector by artists and other low-cost users.

3.9 Ethical considerations/ identify ethical challenges:

A lot of debate surrounds ethical considerations when it gets to innovative out of the box design and implementation of 3D printed artefacts and post-production processing. Artefacts and the preparation apparatus are not always included under current health and safety regulations however both ISO 9001 standards as well as the South African Occupational Health and Safety, Amendment Act, No 181 of 1993 were followed. Responsibility was taken for all participants involved and affected by this research. In the event of undesirable consequences corrective measures would be taken to align the outcomes and the ethics committee notified.

An honest reflection of data generation, analysis, publishing and acknowledgment to contributors will be given. Plagiarism and false representation may not take place at any stage of the research. All data collected is preserved in an appropriate manner as discussed with supervisors. It is the right of the researcher to report the research for the advancement of scientific knowledge by publishing the findings in journals, books or other media.

For the pre-experimentation pilot study and quantitative phase all hazardous materials and liquids were stored in a safe dry environment away from contamination. Adequate ventilation and extraction were used when applying acetone and the acetone fumes were extracted where necessary. No open flame was used for the heating of the acetone into a vapour form. Although an elaborate vapour chamber where constructed with electronic heating elements in the casing of the heating tray, the researcher decided against the use of this apparatus due to time, money and safety constraints. Instead a makeshift ready-made cold vapour fuming unit was utilized instead. However, fire-retardant overalls, chemical-resistent gloves, respirators, safety boots and eye-protective goggles were still worn when operating the chemicals and the adapted acetone vapour chamber.

The acetone Vapour chamber (as a preparation apparatus) did not infringe on any copyright laws or patent rights as it was designed as a prototype and not as a commercial model for sale or profit. If a conflict of interest between scientific knowledge and the protection of intellectual property becomes evident, the importance of publication will be explained to the title holder or inventor. The Intellectual Property Amendments Bill of 2011 will be applied here in such an event or any similar applicable act depending on the basis of the claim.

All laboratory tests were done with SABS standard approved machinery from the respective participating institutions which included Loughborough University in Great Britain as well as Vaal University of Technology and Central University of Technology, both in South Africa. All tests were conducted by qualified technicians and occupatinal health and safety induction received.

To ensure no copyright infringements took place, permission in written consent form was obtained from all the respondents. All respondents reserved the right to their opinions and had the right to withdraw if conflict of interest became evident as stipulated by the Protection of Personal Information Act 4 of 2013. No harm or emotional stress developed for any of the participants as their opinions only included specific guided responses, regarding the application of these techniques and their success from an aesthetic viewpoint. All participants are regarded as experts in their respective industries, rendering their opinions different from each other for the pragmatic nature of phase two to obtain valid data.

Lastly all participants would remain to keep their right to intellectual property for each of the artefacts and no unmentioned publication or other use may take place without written consent and as agreed between the researcher and each respondent individually. All research results should be reported whether they supported or rejected the hypothesised outcomes.

Chapter 4: Phase 1: Quantitative collection/ interpretation

4.1. Apparatus design

4.1.1 Background to acetone vapour chambers (AVCs)

At the beginning of this research project very little academic knowledge was available with regard to the history of acetone vapour chambers, except for what was commercially available on the internet via blog and vlog sites.

For this reason the researcher experimented with a variety of prototypes that would lead to a proof of concept apparatus design during the pilot study. However the intensity of the technical subject matter and skill involved made it clear that this is a research study of its own.

During 2015 while on a fellowship in the UK under the guidance of Dr Ian Campbell at Loughborough University, the researcher met and worked with co-researcher, Miguel Fernandez-Vicente, from IDF institute at UPV University in Spain. It immediately became clear that methods existed to modify the acetone vapour chamber concept that would be inexpensive, very safe and controllable under laboratory conditions.

It was for this reason that the researcher decided against completing the construction of a very expensive, laborious and possibly dangerous vapour fuming chamber and went for the ready-made version so as to not overcomplicate the study and focus rather on the outcomes of the techniques.

4.1.2 Types of AVCs

Typically there are three forms of acetone vapour chambers (AVC's). The first is the heat sink type that disperses nanofluids (Shukla, Brusley Solomon & Pillai 2012). Secondly the compressed nebuliser that sprays and extracts acetone simultaneously under compressed air and lastly the makeshift readymade cold vapour method chamber (Kraft 2014).

4.1.3 Techniques (Hot vs cold acetone application)

The two main methods of indirect application are hot vapour fuming and cold vapour fuming. Hot vapour fuming (HVF) makes use of an enclosed system where acetone is vaporized, exposing the artefact to condensed acetone. The process is rather volatile and takes a couple seconds until completion. For ethical reasons this method is not ideal if the chamber does not meet strict safety measurements.

The cold vapour fuming (CVF) is a much safer and non-invasive method of exposing the artefact to acetone fumes. A makeshift chamber is constructed out of any sealable container that will not corrode in acetone, paper towels and acetone (Kraft 2014). This system is much safer that the HVF method but extremely prolonged lead times can be expected. The controls are easily put in place as it takes very long to expose and is a closed off system.

4.1.4 Techniques (Open vs Closed method application)

In the maker-spaces there are various schools of thought about the application techniques of acetone vapour. The researcher would like to refer to these as Open vs closed application methods. Closed methods would be systems like the acetone vapour chamber concept, whereas the open type would be brush-on as well as dipping/ bathing methods of application. The researcher found that the closed systems have better controlled variables such as amount of acetone exposure, regulating temperature and protecting the specimen during the curing (waiting) period after exposure. However both open and closed methods were tested for this study.

4.1.5 AVCs vs Acetone bath (AB)

Acetone bath or dipping is a well-known method to expose ABS artefacts but poses many obstacles that will be discussed in the results. As said above it is an open application method where the component or artefact is directly dipped into acetone liquid and then removed and left to cure.

4.1.6 How were the design requirements translated into the chamber design?

The original requirements for designing an acetone chamber were not met, as the variables were successfully controlled by a cold vapour fuming system. There are however debates about the validity of makeshift chambers that will be discussed in further detail in the qualitative chapter as well as in the discussion chapter.

For this reason the researcher decided to adapt the design requirements to focus on the technique and outcome rather than on an actual apparatus design.

This led to a very linear approach (discussed in 4.2) so the data could evolve naturally from an explanatory sequential mixed method research perspective. First the researcher experimented with different additive manufacturing and artistic techniques during the pilot study. This was followed by a delimitation towards acetone techniques and ABS material and then further narrowed to specific results in tensile strength and surface profile measurements that would provoke research questions that were used during the next qualitative phase in Chapter 5 of the research.

4.2. Data Analysis (Theory)

4.2.1 Pre-experimental pilot study: Development to test-specimens

The original aim of the individual surface experiments were to apply finishing techniques to improve the visual appearance of artefacts but also to maintain the structural quality of the FDM printed components (Havenga 2014). This led to the ultimate question whether post-production finishing techniques can enhance the aesthetic value of artefacts in art and design.

A variety of experimental surface techniques were utilized that included heat-by-direct-flame application, staining the artefacts, post-process painting with oil paint and aerosol spray, acetone application, abrasive sanding techniques and filler mediums for cracks and deformities. For the experimental assembly techniques the researcher focused on friction welding, bicarbonate of soda with Cyanoacrylate, Polyfilla and woodglue and lastly ABS cement/ slurry. All of the above were common practice on the internet during the experimental phase

From these experiments acetone was identified as the most likely post-production finishing medium when observed from a set of quantitative questions that focused on honing in on which techniques eventually best suited this study. For more information on the results of this pilot study, please refer to Appendix 7.1.

4.2.2 Dog-bone test strip sample production

As previously discussed in 4.1 it was determined that the requirements for apparatus design did not necessitate the further exploration of developing new apparatus (in this case the vapour chamber), as a successful and laboratory ready example can be made in minutes. However, it was necessary to ask what kind of empirical testing can be done to corroborate scientifically the validity of these techniques and not just see them from an artistic qualitative perspective. For this reason the researcher had to focus on specific standards and create test-bone specimens, source the appropriate technology to test it on and find some form of control to measure against the results of the specimens (Havenga, de Beer, van Tonder & Campbell 2015). Please refer to Appendix 7.2. The use of the dog-bone specimens were necessary to create a control to measure the influence of acetone on a scientific level.

As very little academic literature existed at the time this study commenced (that linked the various industries involved in additive manufacturing), it was necessary to adapt some of the test specimens and work with the equipment that was available at that time. From there the ISO 527-2: 2012 standard have been obtained with more relevant equipment and will be discussed in the next point. The full method used to examine the adapted specimens is outlined in Appendix 7.2.

The researcher identified that the focus to address the problems encountered with the aesthetic value and quality of entry-level FDM produced artefacts is directed rather towards solving post-production problems as there are limitations to the software and hardware components of ELFDM. From this deduction a large sample group of experimental dog-bone specimens (120) was created. Some were left untreated (40), some treated with acetone vapour (40) and some suspended in an acetone bath (40). The specimens were created on the specifications of an available Monsanto/Hounsfield W type tensometer as well as the equations from the ISO 527-2: 2012 SABS test standard.

The equation being:

"*The equation used to determine the tensile strength is demonstrated in Eq (1) . This equation was used to produce results in kN/ mm² to determine the breaking point strength of the test samples. Please note: The flexural strength of the test samples was not measured and therefore the results were not converted from kN/mm ² into Mpa. The aim was to determine the exact strength at breaking point to determine whether acetone affects the polymer strength."* (Havenga, et al. 2015, p4)

$$f = \frac{FP}{\pi r^2} \qquad \text{(Equation 1)}$$

f = Tensile Stress (kN/mm²)

FP = Force Fracture point

r= Intended fracture area radius of test sample

To determine the surface roughness, profile measurements had to be documented. This was done by means of a SJ210 Mitutoyo surface tester.

Lastly it was important to collect qualitative visual data that could be scrutinized in parallel with the quantitative data. For this reason anomalies stemming from acetone infiltration were documented with a Techgear Eaglescope digital microscope.

The results showed that acetone weakened the tensile strength of the specimens but also that there was substantial surface roughness reduction. The qualitative observations showed structural changes in the samples that were treated as well as anomalies that the researcher identified as vapour entrapment due to delamination and pooling of acetone. Therefore it was clear from the tensile tests and visual observations that the structural integrity is weakened.

4.2.3 Dog-bone test strip exposure acetone bath, vapour, Superglue and XTC-3D

These tests were corroborated at Loughborough University in the UK. More accurate measurements were collected as the ISO 527-2: 2012 standard dog-bone test specimen design could be used for testing on an INSTRON electronic tensometer (Figure 3).

A new set of specimens were created as a cross-reference point. In addition to creating acetone exposed specimens, cyanoacrylate and XTC-3D epoxy exposed specimens were added to the list to compare.

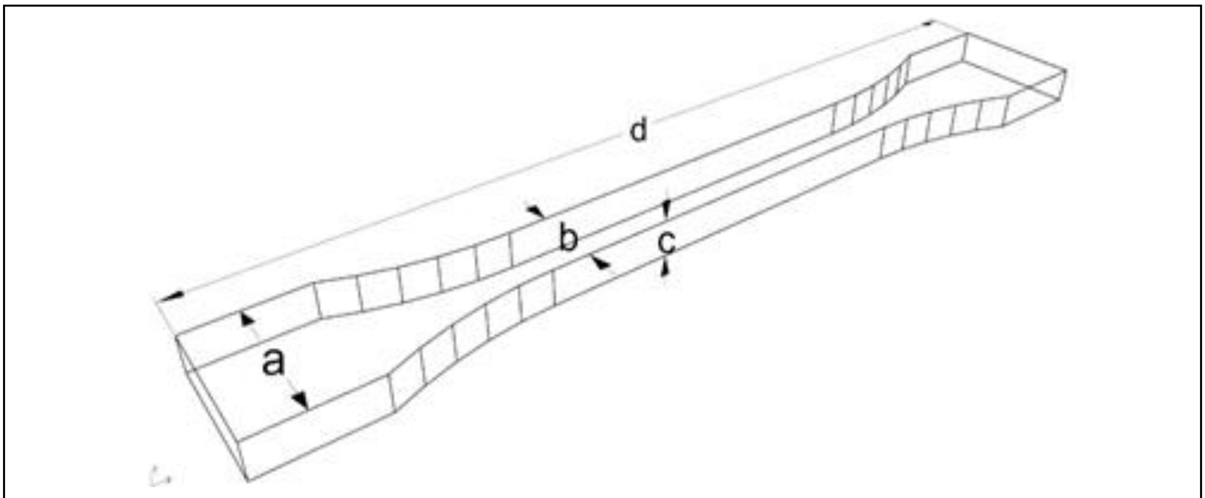

Figure 3 ISO 527-2:2012 SABS Standard dog-bone test strip

Table 4 below shows the results from 2015 specimens produced, tested and collected at Loughborough University in the UK:

Table 4 Dog-bone specimen results from Loughborough University

Name	Offset Yield stress	Modulus (Automatic)	UTS	Strain at UTS (mm/mm)	Stress at Break	Strain at Break (%)	Ra Average	Rz Average
Acetone Dip	15,313	1906,76	28,1	0,0242	22,478	6,74	3,718	10,513
Acetone Dip	15,811	1745,78	23,8	0,0254	22,323	6,29	0,5245	1,484
Acetone Vapour	13,652	1334,17	16,3	0,051	14,596	5,45	0,5665	1,602
Control	19,438	1802,02	24,3	0,02	22,172	4,24	7,536	21,31
Acetone Dip	17,922	1748,87	23,3	0,0227	22,101	4,16	3,187	9,01
Acetone Vapour	12,9	1288,82	17,2	0,0493	15,828	5,53	0,6205	1,7585
Acetone Vapour	15,871	1269,92	18,2	0,0676	17,412	7,4	0,476	1,347
Control	15,696	1692,99	24,2	0,0253	22,14	5,42	3,48	9,8385
Control	22,829	1979,49	28,6	0,0206	24,385	6,99	7,9395	22,45

4.2.4 Dog-bone test strip data analysis.

These samples were sent to the UK for tensile testing on an INSTRON tensometer and the data were then sent back to the researcher to analyse in South Africa. The table below consists of the RAW data and more information can be obtained in Appendix 7.2.

Table 5 below shows the results from 2015 specimens produced at Sebokeng, South Africa, tested at Loughborough University (UK) and interpreted at Valencia University (Spain).

Table 5 Tensile acetone exposed specimen raw data from 2015

Name	Offset yield Stress	Modulus	UTS	Strain at UTS Mm/mm	Stress at break	Strain at break (%)	Ra (average)	Rz (average)
Acetone Dip	13,37533	1503,59	16,817	0,0186	15,688	2,09	1,207	3,4135
Acetone Dip	14,64745	1524,71	19,068	0,0187	17,616	2,98	1,6275	0,9295
Acetone Dip	15,54148	1577,60	19,639	0,0184	18,261	2,39	1,74	2,5675
Acetone Dip	14,11978	1513,98	18,119	0,0187	14,843	2,24	1,381	2,449
Acetone Dip	12,05775	1335,38	13,253	0,0186	12,369	2,49	0,3365	0,939

Control	18,91932	1539,30	20,637	0,0178	17,510	2,26	4,6615	13,175
Control	15,37718	1361,85	15,800	0,0147	15,379	1,58	13,189	37,3
Control	15,06901	1323,44	15,392	0,0145	14,695	1,59	6,1825	17,48
Control	15,92475	1441,70	16,388	0,0137	13,497	1,39	3,141	8,8825
Control	15,81793	1401,69	17,471	0,0167	16,740	1,82	3,9795	11,25
Acetone Vapour	14,56435	1458,84	17,109	0,0209	16,880	2,88	0,2225	0,63
Acetone Vapour	14,28998	1497,98	16,256	0,0209	15,883	2,79	0,295	0,835
Acetone Vapour	15,9786	1623,61	17,717	0,0209	16,997	3,24	0,276	0,7815
Acetone vapour	14,85278	1536,53	16,072	0,0168	15,086	1,78	0,234	0,663
Acetone vapour	15,11123	1585,86	16,804	0,0203	15,760	2,36	0,1915	0,5425

Table 6 below shows the raw data for Smooth on XTC-3D epoxy resin followed by cyanoacrylate exposed specimens

Table 6 Tensile specimens exposed to XTC and cyanoacrylate.

Name	Offset yield stress	Modulus	UTS	Strain UTS	Stress at break	Strain at break	Ra	Rz
XTC	22,247	1703,49	23,211	0,0172	20,619	2,22	0,497	1,4065
XTC	27,0921	1982,52	28,935	0,0185	28,141	1,97	0,4335	1,227
XTC	31,53684	2011,89	33,265	0,0207	31,914	2,36	3,026	8,557
XTC	32,22288	2197,86	35,107	0,0201	35,107	2,01	0,5215	1,4755
XTC	26,47809	1899,71	28,355	0,0191	26,870	2,18	0,8855	2,505
Superglue	20,76732	1729,06	22,405	0,0172	21,600	2,00	5,049	14,275
Superglue	20,41376	1669,79	21,535	0,0155	21,535	1,55	4,944	13,965
Superglue	21,8712	1844,61	22,968	0,0161	22,385	1,75	5,403	15,275
Superglue	20,88179	1776,51	21,920	0,0159	21,414	1,68	6,8035	19,242
Superglue	21,21542	1747,82	22,642	0,0169	21,657	2,01	2,044	5,7805

Lastly, an additional data set was created with new and improved materials now supplied by Tiertime, the official supplier of the UP MINI 3D printers' filament. The researcher decided to include these materials and the tensile test results of acetone exposure as it will bring the research up to date with the current materials available thus rendering the results more relevant in the current additive manufacturing market.

As the research aims to indicate the influence of acetone on ABS, with the addition of other materials like PLA, HIPS and NYLON Composites, the true ultimate tensile strength (UTS) and ductility does not need to be examined in detail. The aim is purely to identify fluctuations in the recorded data to indicate whether acetone and the comparative chemicals influence the materials used for entry-level FDM produced artefacts.

4.2.5 Results of tests.

The results from the 2015 Loughborough/ Sebokeng collaboration are indicated Figure 4 below

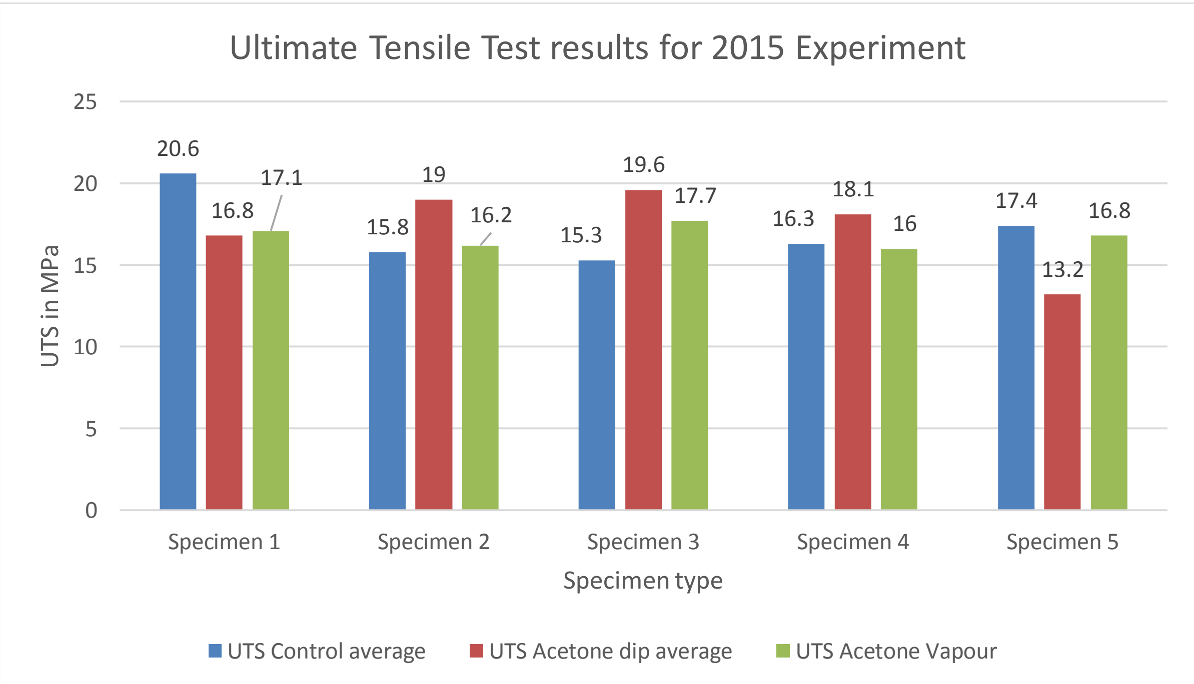

Figure 4 Average UTS of the 2015 control, acetone dip and acetone vapor specimens

When looking at the overall UTS results of the acetone exposure there are some discrepancies, but when they are refined by way of average deduction as seen in fig. 4 above, the tensile reduction and ductility increases are more apparent. It should be noted that the controls for the acetone dipping (room temperature 22 degrees Celsius) and acetone vapour fuming (above 38 degrees Celsius to evaporate), differed in temperature exposure method which clearly indicates the contradiction in assumption that acetone will weaken the ABS materials tensile strength.

ABS as a co-polymer will drastically decrease in tensile strength when heat application is present and less so when cold applications are adhered to. In the case of this specific set of specimens the acetone dipping took place under ‘cold’ application conditions, meaning the specimens were submerged into room temperature acetone liquid. This means that the parts cannot be aggressively infiltrated except where there are delamination cracks. However in the case of the acetone vapour the chamber was heated to beyond evaporation temperature, meaning very aggressive infiltration took place, weakening the tensile strength. This does unfortunately leave open the question why the tensile strength increased in the dipping specimens and the researcher thinks a future investigation can develop from this notion.

The inclusion of the XTC and cyanoacrylate data was deemed unnecessary for this graph as the focus was specific towards the outcomes of acetone exposure on the ABS specimens.

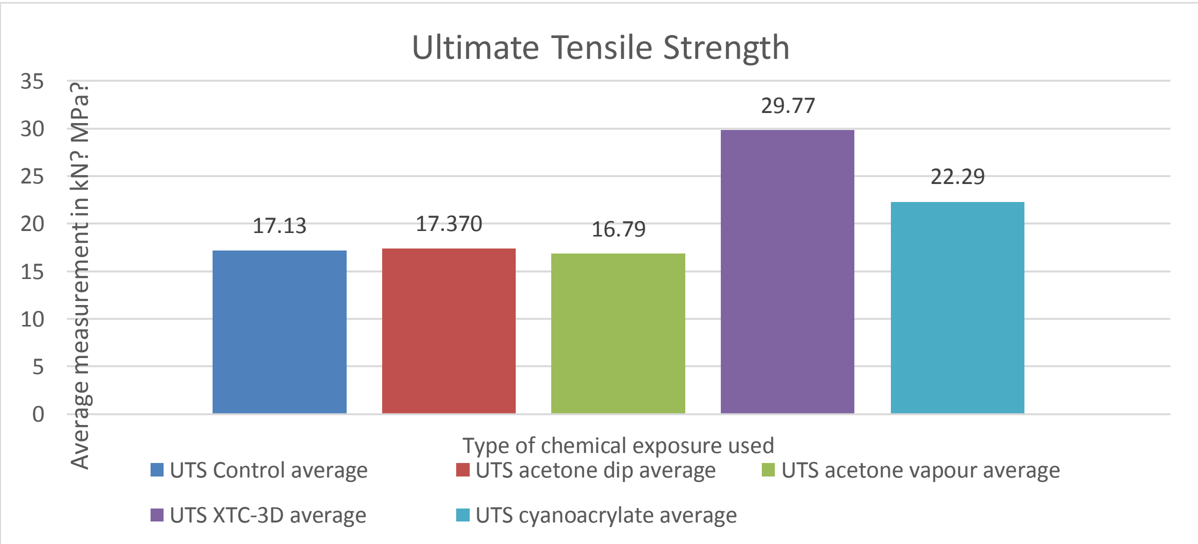

Figure 5 UTS comparison of additive post-production finishing materials

The inclusion of the XTC and cyanoacrylate was done for comparative reasons. It was however decided against including them in the post-production finishing techniques of Phase 2, as they are additive post-production finishing materials, meaning they misconstrue the surface analysis which could influence the aesthetic appearance of the artefacts. XTC epoxy for example will cover some of the smaller detail on the surface of the artefacts. Further it could additionally add prolonged lead times because of gravitational pooling of the epoxy resin. Cyanoacrylate is very difficult to work with as a surface preparation medium and cannot be applied smoothly without streaking the surface of the artefact.

That said, it is very interesting to observe that the additive surface finishing chemicals made a drastic improvement to the tensile strength of the specimens.

It should be noted that the reductive properties of acetone seem most effective in manipulating the surface with only a small amount in tensile strength reduction as can be seen above. It is also noteworthy to observe that the ductility of the ABS material increased. But this does not carry particular interest for the aesthetic value output and quality of artefacts.

Furthermore it is also important to test the surface profile measurements of the specimens to see how the chemical exposure affected the surface and then from there deduce if it could be an effective way to measure the aesthetic appearance of artefacts in Phase 2 of this study.

In the figure below it can be seen that the results very clearly indicated that the Ra average value decreased from 6.23 for the control to 1.25 for the acetone dipping and 0.24 for the acetone vapour fuming. That is a staggering 79.81% reduction for acetone dipping and a 93.09% reduction in roughness for acetone vapour fuming.

For the Rz value the control 17.61 dropped to 2.05 for the acetone dipping and 0.69 for the acetone vapour fuming. Therefore these results represent a drop of 88.31% for dipping and 96.09% for acetone vapour.

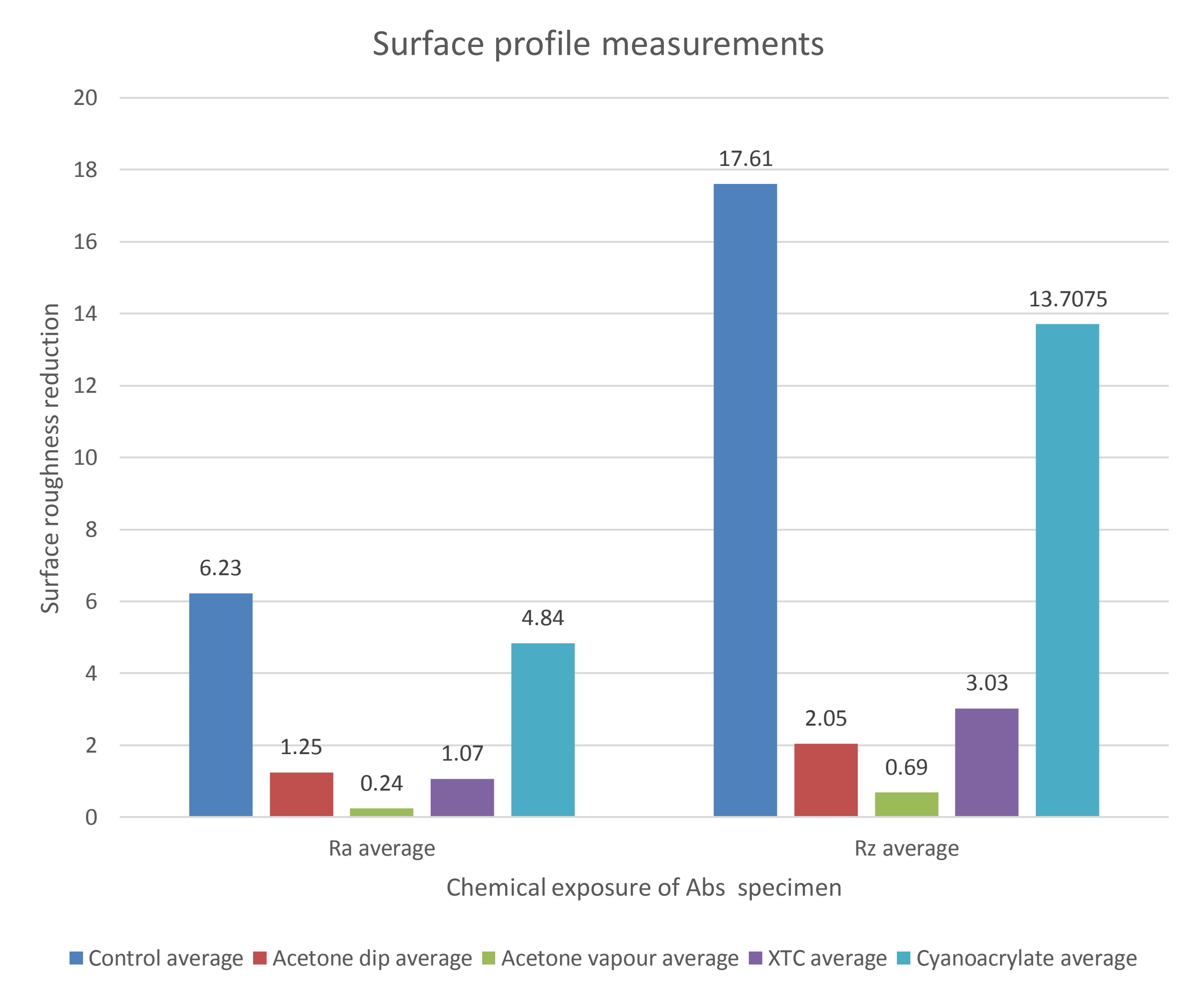

Figure 6 Surface roughness comparison

Results from 2016 specimens produced at Sebokeng (South Africa), tested and collected at Central University of Technology. CPRM, (South Africa) are shown in Table 7 below. Note the method was cold vapour fuming.

Table 7 Specimen comparison 2016

Name	Offset yield Stress	Modulus MPa	UTS MPa	Strain at UTS mm/mm	Stress at break	Strain at break	Ra	Rz
Black PLA	26,62	1827,30	34,1	0.029	34.14	2.5	0.61	1.73
Black PLA A	27,45	1857,76	37,1	0.028	37.12	2.7	0.81	2.29
Black ABS	16,16	1095,54	22,1	0.030	22.52	2.9	1.64	4.64
Black ABS A	13,54	1097,58	20,6	0.030	20.57	3.1	0.43	1.22
Black ABS +	19,41	1251,65	24,0	0.028	24.03	2.6	1.75	4.96
Black ABS + A	10,41	1334,71	10,9	0.011	10.87	1	0.19	0.54
UV Sunburn Chameleon ABS	12,81	1330,12	12,9	0.014	12.91	3.1	2.54	7.20
UV Sunburn Chameleon ABS A	12,03	1321,91	12,4	0.013	12.42	1.2	1.53	4.32
UV 33 ABS	13,35	1432,81	13,5	0.015	13.48	5.0	1.59	4.51
UV 33 ABS A	11,27	1425,57	11,8	0.018	11.80	2.8	1.50	4.26
Pacific Blue ABS	12,93	1414,95	13,1	0.027	13.13	5.0	2.57	7.28

Pacific Blue ABS A	11,78	1388,69	12,3	0.014	12.30	1.5	2.35	6.65
Hips A	10,46	1278,43	11,8	0.015	11.83	1.6	1.53	4.32
Super Silver PLA	17,63	1077,640	27,0	0.042	26.97	3.8	4.54	12.8
Nylon Comp	8,862	531,950	25,6	1.363	25.57	128.9	3.99	11.3
Nylon Comp A	6,966	457,309	23,2	1.515	23.78	115.1	4.54	12.8
ABS white	19,45	1368,36	23,4	0.030	24.25	2.3	3.63	10.2
ABS white A	-0,17	1358,49	12,0	0.013	12.68	1	1.06	3.01

As a supplementary to the 2015 specimen results another set of tests was run to verify the results one last time, but with the addition of new materials that have been developed by Tiertime[10] . The researcher deemed it necessary to compare the most recent material to investigate the exposure of acetone on such ABS material. However the results cannot be directly linked to the artefacts that were reproduced as only the standard ABS material filament was used. Therefore the data can only exist as a theoretical supplement and nothing more.

Before we can discuss and analyse the above-mentioned RAW DATA set, the researcher needs to mention that the data that was produced at CRPM CUT is slightly different from the data set from Loughborough University. Therefore when the reader reflects back to Appendix 1.2. They will find some terminology would be different and it was decided to include a short description below to clarify and avoid misinterpretation.

The corresponding values from the table below illustrate the previous tests from 2015 and the new data from 2016. The researcher would like to extend thanks to Miguel Fernandez-Vicente, from IDF institute at UPV University in Spain for his assistance in the breakdown of the following explanation.

Table 8 Tensile testing example between two formats.

Previous	Offset Yield stress	Modulus (Automatic)	UTS	Strain at UTS (mm/mm)	Stress at Break	Strain at Break (%)
New	Stress at Offset Yield (Mpa)	Modulus (Mpa)	UTS (Mpa)	Extract from the graph (see example)	Extract from the graph (see example)	Strain at Break (mm/mm) multiplied by 100. Review it!!*

[10] http://www.tiertime.com/products/consumables Accessed on 06/07/2016

To examine the areas indicated in red please make use of the following information provided below (**Example:** Graph of ABS_Black_+.xlsx)

1. - Obtain the specimen area (Width x Thickness) = 10.37x3.96 = 41.0652 mm^2

2. - Strain at UTS = Extension value (near 1.9mm) / Initial length (66mm, from the document “plastics_measurements.xlsx”) = 0.0288

3. - Stress at Break = Load value (near 890N) / Area = 21.673

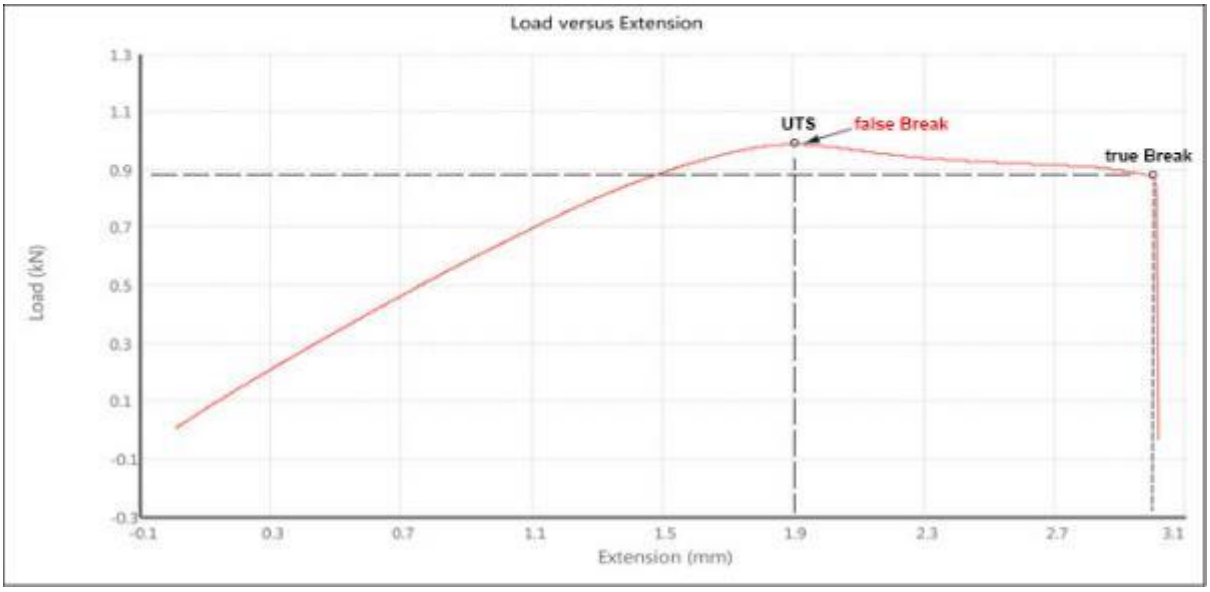

Figure 7 UTS with true and false breaking points (Courtesy CRPM CUT)

PLEASE NOTE THE FOLLOWING COMMENT (FERNANDEZ-VICENTE):

“ Be careful with the Strain at Break of the tables that they sent. It seems that the computer has automatically decided where it is the break”.*

In this example it has decided that the break is in the same place as the UTS (in the figure above ‘false break’). You can see where the machine has put it with the column “Elongation at Break (mm)”. In this example it says that it is 1.895mm, and it is not true.

In this case, the “True Break” point elongation is near 3mm. So using the same formula of point 2: Elongation value / initial length = 0.045 (mm/mm) Strain at ‘true’ Break. If you want to compare it with our previous tests, multiply the value by 100”.

To get back to the data, it was important to see if the new materials are affected in the same way that normal ABS would, when exposed to acetone exposure. It should further be noted that these specimens were created under the same conditions as the artefacts (same controls) as well as the same cold vapour fuming technique exposure. Therefore hypothetically these latest specimens should reflect a very close resemblance to the quantitative chemistry of the artefacts that were produced for Phase 2.

For the UTS measurements the researcher looked for a decline in tensile strength when he observed the acetone exposed specimens. The following graph illustrate the results:

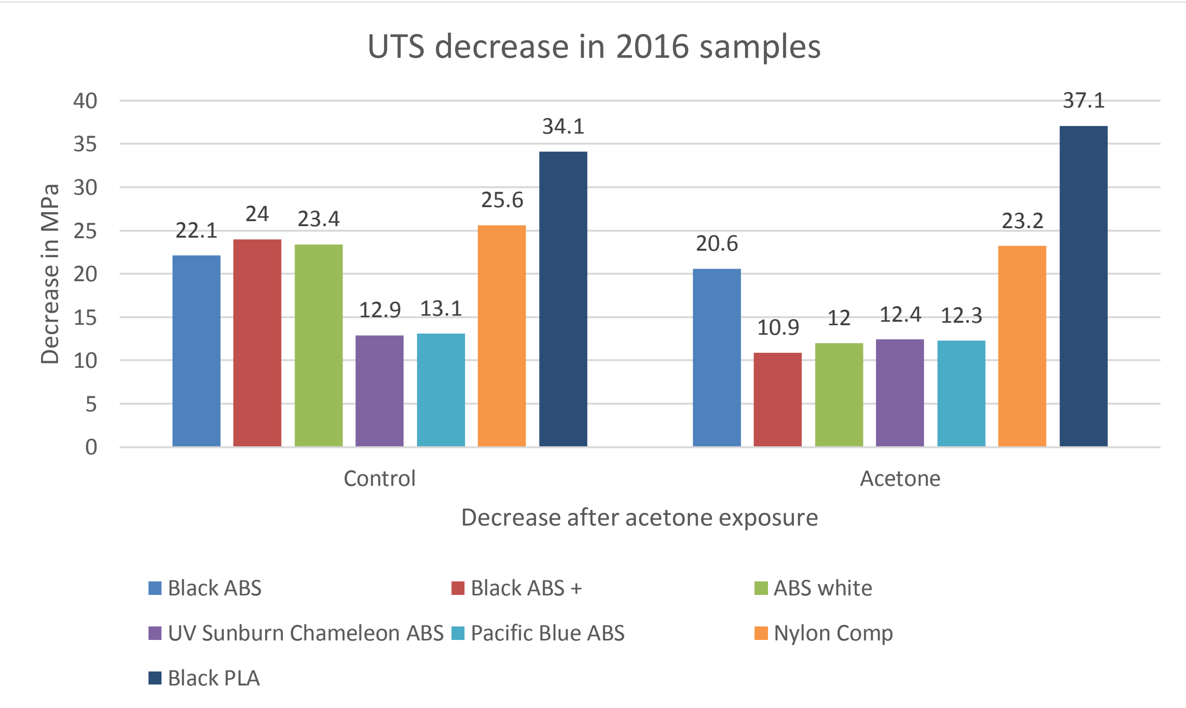

Figure 8 UTS decrease and increase for 2016 specimen

The results show that all of the ABS specimens reduced in tensile strength when exposed to acetone. The standard black ABS filament reduced its tensile strength by 6.78%. The new black ABS+ material was reduced by 54.58%. The standard white ABS filament reduced its tensile strength by 48.71%. The new UV Sunburn Chameleon ABS tensile strength reduced by 3.88%. The new Pacific Blue ABS material reduced its' tensile strength by 6.11%. The latest Nylon composite co-polymer blend material had a tensile strength reduction of 9.375%. Lastly the black PLA had an increase in its tensile strength by 8.08%.

It is of particular interest to see that the PLA black material increased in tensile strength when exposed to cold vapour fuming. It would be of interest to conduct a future study to verify these results, as earlier experiments during the experimental pilot study rendered negative surface texture when earlier versions of PLA were exposed to acetone.

Furthermore, it seems that the Black ABS is the most likely material to use for optimal post-production finishing. Because of the low decrease in tensile strength as well as the surface roughness reduction that will be discussed in the next graph. The researcher recommends this material as optimal for artefact production that will be post-production finished with acetone.

It should also be noted that the UV Sunburn and Pacific Blue ABS have even less tensile strength reduction, however their surface profile measurements seem to be minimally affected by the exposure to acetone to any drastic degree. From a visual qualitative perspective these last two specimens seem unaffected at all. Therefore even though the acetone minimally affect the tensile strength of the above mentioned two filaments, it also does not affect the surface profile and is therefore rendered ineffective to use for this study.

These results will be further discussed in chapter 6 to analyse if all the criteria were addressed. The above-shown results brought into thought that the quantitative data clearly indicate the scientific effect that acetone will have on the structure and surface profile of ELFDM produced artefacts.

However when addressing visual aesthetics it becomes important additionally to support the above-mentioned findings with a parallel qualitative data collection set. In the next chapter the production of the artefacts and interviews that were conducted will be discussed.

Chapter 5: Phase 2: Qualitative data collection and interpretation

The findings from phase 1 (Chapter 4) indicated quantitative proof that acetone weakens the integrity of the ABS plastic, increases the shear strength (ductility) and decreases the roughness of the surface texture. This however, does not validate the impact that these post-production surface finishing techniques will have on the aesthetic value of artefacts which motivated the importance of following up with a qualitative component in this phase.

Design, art and engineering all have different qualitative views on the aesthetic value of artefacts and their respective surface finishing so it was important to include the whole spectrum to get a clear opinion about the successes or failure of post-production finishing techniques.

This chapter discusses the methods and findings as to how the qualitative data set was chosen, set up and then collected. Please keep in mind that the data collection and interpretation were designed to ascertain what limitations exist and how they correspond with the appropriate technological advances; it further tries to identify any shortcomings that might steer artists and designers away from using entry-level fused deposition modelling. Another aspect would be whether poor aesthetic value outputs of entry-level fused deposition modelling artefacts influence the gap between high-end and low-end production methods. Lastly to look at whether these techniques could offer a cost-effective alternative for design and manufacturing, size limitations and improved aesthetic quality.

5.1. Application of finishing and assembly techniques

5.1.1 How the designs were chosen (Industry status and high-end quality for example laser sintered (LS)

The resulting data from the quantitative phase as well as the experimental pilot study provided the platform on which the designs for the artefacts were chosen. It was important to focus on one entry-level (low-end) and one high-end technology to make a comparative study. The study was focused on entry-level fused deposition modelling (ELFDM), so it was the obvious choice for this study to use the UP MINI 3D printer technology. All of the respondents that were identified had used very accurate high-end laser sintering (LS) processes before for example the EOS machines. This helped to obtain very accurate reflections on the quality and aesthetic value of the entry-level produced specimen artefacts.

5.1.2 Collect CAD designs of selected artefacts, print the (.stl) files and apply finishing and assembly techniques

All the respondents cooperated to help choose artefacts that they knew would fill the above criteria and the artefacts were then identified and sent to the researcher in a CAD file format. The artefacts were all reproduced on an UP MINI 3D printer as it has the size limitation of a $120mm^3$ printing bed platform. All the artefacts were larger than the printing bed platform, compelling the researcher and respondents to slice the CAD files into sections that were reproduced separately. This was necessary to illustrate the need to fuse the artefacts in post-production whereby the researcher could test the post-production assembly technique using ABS cement glue.

Thereafter all the components of the artefacts were assembled and post-production finishing techniques in the form of acetone vapour finishing was applied. It needs to be noted that all artefacts were reproduced in duplicate and none of them were completely finished off so as to illustrate the shortfalls, identify problem areas, show limitations and successes.

The whole production process, with failed prints, grams, separate components, assemblies, lead times, finishes and finishing times were documented. It was important to document all of the above so that a comparison could be drawn to validate or dispute the time vs quality vs expense debate. Please refer to appendix 9.2 for more detail/ information regarding this comparison.

Before the respondents findings are shown below it is also important to be aware that for quality control, the same printer settings for optimum results were chosen. These settings reflect the finest detail the entry-level FDM UP MINI can produce artefacts in, but a setback almost certainly from the word go would be very prolonged lead times. So time was sacrificed over the ability to retain quality.

The specific printer settings were 0.20mm layer thickness, with a solid infill, set to fine quality and with an activated thin wall function. Furthermore the part orientation was set to 45 degree with 6 layers and the support generation was set to 30 degrees orientation with a 3 line density and lastly with the stable support function activated.

5.1.3 Artefacts documentation: Visual and data

The findings of the production phase as well as the post production finishing technique documentation will now commence:

Respondent one's, artefact consisted of four components (x1) (Figure 9). It weighed 336.4grams and took 43h20 to create during production. The post-production can be split up into 21 hours to remove support material, 8 hours to vapour expose and assemble the components and a further 6 hours surface finish by abrasive sanding and acetone exposure. The ABS acetone cement glue needed 200ml acetone and a further 2000ml was used during the acetone vapour exposure. One of the four components failed during the printing, due to load shedding and had to be printed again. The additional loss in material was 113. 2 grams.

Respondent two's (LTD), artefact consisted of four components (x1) (Figure 9). It weighed 350.5grams and took 43h56 to produce during production. Post-production consisted of 20 hours to remove support material, 8 hours to vapour expose and assemble the components and a further 6 hours surface finishing by abrasive sanding and acetone exposure.

The ABS acetone cement glue needed 200ml acetone and a further 2000ml was used during the acetone vapour exposure. One of the four components was not suitable for use due to burn scarring and had to be printed again. The additional loss in material was 110.8 grams.

Respondent three's artefact consisted of four components (x2) (Figure 10). It weighed 423.4grams and took 56h18 to produce during production. Post-production consisted of 5 minutes to remove support material, 21 hours to vapour expose and assemble the components and a further 14 hours surface finishing by abrasive sanding and acetone exposure.

The ABS acetone cement glue needed 250ml acetone and a further 350ml was used during the acetone vapour exposure. Two of the eight components failed during the printing, due to load shedding and nozzle clogging and had to be printed again. The additional loss in material was 23.5 grams.

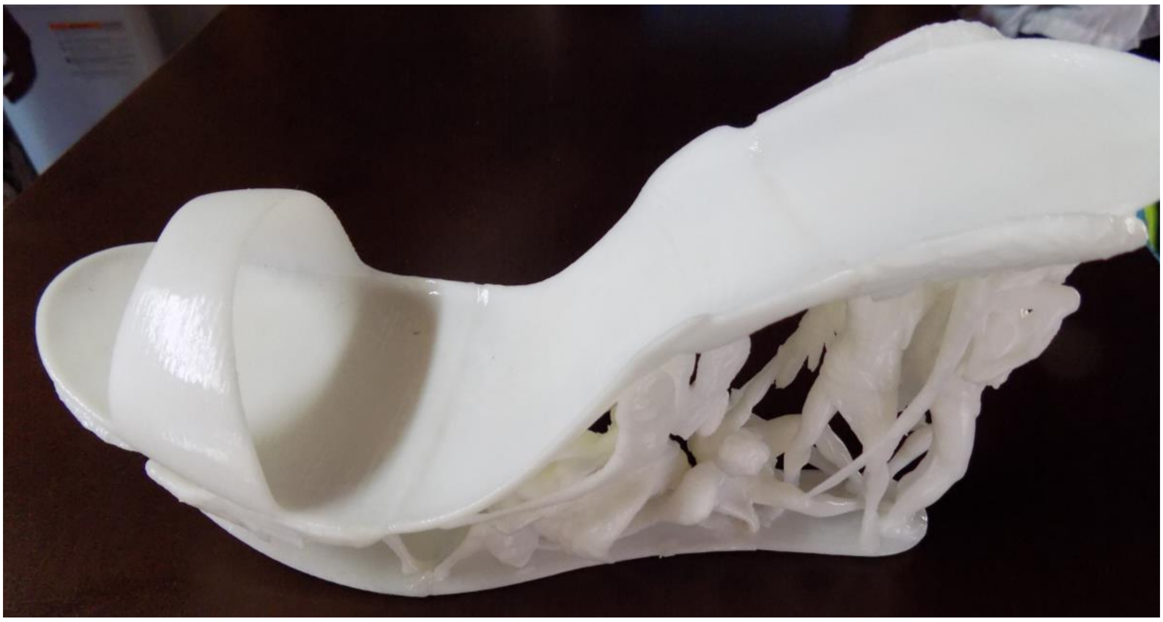

Figure 9 Respondents 1 and 2's artefact (Image courtesy of the researcher).

Respondent four's artefact consisted of 65 components (x1) (Figure 11). It weighed 528grams and took 83h31 to produce during production. Post-production consisted of 43h50 to remove support material, 45 hours to vapour expose and assemble the components and a further 15h30 surface finishing by abrasive sanding and acetone exposure.

The ABS acetone cement glue needed 250ml acetone and a further 420ml was used during the acetone vapour exposure. Seven of the 65 components failed during the printing, due to load shedding and had to be printed again. The additional loss in material due to print failure was 82.21 grams.

Figure 10 Respondent 3’s artefact Dinosaur

Figure 11 Respondent 4’s artefact Carousel Clock

Respondent five's artefact consisted of three components (x2) (Figure 12). There were two specimens therefore consisting of six components in all. The two artefacts weighed 506.9grams and took 65h50 to produce during production. Post-production consisted of 35 hours to remove support material, 18 hours to vapour expose and assemble the components and a further 60 minutes surface finishing by abrasive sanding and acetone exposure.

The ABS acetone cement glue needed 250ml acetone and a further 800ml was used during the acetone vapour exposure. Five of the six components failed during the printing, due to load shedding and had to be printed again. The additional loss in material was 110.8 grams.

Figure 12 Respondent 5's Trophy

Respondent six's artefact consisted of 26 components (x2) (Figure 13). It weighed 243.4 grams and took 34h18 to produce during production. Post-production took 13h46 to remove support material, 25 hours to vapour expose and assemble the components and a further 8 hours surface finishing by abrasive sanding and acetone exposure. The ABS acetone cement glue needed 250ml acetone and a further 160ml was used during the acetone vapour exposure. Four of the twenty-six components failed during the printing, due to deformation and poor quality. These had to be printed again. The additional loss in material was 60 grams.

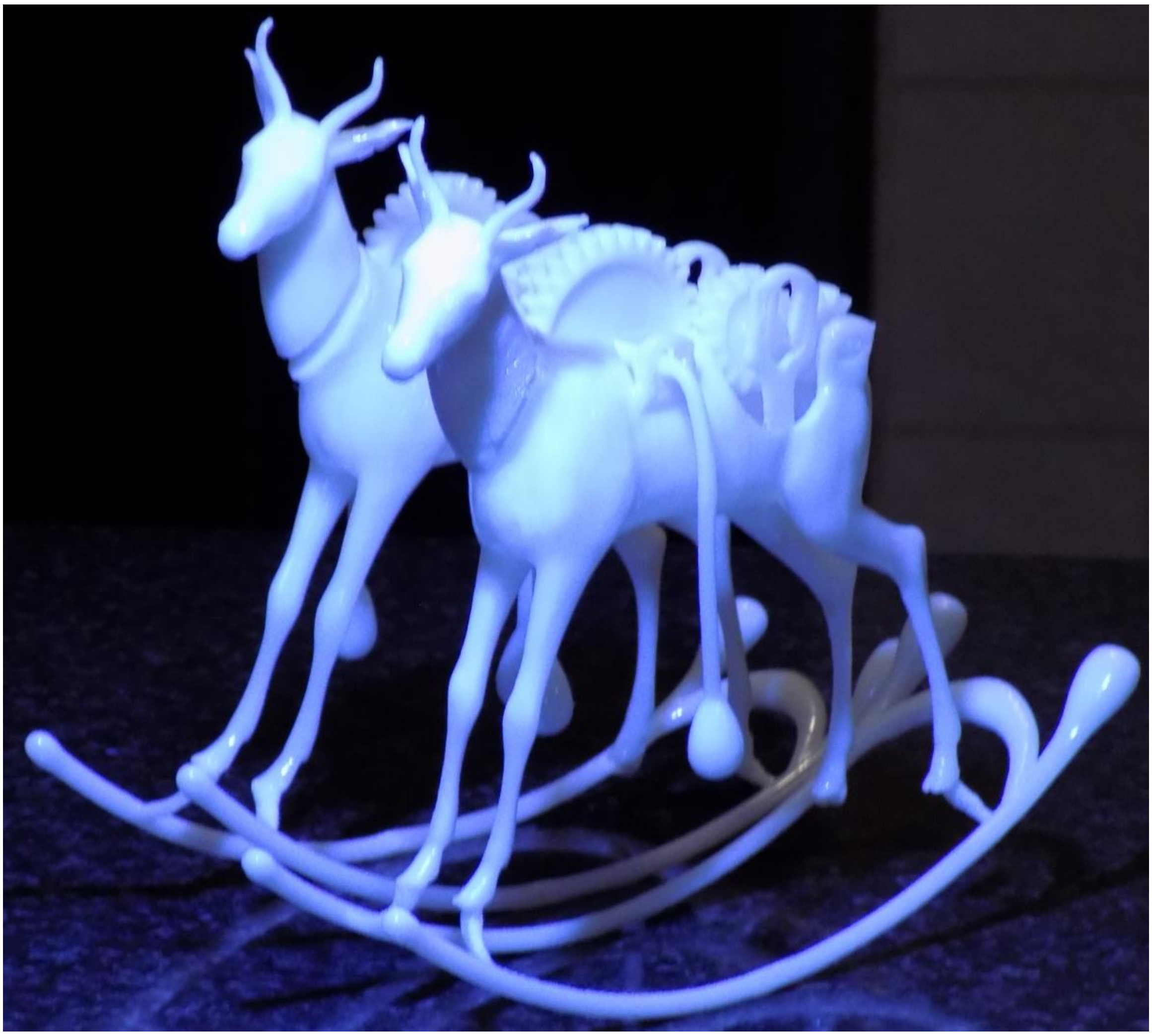

Figure 13 Respondent 6's artefact Rocking Springbuck

The above-mentioned results can be better categorized when they are seen comparatively in the following formats below.

5.1.4 Time it took to print vs time it took to surface finish.

It took respondent one's artefact 43h20 to be produced and overall 35 hours to apply post-production finishing techniques. Respondent two's artefact took 43h56 to be produced and an overall 34 hours to apply post-production finishing techniques. Respondent three's artefacts took slightly longer to produce at 56h18 and took 35 hours to be post-processed. Respondent four's artefact took 83h31 to be produced and a very exorbitant 104h20 to complete post-production finishing. Respondent five's artefacts took 65h50 to be produced and 54 hours to apply post-production finishing techniques. Respondent six's artefacts took 34h18 to be produced and were post-processed for a further 46h46. Figure 14 illustrates the production vs post-processing ratio.

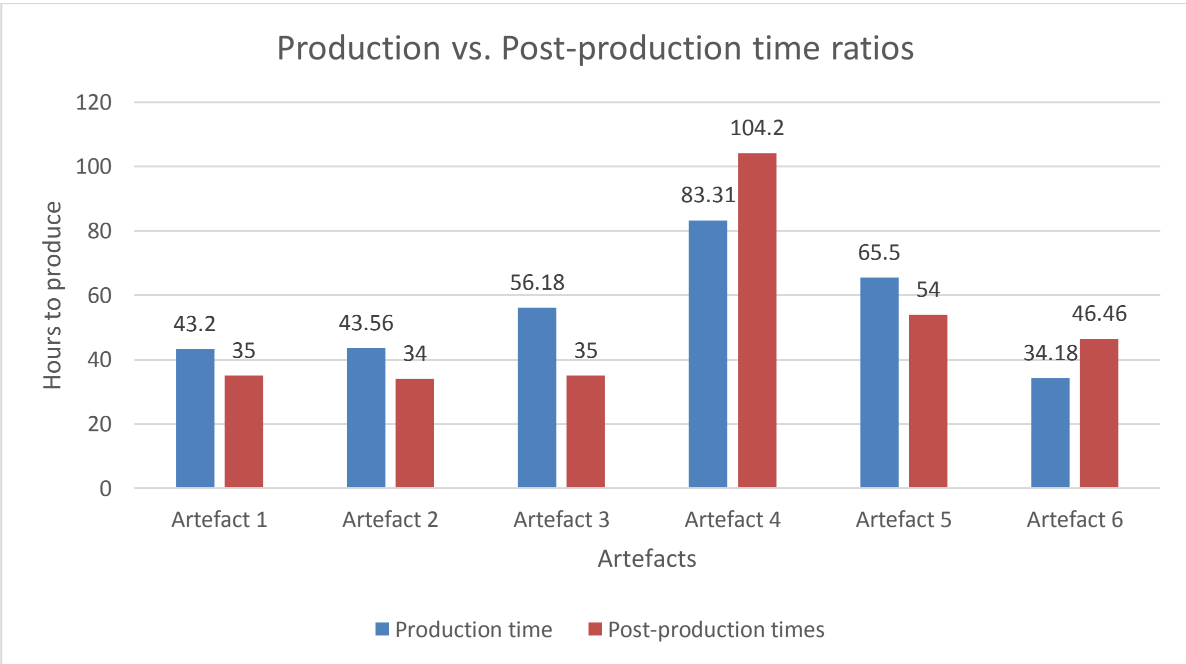

Figure 14 Lead times comparison

5.1.5 Amount of ABS material and acetone used.

Artefact one weighed 336.4 grams, used 200ml acetone for the ABS cement and a further 2000ml to apply vapour fume finishing. Artefact two weighed 350.5 grams, used 200ml acetone for the ABS cement and a further 2000ml to apply the vapour fuming finishing. Artefact three (x2) weighed 423.4 grams, used 250ml of acetone for the ABS cement and a further 350ml acetone for the vapour fuming.

Artefact four weighed a large 528 grams, used 250ml acetone for ABS cement and a further 420ml acetone for vapour fuming. Artefact five (x2) weighed 506.9 grams, used 250ml acetone for ABS cement and a further 800ml acetone for the vapour fuming. Lastly artefact six (x2) weighed 243.4 grams, used 250ml acetone for ABS cement and a further 160ml acetone for vapour treatment. The graph below illustrates the artefact weight vs acetone volume ratio.

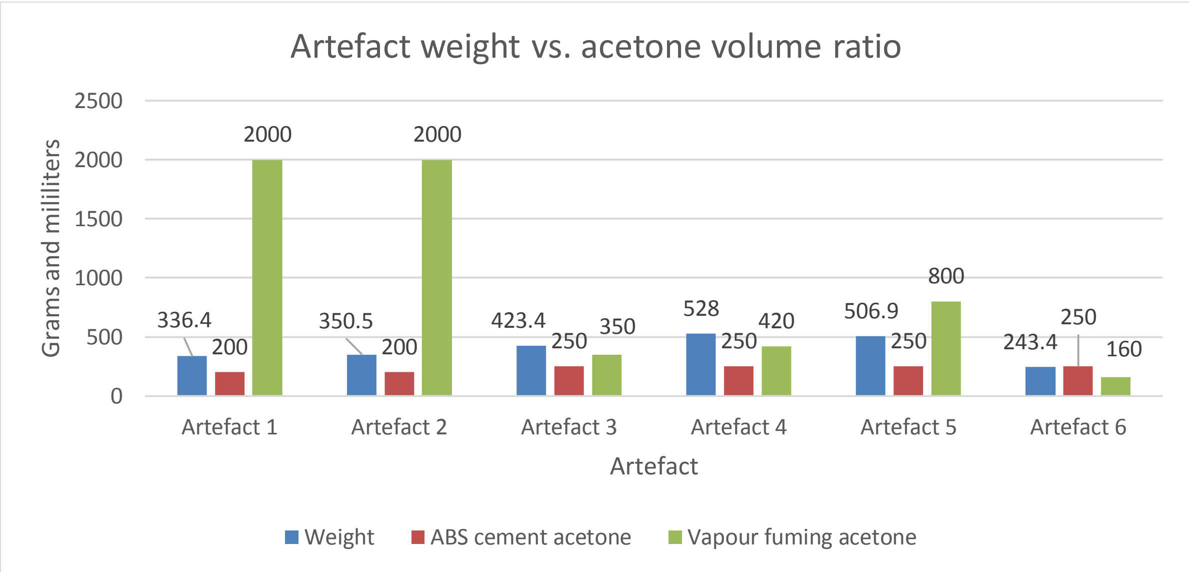

Figure 15 Weight comparison

5.1.6 Amount of failures.

For artefact one, one out of four components failed and weighed 113.2 grams. Artefact two, one out of four failures, weighing 110.8 grams. Artefact three had two of the eight components fail at 23.5 grams. Artefact four had seven out of 65 component failures at 82.21 grams. Artefact five had five out of six failures weighing 110.8 grams and artefact six had four out of 26 failures at 60 grams.

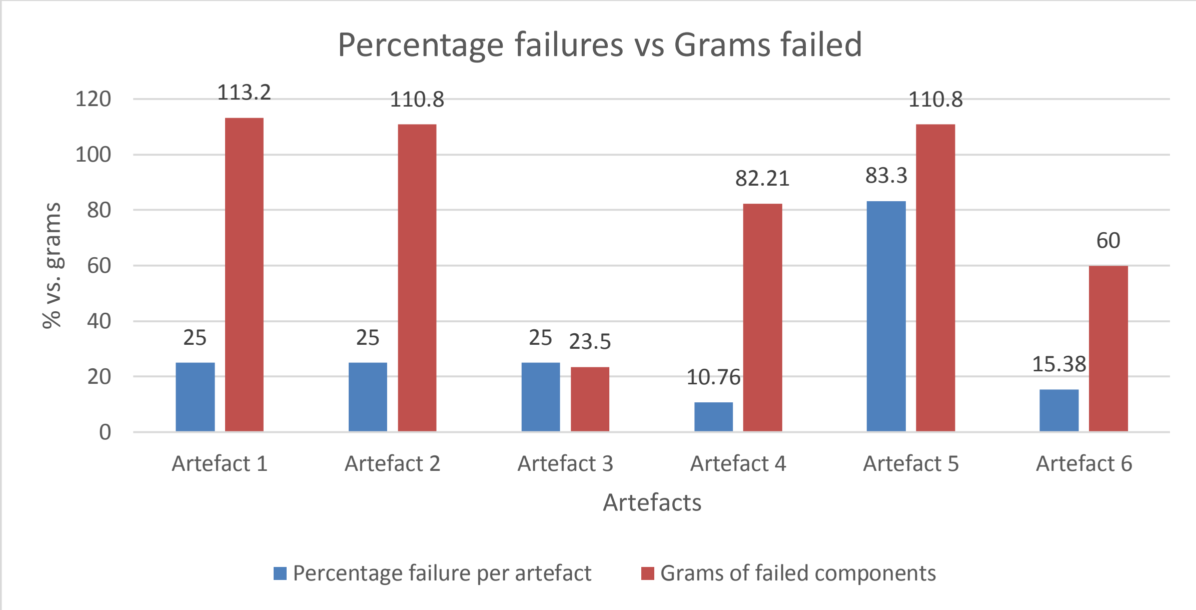

Figure 16 Weight and percentage failures

5.1.7 EOS artefact slice and component comparison.

The first ELFDM artefact was compared to an EOS specimen, which yielded a ratio of 4 to 1, artefact two at 4 to 1, artefact three also 4 to 1, artefact four at 65 to 1, artefact five 3 to 1 and lastly artefact six was produced at 13 to 1 ratio.

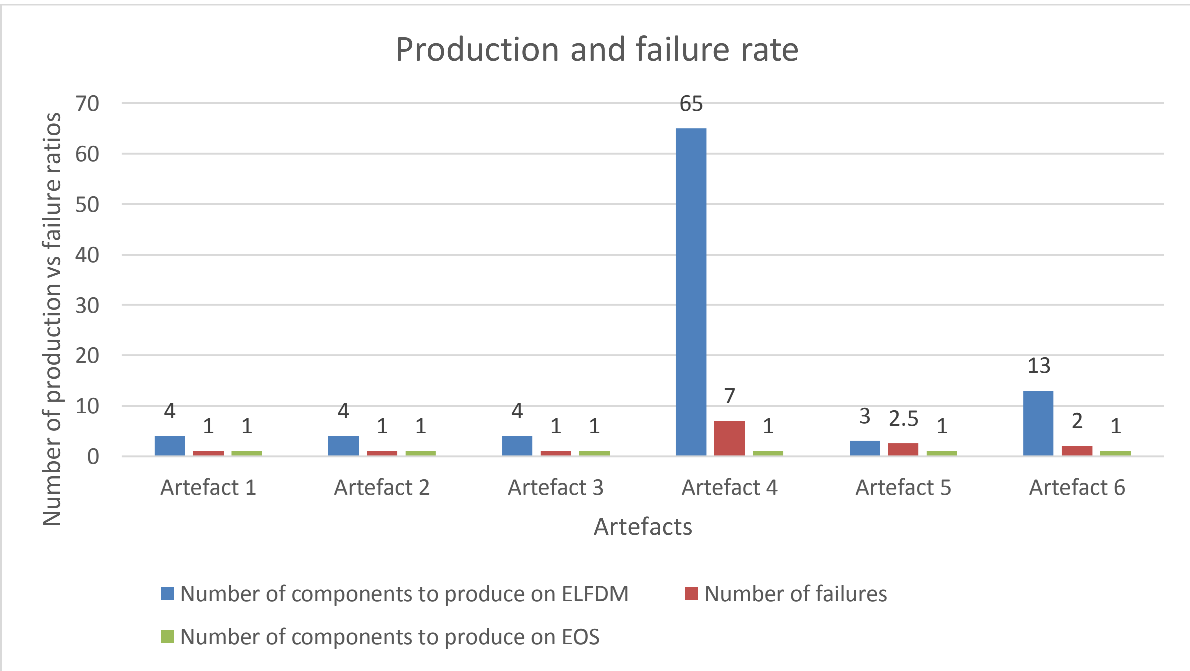

Figure 17 Number of production and failure comparison

5.1.8 Record qualitative observations

Hereafter it was determined by means of deductive reasoning to use a set of questions chosen to focus on the design of the artefacts, the application of post-production finishing techniques and the respondents that need to participate. After the artefacts were reproduced, assembled and post-production finishing techniques were applied, .they were sent to the respondents to have a visual reference point.

It was evident from the mixed method research paradigm that it was necessary to choose two forms of interview. Firstly it was important to select a small (closed) population group of highly experienced/ trained experts in the field of additive manufacturing (AM). There was no need for randomization in the population group as the technology is still evolving and not a lot of people in the general public carry expert knowledge on the research topic. Some of the respondents were from international locations making it easier to conduct online interviews on the SKYPE platform because of logistical reasoning. It was also easier to document electronically.

Secondly a randomized online survey was completed to conclude the qualitative opinions of the respondents. The survey was completed on Survey Monkey and the link[11] was sent to all the respondents to complete randomly at any time before a specified date to ensure anonymity.

5.2. In depth interviews via blog and SKYPE

5.2.1 Compile interviews based on problem statements questions and findings in chapter 4.2.5.

It became immediately evident that the questions needed to determine the biographical background of the respondents followed by their opinions on the post-

[11] https://www.surveymonkey.com/r/QJ6FGGS

production surface finishing techniques and concluding with suggestions and recommendations.

For the biographical questions it was important to ask each respondent what their background was in additive manufacturing and 3D printing. Thereafter it was important to identify the industry they work in, specifically pertaining to 3D printing.

They were then asked what they knew about post-production finishing techniques and whether they prefer to do PPFTs themselves or subcontract it out (outsourcing).

From there the questions asked the respondents about their overall opinions with regard to the step-layering, assembly techniques, surface finish and aesthetic value output of their artefacts.

They then had to debate which area was the most successful, whether the post-production finishing techniques improved or made the quality of the artefact worse.

Thereafter they had to discuss whether they thought these post-production finishing techniques could compete with high-end additive manufacturing processes and whether the skill of the finisher is important in ratio to the finishing technique and the technology.

Lastly, they were asked to suggest improvements for the step-layering, assembly techniques, surface finish and aesthetic value output of the artefacts. This was concluded with their opinions on the future of these techniques in additive manufacturing and their recommendations and suggestions.

5.2.2 Conduct interviews via SKYPE and online survey.

The interviews were conducted over a period that lasted nearly two months as they needed to be scheduled around the respondents' available dates. In total there were six interviews which were done on six days during two months. During the same period of time, the online survey was completed, by the respondents.

The interviews can be summarized as follows and the transcripts of the complete interviews are available in Appendix 3.

5.2.3 Respondents from appropriate background. First set of questions can be summarized as:

Respondent one has been in the additive manufacturing industry since 2004 (12 years). His background comes from graphic design into CAD design for jewellery, to medical implant design and ending off with product development. He has worked both with entry-level and high-end pre-production (CAD), production (printing) and post-production (finishing techniques) on a South African and an International market. He services mainly the artistic, medical and product development sectors making digital sculptures for industrial type production.

Respondent two has been in the industry since 2003 (13 years). His work evolved out of rapid prototyping. He works from within the industrial design and art industries.

Respondent three is relatively new in the industry, working with additive manufacturing technologies for only two years. He crossed over into the 3D printing world through his sculptures and work from within the fine art sector.

Respondent four has been working in the additive manufacturing world for six years. She comes from the graphic design world and from there developed her CAD3D design work through the Rhino software suite.

Respondent five has been working in additive manufacturing since 1996, making this year his twentieth year in the industry. He started off in the jewellery industry and moved over to 3D printing through winning a competition, from there into powder metallurgy through LS. After that he travelled overseas where he got introduced to polyjet systems, vapour fuming and other techniques. His main focus and drive was fashion and jewellery for female lifestyles. From prototyping for moulds he moved into fabrication and finishing where he started working in the medical industry. After this he did medical research for RAPDASA with Terry Wohlers and Deon de Beer. Then he did extensive training at Materialize. At the moment he is involved with all forms of 3D printing finishing. He works from the jewellery, fashion, medical, commercial manufacturing and composites industries.

Respondent six has been in the additive manufacturing world since 2006 (10 years). She did her Post-doctorate in medical design, from where she founded her own company NOMILI creating end products and user ready artefacts. She works from within the fine art and design industries. She creates for herself and does not sell her CAD files for commercial reproduction.

5.2.4 All the respondents carry knowledge about PPFTs and had the following to say about using these techniques:

Respondent one carries knowledge of PPFTs and has worked with them in person. He has done FDM post-production finishing as well as paint and dye selective laser sintered parts. He has also experimented with fusing ELFDM ABS components with ABS cement. Even though he would like to do finishing himself he would rather outsource because of time constraints, not having the right equipment, skills level and labour intensity to finish.

Respondent two does carry knowledge of post-production finishing techniques but non-specific to ELFDM, more focused on high-end hand finishing as well as electro-forming but not specific to vapour treatments. He prefers to do the finishing techniques himself as he feels it is difficult for other people to get the quality that you needed at a reasonable price

Respondent three has limited knowledge about post-production finishing techniques except for vapour treatment that he has experimented with. Even though he does not have a lot of experience he would prefer to do these finishing techniques himself as he would like to gain more experience and does not think it takes a lot of time.

Respondent four has limited knowledge of PPFTs for ELFDM as well as LS, but she does not know how to do them herself. She prefers not to do it herself due to work load and time constraints.

Respondent five has extensive knowledge of PPFTs, having done commercial fabrication of acetone vapouring, ethyl acetate vapouring, cold composites, polymer over-sprays, priming, making material conductive and electroforming. He would prefer to do finishing in-house as it gives him better control over the products outcome.

Respondent six has knowledge of PPFTs. She knows about abrasive sanding techniques and acetone treatment. She designs artefacts specifically for ready-made technologies like the LS processes. She would outsource PPFTs because of her lack of experience, as well as time and space constraints.

5.2.5 Overall viewpoints on the reproduction of the artefacts as well as PPFTs applied:

Respondent one was very impressed with the overall level of detail and quality of the artefact as it was specifically designed for the LS process. The detail of the LS and ELFDM artefacts are very similar. With regard to step-layering he felt the larger areas were more successful as the thin-walled areas and small prints were jaggedly edged and with acetone vaporing detail loss was evident. The respondent, however, agreed he saw a clear difference of improvement where the acetone was applied. He further felt that the assembly techniques were fairly successful but can visibly see the seam lines. Certain areas were more visible than others. He preferred the acetone surface finished areas that covered the seam lines. The very smooth area of the shoe bridge was successful, however he did not like the texture of the smaller sections. Although the respondent felt the artefact was aesthetically pleasing he does not agree that accidents can be incorporated into the design. This kind of finish may work for testing prototypes but not for presentable show piece artefacts.

Respondent two felt he was impressed by the detail. He thought it gave an overall good impression even though the artefact was not designed for this process but for LS. He felt the finishing techniques were successful in making the step-layers less visible and where they are visible it is in places of little importance. He felt that the assembly techniques worked very well even though some of the seam lines were visible. He also felt the surface texture is more successful where the acetone smoothing was added after the ABS cement fused the two components. According to him the aesthetic appeal is less disturbing when applying PPFTs, however it is still not a finished artefact.

Respondent three found the artefacts interesting overall, but preferred the one specimen over the other because it looked less dirty. He can clearly see and identify where more acetone application had smoothed the surface. He felt the assembly techniques were partially successful because cracks and air entrapment were visible on the surface of both artefact specimens. He preferred the smoother surface finish of the first artefact. He felt from an artistic perspective that the accidental acetone infiltration cracks made the artefact more appealing in an aesthetic sense however only in controlled measures.

Respondent four said that she loved the artefact but was slightly disappointed that they needed to be reproduced on a larger scale than the original LS artefact. She felt the step-layers were only vaguely visible when you looked very closely. She also felt that the assembly techniques were successful and barely visible. Surface texture was finished successfully by the acetone but she felt it would be a problem if a less smooth/polished finish would be required. Furthermore she found the visual aesthetical appeal successful and felt without PPFTs the artefacts would not have been successful on ELFDM technology.

Respondent five felt that the step-layers were controlled nicely but with loss of detail. Furthermore he noticed that the artefacts were fused differently and said that with continued PPFTs the artefacts could become commercially acceptable if done as a once off. For batch production this would become problematic. He felt for the surface texture that the areas that received more 'buffing' were more successful, but it was not completed to the standard of high-end commercial production. He cautioned the researcher against moisture build-up/flow areas. He felt under certain conditions these techniques are a viable option to finish EFDM artefacts, but further technique suggestions have been made such as splitting the components and then fusing them. Further information can be found in the next chapter. He concluded that the artefact was successful as a once off aesthetically pleasing object but would become problematic if it is to be reproduced in batch production.

Respondent six did not like low-cost printed artefacts but felt that these artefacts were better that the general standard. She was however impressed by the fact that ELFDN could produce complex geometry. She hypothesised that if you know the limitations you can eradicate most of the problems and that these techniques might assist in narrowing the gap between entry-level and high-end additive manufacturing processes. Previously she would have preferred to incorporate step-layering into her design, now these PPFTs makes it easier to do post processing. She thought the assembly techniques were very successful as she could barely see the seams. She felt the surface texture improved but for the aesthetic value output the answer was more complicated. For the high-end design market that needs to be perfect, the aesthetic appeal was unsuccessful, if seen from an engineering perspective as a visual aid or prototype it might be aesthetically pleasing. From an artistic perspective it definitely is aesthetically pleasing as a finished artefact as well as an armature.

5.2.6 Areas found most successful and whether PPFTs improved or made worse the quality of the artefact:

Respondent one felt the heel and the upper bridge area of the shoe artefact (Figure 18) was most successful but also said that it would be more successful if a consistent surface was followed through. He felt that the application of these techniques did improve the quality of the artefact.

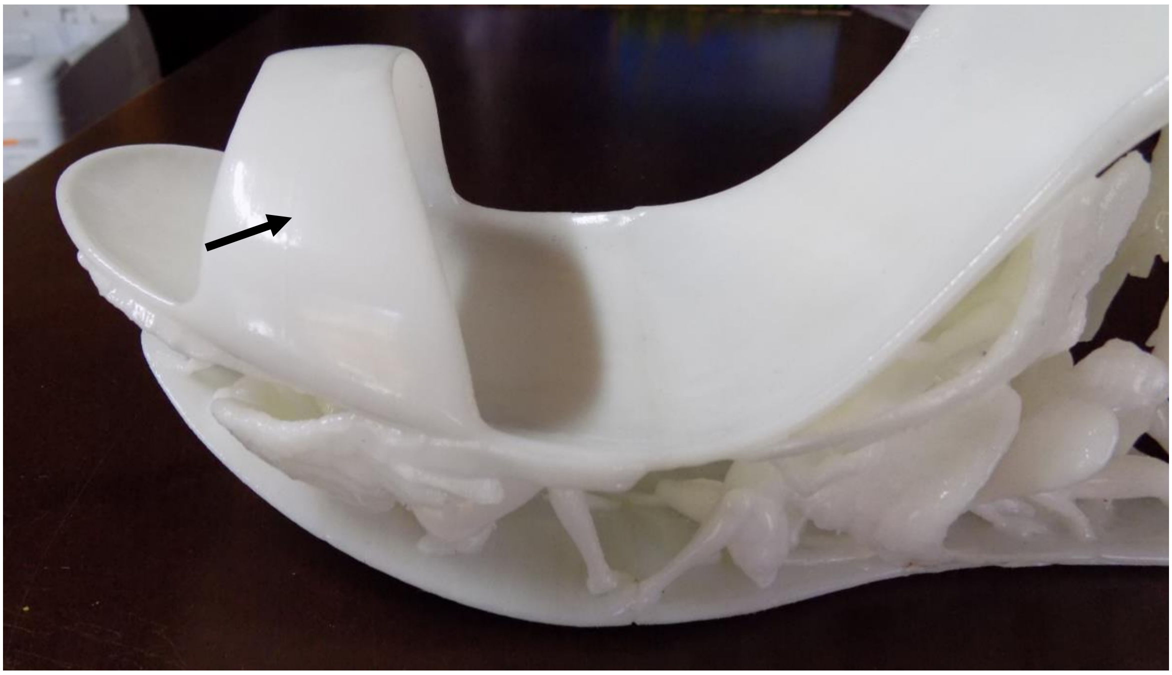

Figure 18 Bridge close-up

Respondent two felt the bridge area (Figure 19) of the shoe was most successful and he felt the PPFTs had improved the quality of the artefact although it was not showroom ready.

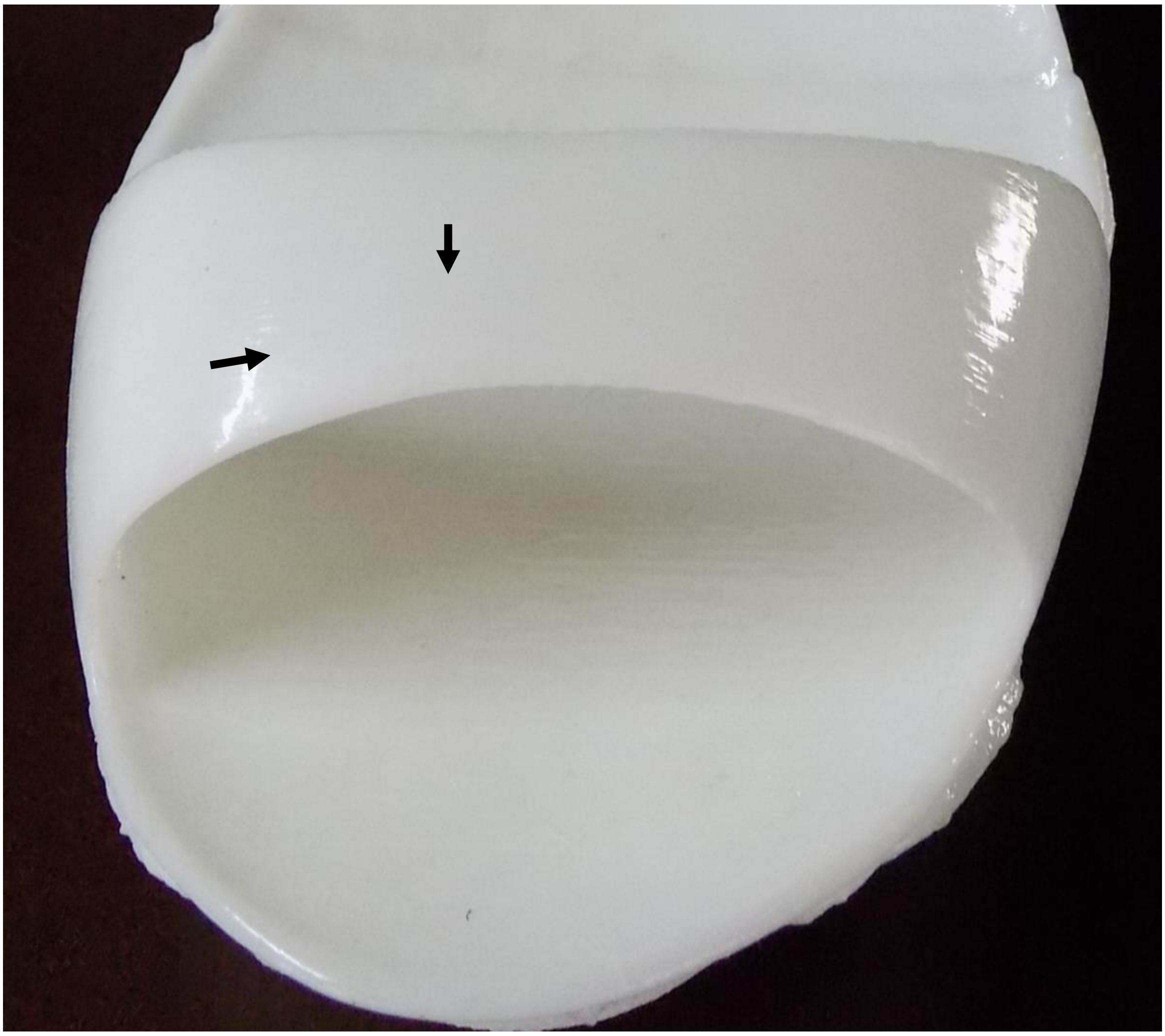

Figure 19 Bridge close up (frontal view)

Respondent three considered the right jaw area (Figure 20) of specimen three as the most successful as the application of the acetone ABS cement made the surface look like skin pores. He therefore found one of the flaws as appealing because of the subject matter of the artefact (dinosaur). He thought that the PPFTs did improve the quality of the artefact.

Respondent four felt that the roof (Figure 21) of the reproduced artefact was the most successful are. Where it was smoothed out and the finer detail of the flowers and railings. She felt that PPFTs definitely improves the quality of the artefact.

Figure 20 Jaw close up

Figure 21 Roof close up

Respondent five preferred the uniformity of smooth finishing in specimen five (Figure 22) from a commercially viable viewpoint. He felt that the PPFTs definitely improved the overall quality of the artefact.

Figure 22 Trophy close up

Respondent six felt that the leg areas (Figure23) where most of the step-layers have been removed to be the most successful. She felt that the PPFTs have improved the quality of the artefact from the raw unprocessed ABS print and was even viable comparatively to high-end production for certain markets if the finishing is pushed through.

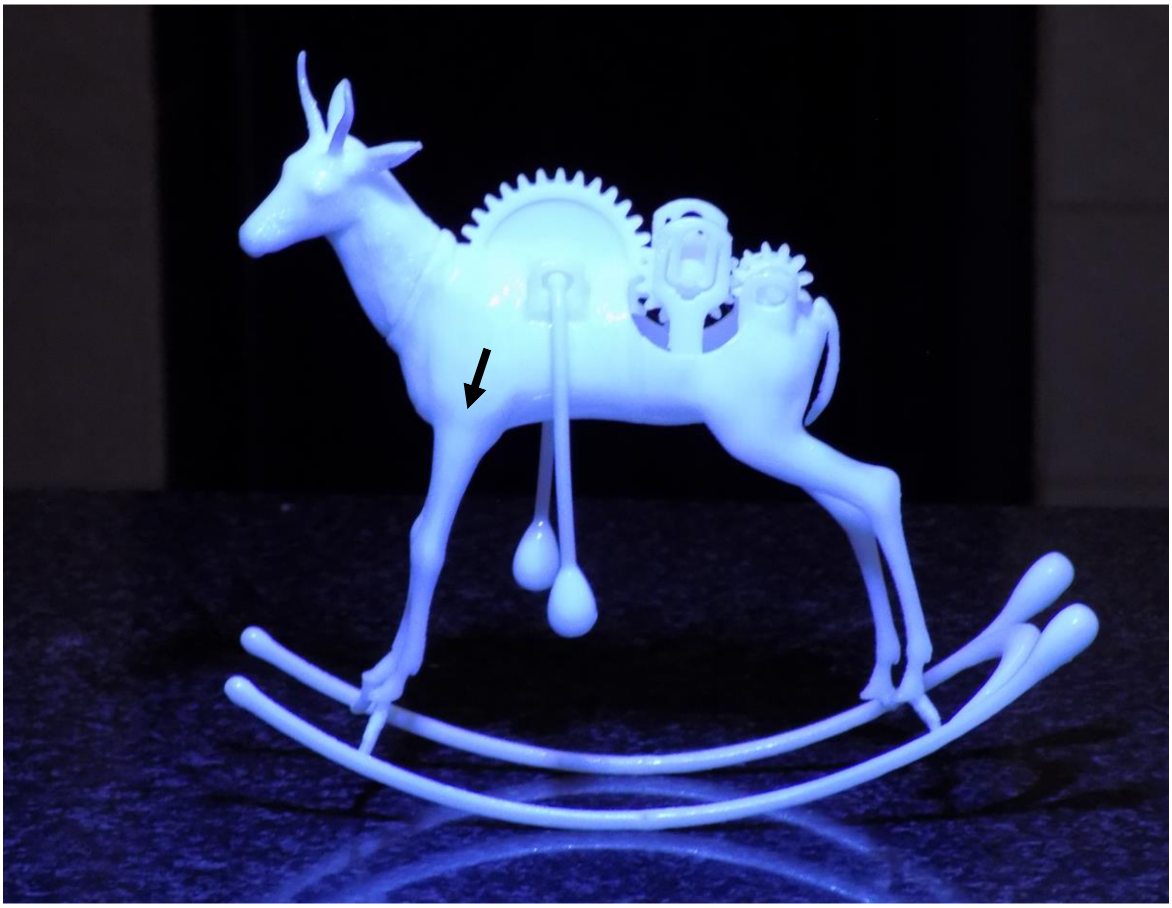

Figure 23 Smoothly finished legs specimen 6

5.2.7 Can PPFTs compete with the high-end additive manufacturing processes and will the involvement of the finishers' skill level influence the outcome:

Respondent one did not feel that these PPFTs make the artefacts ready to compete with high-end additive manufacturing processes. He argues that LS can make final production in one go, that the ABS material is not strong enough and takes a lot of time to surface finish and assemble. He does however recognize that there are shoe designers that make use of ELFDM to produce end products. He does feel that the skill of the finisher plays a very important role.

Respondent two disagreed and stated that these PPFTs could compete merely on the grounds of costing. Depending on the quality you wanted you paid for, but these techniques improve the quality making the margin of error less in ratio to the cost of production. He continued stating that the skill of the finisher plays an important role just by observation of areas that have been finished on the artefact.

Respondent three thought that these PPFTs would assist ELFDM to compete with high-end additive manufacturing but more experimentation is needed by artists. The respondent was uncertain about the involvement of the finishers skill set but indirectly answered that artists and engineers would finish differently depending on their training skill set, from which we can deduce that he does feel that the skill of the finisher is important.

Respondent four thinks these PPFTs are a viable option to compete with high-end production from a point of costing as she feels she can get much larger models for less if you keep in mind to design for the specific technology (ELFDM) that you are working on. She further continued to say that the skill of the finisher would play a role in knowing what to do or not.

Respondent five says that the actual machines cannot compare but directly links what he calls '*hard-skills'* to the finisher and how important it is for the success of competing with high-end manufacturing. With the proper skills the printing technician and PPFTs finisher would be able to compete with high-end additive manufacturing.

Then respondent six (MJvV) felt that the PPFTs had the potential to develop into a viable option if you take the design-for-technology concept into account. She does say that the skills of the finisher would play a huge role in the outcome of the artefact.

5.2.8 Suggest improvements for step-layering, assembly techniques, surface finish, aesthetic value output of the artefacts and the future of these techniques.

Respondent one felt improvements should first and foremost be done on the hardware and software of the printers to attain finer resolution before we can address PPFTs. He felt focusing on where the parts will be split and the orientation of the build would assist the PPFTs process. More detailed surface preparation by means of abrasive sanding was also suggested as well as developing ABS cement consistency and specific tools for assembly application. He further suggested to compensate in the design for the technology, so make the artefact slightly larger if you were going to apply acetone and use abrasive sanding where you would get surface loss. He concludes by saying that he has always advocated surface finishing although it is lacking in the South African market place and that it will be crucial in future additive manufacturing. In his words: "…the finishing is actually the key of taking 3D printing from just doing prototypes to selling products in the market".

Respondent two felt there is room for improvement as he clearly could see a difference between the finishing and assembly techniques of the different artefacts. He is in favour of a more consistent finish and felt hardware development would resolve these issues easier than PPFTs. He further suggested that the skill level of the operator will help improve the PPFTs. Just like respondent one here the respondent suggested that the design be adapted for the technology rather in pre-production than to fix it in post-production. He concluded that if these PPFTs can be adjusted it would help entry-level ABS to be seen as a higher valued production material that will then compete with the high-end additive manufacturing industries.

Respondent three felt there were areas where the techniques could be improved when focusing on the surface preparation by abrasive sanding. He felt there is a definite future for PPFTs to assist industries to obtain end products that are presentable.

Respondent four suggested better control of the PPFTs application could result in less detail loss as well as careful planning when assembling the different components to avoid rough areas. She thought further that incorporating colour into the PPFTs would be an advantage. She felt that PPFTs could help artists to create affordable additive manufactured artefacts for a commercial market and that it would open a path of exploration and experimentation. She does not feel it would impact other industries by taking away from them but rather to add to itself, to become an industry on its own.

Respondent five suggested a focus on the orientation of the build would help eliminate step-layers as a form of pre-production control. He agrees that there are not a lot of choices available except acetone to perform PPFTs on ELFDM artefacts. He felt that PPFTs will definitely grow as a viable addition to additive manufacturing and said that the higher the technology will develop the higher the need for a specific skill set would be. At some or other point a formalized form of course training would develop and would need to be run in parallel. These techniques will lessen the gap between high-end and entry-level because the high-end will reach a ceiling in its development without the addition of post-processing.

Respondent six suggested that in the event that fine layer printing cannot be achieved certain parts should be moulded, especially when it comes to functional parts like gears. Overall she felt that a more thorough approach to finishing could eliminate surface roughness better, making the artefacts more successful. She also suggested that a white glazed paint could be added to obtain a more consistent visual appearance. She concluded that for the artist and small business end-user the use of PPFTs would become more important, but not in the mass production arena.

The online survey can be summarized as the following and is available in detail in Appendix 4.

Firstly the respondents were asked if they knew what post-production finishing techniques (PPFTs) are. From their responses it can be deduced that all respondents (100%) had a clear understanding of what PPFTs are and therefore marginalize the population group to industry specific experts. It was necessary to marginalize the group for the specified outcomes. We were not trying to establish whether a random sample group carried knowledge about PPFTs but whether industry specific experts have knowledge on the topic of post-production finishing techniques. The fields identified were industrial, engineering, design and fine art. All of the respondents knew what PPFTs are.

It was important to establish whether the respondents have been exposed to any of the post-production finishing techniques to validate their viewpoints as industry experts. Although all the respondents are experts in their respective fields, only 66.67% have used PPFTs on ELFDM 3D printed artefacts. Some of the reasons were that their exposure to these finishing techniques was limited. Most of the respondents have had exposure to high-end LS processes because of its accuracy in detail and ability to reproduce the same artefact. They therefore have had no need to use the ELFDM process before but were aware of the PPFTs used in low-cost production. That includes 33.33% of the group.

Thereafter it was decided to determine if the respondents felt that PPFTs are important for ELFDM. Half of the respondents (50%) felt that PPFTs are "very important" for entry-level 3D printing. A third of the respondents (33.33%) felt it was "important" and only one sixth of the respondents (16.67%) felt it was "moderately important". This indicated clearly that the respondents are all of the opinion that PPFTs are important to finish off entry-level 3D printed artefacts.

Then the respondents were asked to rate the success of PPFTs on ELFDM produced artefacts. Half of the respondents (50%) felt that PPFTs are moderately successful on entry-level FDM artefacts. One third (33.33%) felt is a successful process while only one-sixth of the respondents (16.67%) felt it is very successful. Even though there are a variety of responses, all of them are in the success range showing that all respondents across their respective fields of expertise felt that PPFTs were a successful post-production finishing method.

The question of whether PPFTs could establish a niche market to compete with high-end additive manufacturing was then asked of the respondents? 83.33% of the respondents felt that PPFTs could support the establishment of a niche market that would narrow the gap between high-end and entry-level additive manufacturing. Only 16.67% of the respondents felt that this could only apply if the artefacts were used for display purposes. Overall it can be documented that all respondents therefore felt that PPFTs will assist in narrowing the gap between entry-level and high-end FDM 3D printing.

Then reflecting back to the reproduced artefacts, respondents were asked to judge the success of using acetone ABS cement glue as an adhesion method. 83.33% of the respondents felt that acetone cement glue can be used successfully on entry-level FDM artefacts. However 16.67% of the respondents felt that they are indecisive about the cements' success rate and responded that it seems to depend on the size of the artefact surface area that need to be assembled.

Respondents were then asked to determine if their artefacts would still be successful if they need to be split into smaller sections to accommodate the limited build size of the UP MINI 3D printer. 66.67% of the respondent felt conclusively that splitting the artefact into components to accommodate the UP MINI build size limitation was successful. Only one respondent (16.67%) felt the answer was conditionally yes, depending the outcome of the surface finish. Lastly one of the respondents (16.67%) felt that it is not a viable option at all. Opinions included that the layout of the parts (sections) are important and are part-specific. Some respondents also responded that successful surface finishing should be applied to hide any seams from fusing the components together. One of the comments stated that the artefact can only be used for a display example when using this ‘splitting’ of the artefact and it cannot be seen as a usable end-product.

Respondents were then asked to reflect about the structural integrity of the artefacts and whether applying these PPFTs compromised the quality. Half of the respondents (50%)[12] thought that the structural integrity of the artefact is not compromised by acetone gluing/ ABS cementing the components together after production. 33.33% of the respondents however did feel that the structural integrity is compromised, making the artefact weaker when seen as a functional part. A response was made stating that it depends on the original structure of the artefact and where it was split. This respondent was uncertain.

The respondents then had to decide whether the acetone surface finishing improved the aesthetic visual output value of the artefact. All the respondents (100%) are of the opinion that acetone surface finishing improves the aesthetic value of the reproduced ELFDM artefacts. It can therefore be be assumed that the artefacts are visually more appealing after surface finishing was done with acetone. However it should be noted that one of the respondents commented that it is only successful if a glossy finish is required and loss of detail may occur in the event of overexposure to acetone.

Lastly the respondents had to decide whether PPFTs can be considered as a competitive alternative to high-end additive manufacturing. 83.33% of the respondents agreed that there is a good chance of acetone finishing competing with high-end AM as an alternative method and only 16.67% felt there is a moderate change. It can therefore be deduced that all respondents felt there is a change of competing with high-end AM.

[12] Note to the reader: Respondent 4 by accident omitted question 8 by double clicking their answer, therefore the researcher has adapted the original graphical representation to reflect the complete submission. The respondents answer was NO, and are verifiable via the post interview email correspondence.

Some comments suggested that it depends on the context and geometry of the artefact. Another suggests that it competes from an aesthetic viewpoint rather than from a functional side, they also felt that the size of the object, intricacy and precision of the artefacts plays a role, meaning the larger the artefact the more likely the technique would succeed. Lastly it was suggested that it is only successful from a visual display viewpoint as there is detail loss with the application of acetone.

There are very clear indications that support and contradict some of the notions that were brought under discussion when looking at the above results. This is very evident with regard to the development vs limitations, shortcomings, aesthetic outputs and cost effectiveness of entry-level fused deposition modelling. The idea that pure empirical data establishes the validity of an aesthetic artefact in 3D printing seems very lacking and the above-mentioned findings clearly motivates such a notion.

The following chapter will focus on a discussion that will encourage the validity of why both quantitative and qualitative data were analysed and that a mixed method approach reflects the data in a parallel setting that complements each other.

Chapter 6: Discussion

6.1 Combined data collection and interpretation

As this explanatory sequential mixed method research study developed it became clear that both the quantitative as well as the qualitative phases needed to ask specific research questions to address the nature of entry-level manufacturing and its relation to high-end additive manufacturing.

The one cannot exist without the other and are intertwined and should be seen in parallel. The figure below illustrates what these questions were and how they applied to all the phases and stages of this study.

Table 9 Quantitative and qualitative research questions

Quantitative	Phases	Qualitative
Which techniques and how can they be applied to post-production surface finishing?	Pre-experimental pilot study	Why would PPFTs influence aesthetic output of artefact and lead to gap between ELFDM and art?
What are the requirements for apparatus that can be constructed to assist surface prep and customization?	Phase one, Stage one: Apparatus design	What improvements must be made to entry-level fused deposition modelling technology to enhance aesthetic value in visual art and design?
Which tech and standards are best suited to test strength & surface texture roughness? What are typical values of surface finish, etc. that can be achieved?	Phase one, Stage two: Test strip samples	What PPFTs can be implemented to improve the surface finish of entry-level fused deposition modelling in visual art and design?
To what extent can finishing techniques successfully be implemented in visual art?	Phase two: In depth interviews	What determines the aesthetic value of surface finishing techniques on entry-level fused deposition modelling in visual art?

6.1.1 Quantitative discussion:

6.1.1.1 Types of techniques and how it was applied

For the first pre-experimental study it was important to identify potential techniques that could be applied and this was done successfully. However these techniques were only observed from the researchers' subjective qualitative viewpoint as they were applied directly onto proof of concept artefacts. They were created merely for the researcher to identify potential techniques that would be researched further in the two phases of the study.

6.1.1.2 Apparatus construction to assist surface preparation and customization

Apart from possible post-production techniques, it was also necessary to investigate the appropriate apparatus design and requirements needed to safely practise these finishing techniques. The investigation fulfilled the outcome by identifying an Acetone Vapour Chamber (AVC) design. The AVC went into prototyping phase during which the researcher identified similar techniques possible through a makeshift apparatus that were less laborious and safer for the maker-space consumer.

It is worthy, however, to mention that there are various prototypes and commercial AVC's available on the market, but these are very costly and therefore does not apply or fall in line with the outcomes of this study, which is to support and develop the entry-level fused deposition market place. It was decided to make use of a makeshift cold fuming AVC due to same parameters and controls that needed to be maintained. No photo documentation was included of first prototype as it was not completed.

It was decided to move away from subdividing the acetone exposure method. Originally there was a focus on AVC's as well as acetone dipping/ bathing. Although the acetone dipping produced less invasive results than the acetone vaporing, the results were very similar. The researcher therefore decided to focus on the more aggressive exposure of acetone vapour fuming for clearer results in the last phase of the research.

6.1.1.3 Which technology and standard are best to test strength and texture

For this phase the researcher looked at two formats of acquiring quantitative data. Firstly it had to establish the tensile strength and for that a MONSANTO, then

INSTRON and lastly a MTS tensometers were used to collect the data. The data where analysed and the parameters built around the ISO 527-2:2012 standard. The first specimens that were tested on the MONSANTO tensometer had to be redesigned to accommodate the equipment. ISO standards was used as a guideline to adhere to the formulae of tensile testing, but the full scope of the data was never analysed as that was not the aim of the study. Tensile testing was used to set control parameters for plastic strength and measure the influence of chemical exposure on said plastic.

The researcher merely wanted to make use of the standards to identify the parameters and observe any fluctuations between the recorded data. Furthermore, the researcher also observed the data from a design perspective and not as an engineer, so the outcomes of the data analysis reflect somewhat differently than usual data collection in this format.

It was also important to collect the surface profile measurements to observe how the application of these techniques would affect the actual outer surface roughness of the artefacts as previously discussed. Two different surface profile measurement apparatus were used. The first was a SJ210 Mitutoyo surface tester at CRPM CUT in Bloemfontein and the latter was a Dobamoni that was used at The Science and Technology Park, VUT, Sebokeng, to measure the different profiles.

The Standards that were used were ISOTC213:1997 and ISO 25178-1:2016. The reader should take note that ISOTC213:1997 is only for reference purposes and not seen as an accepted ISO standard at the time of publication. The standard is still known as ISO 4287:1997 'Geometrical Product Specifications (GPS)'.

6.1.1.4 Typical values of surface finish to be achieved

Although a whole array of results were collected during the tensile testing, it was only of interest to the researcher to focus on the ultimate tensile strength (UTS) as well as the elongation of the specimens (stress/strain ratios).

All the ABS specimens showed a reduction in tensile strength from between 3% to about 55%. Most of the filaments tested were in the lower affected ranges, meaning the acetone did not affect the specimens enough to raise concern for structural integrity damage. However this could be debated depending on the outcome/purpose of the artefact. If it is a functional artefact/prototype even 3% reduction can have an influence on the performance or function.

For the profile roughness the focus was mainly on Amplitude parameters: Rz (top – valley) and Ra (mean value) measurements. The (R) represents the profile parameters [Roughness parameters] (ISO 4287:1997 and ISOTC 213 N 159). The ideology was that if a clear reduction in Rz and Ra values can be observed, the researcher could hypothesise that the application of acetone post-production finishing techniques improved the surface roughness reduction. That quantitatively supported the notion that these techniques improve the aesthetic value of the reproduced artefacts.

The results showed an astounding surface roughness reduction percentage when the specimens were exposed to acetone as can be seen in other research (Schuetz 2002). The dipping samples reflected over 80% reduction in surface roughness and the vapour samples indicated over 90% reduction. This conclusively verified that the acetone very successfully manipulated the surface texture and could therefore be used to investigate the respondents' observations in the qualitative phase.

6.1.1.5 Extent of post-production finishing techniques implementation in visual art

The above mentioned results led the researcher to critically ask to what extent these techniques can then be implemented in art and design. The results created the base on which the research could stimulate the respondents in the qualitative phase to see if and how these techniques could be implemented.

6.1.2 Qualitative discussion

The pre-experimental pilot study dealt with a whole array of techniques scoped from across the internet via blogs and immediately identified the first qualitative question: Why would post-production finishing techniques (PPFTs) influence the aesthetic output of the artefact and lead to a gap between EL3DP and art? This prompted the researcher to think critically about the background setting for collecting data from the respondents to form a cohesive opinion.

To understand how post-production techniques can influence the aesthetic value of artefacts the researcher had to first go back and address/identify the environment and industries involved, to establish who the experts were so to speak. Then see what they knew about these finishing techniques and how they would react to low cost reproduction on entry level, of their artefacts (that were originally created for a high-end manufacturing platform).

The researcher then had to identify what the respondents deemed successful and what they would feel can improve this finishing technology. This addressed the two research questions of phase one that stated what improvements must be made to entry level fused deposition to enhance aesthetic value as well as which techniques best suited this technology. Lastly the question had to be answered about what determines the aesthetic value output of surface finishing which is why the interviews had to be constructed to provide subjective expert opinions that could not be collected from pure empirical data collected in the quantitative phase.

The researcher will now discuss the findings from Chapter 5 to motivate responses for the above-mentioned questions.

6.1.2.1 Respondents' backgrounds and industry

It was very important to create a delimitation of the population group so the experience/knowledge of the group would not be watered down. All the respondents had knowledge of post-production finishing techniques and had been working in the industry between 2 to 20 years. Of the six respondents four had more than 10 years' experience in the field of additive manufacturing.

All the respondents come from specialist fields that included art, graphic design, jewellery, medical (commercial prosthesis design), product design, industrial design, fashion design, commercial manufacturing and composites industries. The majority of them have some or other form of artistic background but limiting the field of research to art, design and industrial application which were the areas of focus for this study.

6.1.2.2 Respondents' knowledge of PPFTs and choice of usage

All the respondents have knowledge of PPFTs however some have not used any of the techniques. Half of the respondents feel that they would prefer to do surface finishing themselves. The reasons stated was that you can control your products outcome better when doing it yourself as well as giving yourself more experience by doing it in-house. The other half of the respondents felt it would be better to outsource PPFTs because of time constraints, laborious work, lack of skill, limited experience, space constraints and not having adequate equipment. A consensus cannot be reached as both sides raise valid arguments. It does seem to have an influence when we take skill and experience into consideration and this will be discussed this further down.

6.1.2.3 Overall impression of reproduction and aesthetic value output

Most of the respondents were impressed by the level of detail, overall surface finish and complexity of geometry that was achieved by reproducing and applying these PPFTs to their artefacts. Not a single observation was made that the application of post-production finishing techniques made the visual quality of the unprocessed artefacts worse.

Although most respondents felt that the step layers were adequately controlled by applying acetone and in some instances were only vaguely or not visible at all, some felt that it was more successful on the larger areas and more visible on smaller areas that are less controllable. However even in areas where it was visible, it was agreed that the PPFTs did improve the surface.

Out of all respondents only one felt that the assembly techniques were not successful, pointing out subsurface acetone vapour entrapment and surface cracks. The rest of the respondents felt that the assembly techniques were fairly successful to very successful. One respondent did suggest that acetone combined with burn scarring could weaken the tensile integrity of the artefact.

The surface texture improved according to all the respondents, however not necessarily to a completed standard for high-end commercial production due to the fact that the specimen artefacts were not completed. It was also suggested that the surface finish is need-specific; if for example a non-glossy surface is needed then acetone is not successful unless a further technique could be used.

Some of the respondents reacted negatively towards the notion that mistakes can be incorporated into the artefact during post-production and felt that the artefact should be as precise and accurate as the CAD files and renderings. Although all respondents felt the artefacts are aesthetically pleasing and more appealing after PPFTs were applied, they also felt the artefacts were not commercially viable as end-products. They continue that with more skilled and repetitive technique application the artefacts could become more aesthetically acceptable in the design industry. This however applies to once off artefacts as batch production would be virtually impossible to repeatedly duplicate the exact same object. In the engineering fields there are some grey areas as it depends on the application of the artefact. If it is used as a visual display prototype it would be aesthetically acceptable, but not as a finished design. In the art industry the artefacts are seen as successful aesthetically appealing specimens.

6.1.2.4 Areas of success and suggested improvements.

It was very clear from all the respondents that the application of PPFTs was indeed successful from a qualitative perspective. All respondents felt these techniques improved the quality of the artefact but for various reasons. Most of the respondents felt that the smoothing of acetone vaporizing on the surface appealed to them most when the areas of interest were observed however one of the respondents reacted positively towards application mistakes where the surface became porous and leaving a skin pore texture.

6.1.2.5 Can ELFDM compete with high-end AM and develop skills?

All of the respondents except one felt that the PPFTs makes these techniques viable to compete with high-end manufacturing. Most argued just from a costing perspective alone it is already competing with high-end processes. The main argument against its viability was the strength of the ABS material as well as the laborious time it takes to finish. All of the respondents felt that the skill set of the finisher is of very high importance and one respondent linked the success of competing with high-end manufacturing with what he called ‘hard-skills’. Therefore it can be deducted that the PPFTs and the skillset of the operator/finisher are inseparable and of equal importance.

6.1.2.6 Suggested improvements for PPFTs and reflecting on future of this technology in AM.

Most of the respondents felt that hardware and software improvements should develop before we look at the PPFTs. They also suggested the development of application tools for PPFTs and felt that designing for the technology would assist in making PPFTs a simpler method of approach. Skill set training would increase the sustainability of PPFTs according to some of the respondents. One of the respondents linked the development of PPFTs directly to the progress of high-end machine development suggesting they run in parallel.

All of the respondents felt that there is a future for PPFTs in the foreseeable years to come. Some suggested that developing PPFTs would assist in raising the value impression of ELFDM ABS material.

One respondent felt that PPFTs will impact the art world and small business sectors because of its' once-off-produced nature. She did not think PPFTs will influence the larger high-end additive manufacturing industries. Corroborating her statement another respondent also suggested that PPFTs will develop in their own right as an industry, rather than taking away or directly influencing other high-end industries.

The above discussion can be summarized in Fig 24 below, that clearly state the overall findings that the qualitative phase produced.

The next chapter will conclude the overall findings by providing evidence that the objectives of the study was met with clear indication.

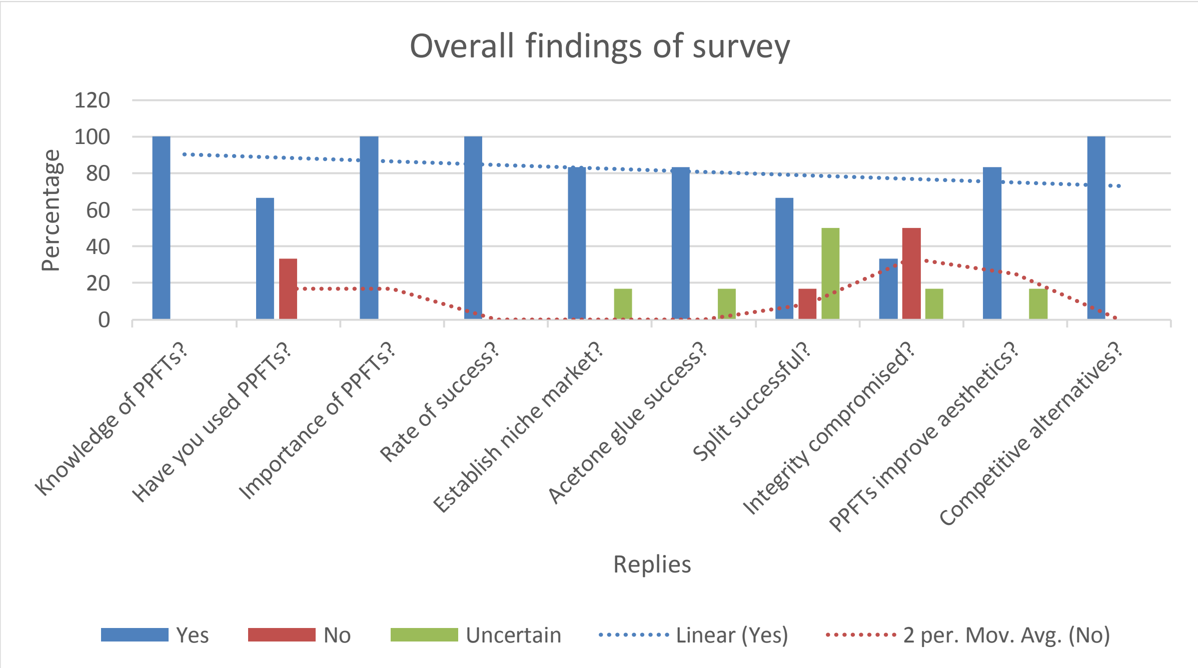

Figure 24 Survey overview

6.2. Cross reference with other existing research opinions.

6.2.1 Compare and contrast results with existing academic, blog and industry specific experts.

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While (Bual & Kumar 2014) as well as (Wohlers 2014) indicate that ELFDM suffers from poor quality that can inhibit the aesthetic value of artefacts, the researcher postulates that such opinions derive from a pre-production and production perspective. These opinions do not necessarily reflect on the nature or value of post-production processing and verifies why this studies results are making an impact on the gap in the industries of additive manufacturing.

It is very clearly indicated through the interviews that all of the respondents agree that the entry-level fused deposition modelling industry is growing as was earlier indicated by (Brooks, Slater, Sofos and Whiteside 2015). There exists a clear need to improve the quality of entry-level produced artefacts and the research argues that this can be done from a post-processing perspective. There also is a need to develop the software and hardware of entry-level 3D printers but the value of post-processing can just as well be argued from a qualitative aesthetic artistic perspective. As respondent five indicated, the high-end industry will reach a peak without the simultaneous development of post-processing techniques to supplement the quality and aesthetic outputs of ELFDM artefacts.

A number of researchers have started addressing post-production finishing in their respective fields and industries, but none of them has addressed the aesthetic output of post-production finishing techniques on actual artefacts for design and art (Brooks et al. 2015, Percoco et al. 2012, Galantucci et.al 2010 and Bual & Kumar 2014). Both the tensile tests and surface profile measurements of this research can be corroborated with Galantucci and Percocos' results. Showing a clear indication of surface roughness reduction and limited decline in tensile strength.

Since the commencement of this study the researcher has only found one other researcher (lise_skytte_jakobsen)[13] who addresses the aesthetic aspects of 3D printed artefacts in her study titled: “Print a thing! Analysis of the aesthetic meaning of 3D printing with emphasis on how artists, designers and architects currently use 3D-printers”.

In her research proposal she states that: “… amidst the technology excitement there is a lack of knowledge about what we print and what kind of aesthetic issues are associated with this particular access to translate two-dimensional images into three-dimensional objects”. It is this lack of knowledge (directed specifically to post-processing) that led the researcher on the quest to observe the nature of the gap between high-end and entry-level production and arguing that these techniques will have a profound influence towards the development of the technology.

Jakobsen continues with: *“There is a great awareness that the proliferation of 3D printing will give us crucial new understanding of ‘things’ and the aesthetic experiences of things – and affect our way of thinking creative processes and design in general*”.

This is in line with the outcomes that are addressed in (Campbell, de Beer and Pei’s 2011) paper in which they outline their Roadmap for South Africa, where an entry-level alternative may assist in constraints bound to high-end manufacturing.

The next chapter will conclude these results and discussions as well as provide adequate evidence that the objectives of this research study have been met to assist the reader in understanding the broader ideologies of aesthetic value outputs for the different industries. It will also focus on areas of recommendation that can further enhance the future of developing post-production finishing techniques in ELFDM and other AM industries.

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13 http://pure.au.dk/portal/files/93389939/Post_Doc_Project_Description_Print_a_Thing_lise_skytte_jakobsen_short_english_version.pdf
Website: http://pure.au.dk/portal/en/persons/id(c69c7dc4-8fbc-4fe5-9071-7b22687a2ca6).html

Chapter 7: Conclusion and the future of ELFDM

7.1. Conclusion

It was important to provide evidence that utilizing post-production finishing techniques could improve the quality of entry-level fused deposition modelled artefacts. When such a notion is addressed and corroborated it would provide evidence to argue that the gap between entry-level and high-end additive manufacturing is lessened.

This, in turn, provided evidence that the technology will be more accessible to a larger spectrum of prosumers because of the inclusion of low-cost production with an increased quality. Both the quantitative data as well as the qualitative responses provide clear evidence that the technology will develop either independently as a stand-alone or as an addition to the growing additive manufacturing and artistic worlds. There are various debates about the place of such a post-processing technique system, but everyone agrees that post-production finishing techniques are here to stay. It is just a matter of whether it will develop inside the parameters of additive manufacturing or become more adaptive in its own sense.

Furthermore, it was desired to examine whether feasibility could be drawn from investigating assembly techniques on entry-level fused deposition modelled artefacts. If larger artefacts can be produced on very small ELFDM machines, the limitation of the build size would be addressed which could change their usage expectations. This, in turn, could affect the aesthetic value and outputs of such artefacts. The study successfully provided evidence to corroborate this. There however remains an argument about the validity of the artefacts' quality and visual appearance. Some respondents felt that the technology is just not quite there yet and that the techniques are successful for use on prototypes but not on finished end-user products and artefacts. The different schools of thought seem still to be influenced by their own background experience and training to some extent. People from a pure design background support the precision of the technology rather than a more organic evolution as usually seen in an artistic environment.

The quantitative data produced clear evidence to support that the structural integrity of these artefacts is affected adversely. The tensile strength of the artefacts are slightly weakened by applying acetone post-production finishing techniques. However this is not to say that it is a negative result as it depends on the use of the artefact. If its' use is purely for visual purposes then obviously it will have null effect on the artefact. If however it is a functional object, the situation would be different. It might also be of interest to mention here that the ductility of the ABS plastic increased with exposure to post-production finishing techniques therefore this could influence the artefact positively for functional objects. At the end of the day it all depends on the intended function of the artefact.

So the question arose whether these post-production finishing techniques could eventually then become a cheaper competitive alternative to high-end additive manufacturing and could that then influence the aesthetic value output of entry-level produced 3D printed artefacts? The answers were very concise and clear that if you are willing to sacrifice quality over cost, then the answer is yes. However skill set development (hard-skills) could have a huge influence on the quality of the finished artefact. With improved tool development and advanced post-production finishing technique skills it definitely would be a much cheaper alternative and would increase the aesthetic value of entry-level produced artefacts.

Another area of concern that came up was whether the development of these techniques could help improve the recycling of the waste material produced from the raft and support material. Although the researcher decided not to go into too much depth into the matter, a substantial amount of repurposing was brought into effect by lessening the amount of waste material. This was done by repurposing the waste material generated during printing production into the ABS slurry/ cement. It therefore has an impact on addressing wastage. See further recommendations for more information.

Lastly, the study aimed to look whether the application of post-production finishing techniques could stimulate the development of new techniques. If so, would it also affect the gap in the market between the entry-level and the high-end production industries? It does seem very certain that new techniques will develop out of this growing field exponentially. This study did not provide any new techniques that were developed but it did address the known techniques in an academic setting where it previously was only used in the maker-space. There are clear indications from the respondents who were interviewed that not only do the post-production finishing techniques need development but also the tools used for apply such techniques. It is also clear that it would influence more prosumers in different creative sectors by making use of entry-level fused deposition modelling for the creation of artefacts.

As was shown in Chapter 6, Figure. 24, all the respondents gave a positive feedback arguing for the implementation and use of acetone as a post-production finishing technique for entry-level fused deposition modelling.

It can therefore be concluded that post-production finishing techniques are recognized as a competitive alternative in the AM world that could improve the overall aesthetic value output of entry-level fused deposition model produced artefacts.

7.2. Recommendations for future research

There is a strong need for the development of entry-level fused deposition modelling (ELFDM) printing techniques and how it will fall in line with the conceptualized Roadmap to RSA (Campbell et al. 2011). In previous papers the researcher also discussed that a need existed to further introduce entry-level fused deposition modelling (ELFDM) additive manufacturing (AM) in the South African education system. Further development of the technology into a viable and sustainable option would stand opposed to more expensive alternatives in such an event. Advancing post-production finishing techniques and structural integrity research of such entry-level artefacts could assist in attaining these goals.

Further there exists an array of debates about the best ratios of chemical exposure. Unmistakably the literature reviewed motivates further investigation on the use of acetone for surface profile manipulation as researchers like Rao (Rao, Dharap, Venkatesh & Ojha 2012), Galantucci and Percoco (Galantucci et al., 2010) all utilized different ratios of acetone to water mixtures. If some consensus towards a ratio guide could be developed it would assist post-processing finishers.

Chemical analysis is recommended to ascertain which structural components of the polymer is weakened during the acetone exposure. Some form of dehydration/

brittleness seems evident after exposure but cannot be speculated on without the support of further scientific data analysis. Respondent five made a suggestion that future research could be done on a finite element analysis to determine the deviations and distortion caused by post-production finishing techniques.

Dimensional and weight displacement and increased ductility in the specimens are also areas that could bring to light the behaviour of the ABS material when exposed to acetone. Although some research (Galantucci et al. 2009) exists on the matter it is purely from an engineering perspective and should be investigated from a design perspective as well.

Some of the acetone-dipped specimens in ABS as well as the PLA specimens in cold vapour fuming indicated an increase in tensile strength and should be investigated as a matter of high priority as this will address improved tensile strength with the addition of improved aesthetic surface finishing. Not enough data was collected during this study to conclusively corroborate this increase in tensile strength.

Recommendations can be argued to implement technique adjustments as well as pre-production considerations that might be advantageous to the successful application of acetone finishing in entry-level fused deposition modelling (ELFDM). The creation of designs specific to entry-level machines is such a suggestion that could be taken into consideration. During production the orientation of the build may assist in depositing more accurate detail. For the post-production phase more controlled application methods and further prolonged post-production finishing technique application may assist in obtaining a more commercially acceptable artefact. A more detailed study of the above is suggested for future examination.

Some of the respondents suggested that research on the ideal consistency of the ABS cement may be advantageous to control the assembly techniques and needs further investigation. They also suggested specialised tool development for the application of these assembly techniques instead of common household utensils like ear-buds and tongue depressors. As previously stated some respondents suggested that 'hard-skills' development will be crucial for the development and implementation of post-production finishing techniques.

Lastly the exploration of colour addition to post-production finishing techniques was proposed and this could be advantageous to narrow the gap between entry-level and high-end manufacturing. In addition to this, the experimentation of painterly techniques was suggested for a future recommendation to achieve better consistency in the overall visual aesthetical appeal of entry-level fused deposition modelled (ELFDM) artefacts.

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Appendices

Appendix 1: Data sheets for Quantitative analysis:

- **Sebokeng VUT 2014**

No quantifiable results exists for this first pre-experimental stage of the research. All hypotheses were derived from qualitative visual documentation by the researcher.

- **Loughborough/Sebokeng 2015**

INSTRON UTS RAW DATA:

Name	A:	B:	C:	D:	Weight	Offset yield Stress	Modulus MPa	UTS MPa	Strain at UTS mm/mm	Stress at break	Strain at break
A Dip	20,2	10	3,7	150	7,2	13,37533	1503,59	16,817	0,0186	15,688	2,09
A Dip	20,4	9,8	3,8	150,2	7,2	14,64745	1524,71	19,068	0,0187	17,616	2,98
A Dip	20	10	3,8	150,1	7,2	15,54148	1577,60	19,639	0,0184	18,261	2,39
A Dip	20	9,9	3,7	150	7,1	14,11978	1513,98	18,119	0,0187	14,843	2,24
A Dip	20	9,72	3,7	150	7	12,05775	1335,38	13,253	0,0186	12,369	2,49
XTC	20,6	10,1	4,2	150,5	8,2	22,247	1703,49	23,211	0,0172	20,619	2,22
XTC	20,2	10,2	4	150,2	7,6	27,0921	1982,52	28,935	0,0185	28,141	1,97
XTC	20,6	10,2	4,3	150,4	8,2	31,53684	2011,89	33,265	0,0207	31,914	2,36
XTC	20,2	10,3	4,3	150,2	8	32,22288	2197,86	35,107	0,0201	35,107	2,01
XTC	20,4	10,2	4	150,3	7,8	26,47809	1899,71	28,355	0,0191	26,870	2,18
Control	20,4	9,8	3,8	150,3	7	18,91932	1539,30	20,637	0,0178	17,510	2,26
Control	20	9,8	4	149,8	7,2	15,37718	1361,85	15,800	0,0147	15,379	1,58
Control	20	9,8	3,9	149,7	6,5	15,06901	1323,44	15,392	0,0145	14,695	1,59
Control	20	10	3,72	150,2	6,6	15,92475	1441,70	16,388	0,0137	13,497	1,39
Control	20	9,8	3,8	149,6	6,8	15,81793	1401,69	17,471	0,0167	16,740	1,82
A Vap	20	9,9	3,94	148,7	7	14,56435	1458,84	17,109	0,0209	16,880	2,88
A Vap	19,7	9,7	3,9	148,2	6,8	14,28998	1497,98	16,256	0,0209	15,883	2,79
A Vap	20	10	3,95	149,9	7,2	15,9786	1623,61	17,717	0,0209	16,997	3,24
A vap	20	10	3,8	149,9	7	14,85278	1536,53	16,072	0,0168	15,086	1,78
A vaP	20	10	4	148,4	7	15,11123	1585,86	16,804	0,0203	15,760	2,36
Sup g	20,1	10	4	149,9	7,4	20,76732	1729,06	22,405	0,0172	21,600	2,00
Sup g	20	10	4	149,6	7,2	20,41376	1669,79	21,535	0,0155	21,535	1,55

Sup g	20	10,2	4,1	149,7	7,2	21,8712	1844,61	22,968	0,0161	22,385	1,75
Sup g	20,1	10	4	149,6	7,4	20,88179	1776,51	21,920	0,0159	21,414	1,68
Sup g	20	10,1	3,9	150,2	7	21,21542	1747,82	22,642	0,0169	21,657	2,01

- **Sebokeng/ CRPM CUT 2016**

Name	A:	B:	C:	D:	Weight	Offset yield Stress	Modulus MPa	UTS MPa	Strain at UTS mm/mm	Stress at break	Strain at break
BK PLA	19,84	10,03	3,98	149,82	7,9	26,62	1827,30	34,1	0.029	34.14	2.5
BK PLA A	20,16	10,26	3,97	149,72	8,1	27,45	1857,76	37,1	0.028	37.12	2.7
BK ABS	19,05	9,99	4	150,06	6,6	16,16	1095,54	22,1	0.030	22.52	2.9
BK ABS A	18,78	9,99	4	149,56	6,7	13,54	1097,58	20,6	0.030	20.57	3.1
Black ABS +	20,09	10,37	3,96	149,23	6,7	19,41	1251,65	24,0	0.028	24.03	2.6
Black ABS + A	19,92	10,4	3,97	148,74	6,8	10,41	1334,71	10,9	0.011	10.87	1
UV Sunburn Cameleon ABS	20,23	10	4,02	149,82	7	12,81	1330,12	12,9	0.014	12.91	3.1
UV Sunburn Cameleo ABS A	19,05	10	4,09	149,92	7	12,03	1321,91	12,4	0.013	12.42	1.2
UV 33 ABS	19,31	10,02	4,13	149,73	7,1	13,35	1432,81	13,5	0.015	13.48	5.0
UV 33 ABS A	19,1	9,64	4,13	149,66	7	11,27	1425,57	11,8	0.018	11.80	2.8
Pacific Blue ABS	20	9,99	4,01	149,49	7	12,93	1414,95	13,1	0.027	13.13	5.0
Pacific Blue ABS A	20,2	10,02	4	149,4	7	11,78	1388,69	12,3	0.014	12.30	1.5
Hips A	19,94	10,08	4,04	149,85	6,6	10,46	1278,43	11,8	0.015	11.83	1.6
Super Silver PLA	20,35	9,99	4,08	150,07	8,2	17,63	1077,640	27,0	0.042	26.97	3.8
Nylon Comp	19,97	10,09	3,98	149,52	7,2	8,862	531,950	25,6	1.363	25.57	128.9
Nylon Comp A	19.8	10.07	4	149.79	7	6,966	457,309	23,2	1.515	23.78	115.1
ABS white	20.1	9.98	4.02	149.59	6.7	19,45	1368,36	23,4	0.030	24.25	2.3

ABS white A	19.98	10	3.99	149.87	6.9	-0,17	1358,49	12,0	0.013	12.68	1

- **Complete surface texture measurements comparison:**

- **Sebokeng VUT 2014**

No quantifiable results exists for this first pre-experimental stage of the research. All hypotheses were derived from qualitative visual documentation by the researcher.

- **Loughborough/Sebokeng 2015**

1	A Dip	1,138	1,276	2,414	1,207	3,218	3,609	6,827	3,4135
2	A Dip	0,316	2,939	3,255	1,6275	0,894	0,965	1,859	0,9295
3	A Dip	1,591	1,889	3,48	1,74	4,499	0,636	5,135	2,5675
4	A Dip	1,149	1,613	2,762	1,381	0,336	4,562	4,898	2,449
5	A Dip	0,414	0,259	0,673	0,3365	1,144	0,734	1,878	0,939
6	XTC	0,427	0,567	0,994	0,497	1,209	1,604	2,813	1,4065
7	XTC	0,612	0,255	0,867	0,4335	1,731	0,723	2,454	1,227
8	XTC	0,104	5,948	6,052	3,026	0,294	16,82	17,114	8,557
9	XTC	0,149	0,894	1,043	0,5215	0,422	2,529	2,951	1,4755
10	XTC	1,229	0,542	1,771	0,8855	3,477	1,533	5,01	2,505
11	Control	4,695	4,628	9,323	4,6615	13,27	13,08	26,35	13,175
12	Control	18,15	8,228	26,378	13,189	51,34	23,26	74,6	37,3
13	Control	5,567	6,798	12,365	6,1825	15,74	19,22	34,96	17,48
14	Control	4,382	1,9	6,282	3,141	12,39	5,375	17,765	8,8825
15	Control	4,382	3,577	7,959	3,9795	12,39	10,11	22,5	11,25
16	A Vap	0,223	0,222	0,445	0,2225	0,632	0,628	1,26	0,63
17	A Vap	0,381	0,209	0,59	0,295	1,077	0,593	1,67	0,835
18	A Vap	0,277	0,275	0,552	0,276	0,784	0,779	1,563	0,7815
19	A vap	0,187	0,281	0,468	0,234	0,531	0,795	1,326	0,663
20	A vap	0,197	0,186	0,383	0,1915	0,558	0,527	1,085	0,5425
21	Sup g	5,016	5,082	10,098	5,049	14,18	14,37	28,55	14,275

22	Sup g	5,756	4,132	9,888	4,944	16,25	11,68	27,93	13,965
23	Sup g	3,911	6,895	10,806	5,403	11,06	19,49	30,55	15,275
24	Sup g	2,607	11	13,607	6,8035	7,374	31,11	38,484	19,242
25	Sup g	1,569	2,519	4,088	2,044	4,437	7,124	11,561	5,7805

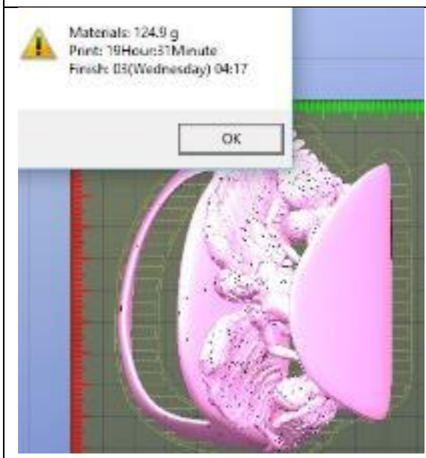
- **Sebokeng/ CRPM CUT 2016**

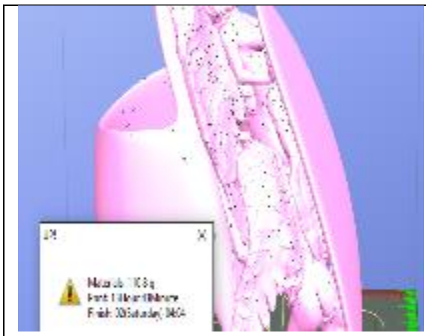
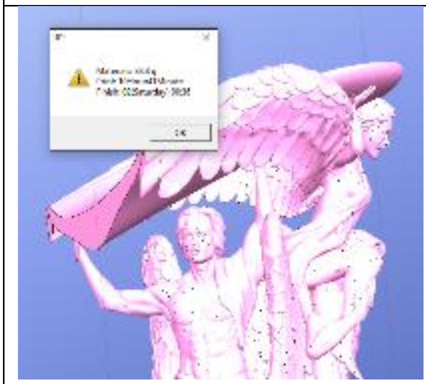
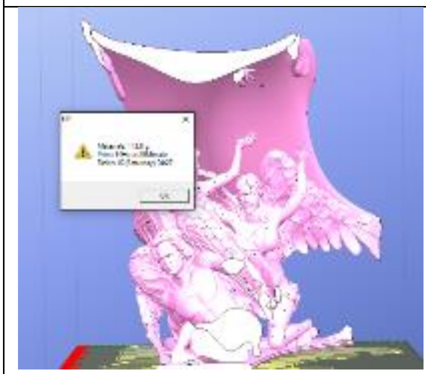
NAME	Ra	Rz	Rq	Rt
Black ABS	1.643	4.6475	1.9665	4.6935
Black ABS A	0.433	1.2265	0.494	1.238
Black ABS +	1.7565	4.968	2.0435	5.0175
Black ABS + A	0.1915	0.5415	0.195	0.547
ABS White	3.635	10.277	3.9665	10.3775
ABS White A	1.067	3.019	1.4345	3.049
UV Sunburn Cameleon ABS	2.5465	7.2025	2.906	7.274
UV Sunburn Cameleon ABS A	1.53	4.327	1.5655	4.37
UV 33 ABS	1.596	4.5145	1.6955	4.5595
UV 33 ABS A	1.508	4.265	1.6155	4.307
Pacific Blue ABS	2.574	7.28	2.911	7.3525
Pacific Blue ABS A	2.353	6.655	2.5135	6.721
HIPS STD	3.408	9.6365	3.734	9.734
Hips A	1.53	4.327	1.6075	4.37
PLA Super Silver	4.541	12.84	4.8065	12.965
Black PLA	0.613	1.734	0.6345	1.751
Black PLA A	0.812	2.2965	0.8255	2.319
PLA White	2.232	6.311	2.544	6.371
PLA White A	1.11	3.1395	1.494	3.171
Nylon Comp	3.9995	11.311	4.3085	11.423
Nylon Comp A	4.5405	12.835	4.729	12.965
0 400mc Fortus	12.905	31.49	13.83	36.855
0 Side 400mc Fortus	0.664	1.878	0.784	1.897
45 400mc Fortus	20.37	57.615	20.77	58.185

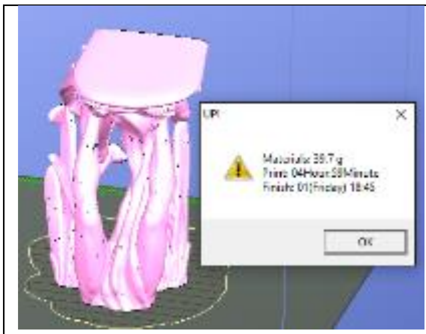
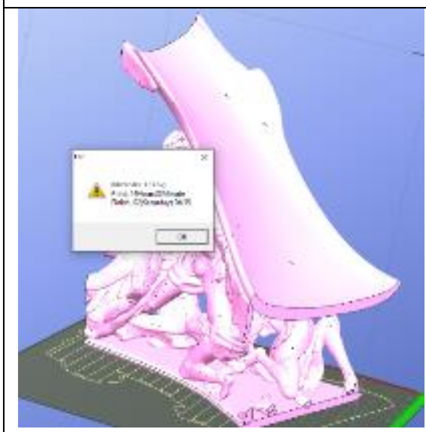
90 400mc Fortus	16.925	47.865	16.88	48.34
0 250mc Fortus	5.1485	14.555	5.3695	14.7
0 Side 250mc Fortus	0.6555	1.855	0.683	1.8735
45 250mc Fortus	21.745	61.49	21.87	62.1
90 250mc Fortus	16.345	46.24	16.305	46.7

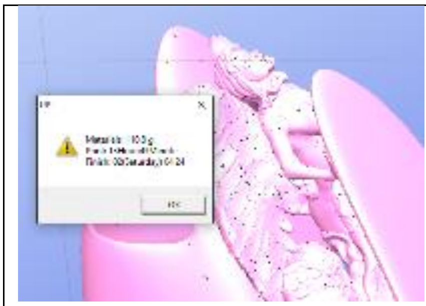
Appendix 2: Visual and info documentation:

2.1 Respondent 1 and 2 : PvdW & LTD

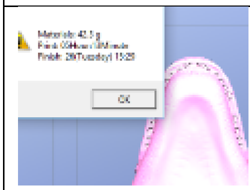
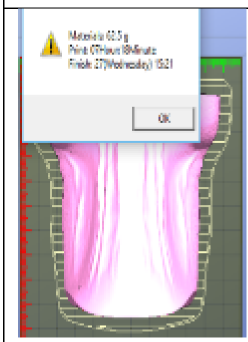
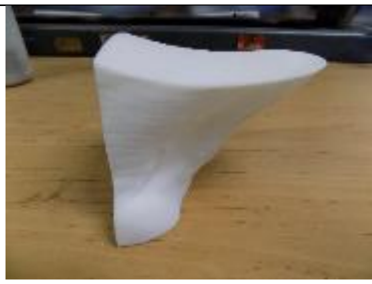
Philip van der Walt and Lionel Dean		
		• Print fail due to electricity being switched off (breaker overload?) • Support material cleaning time: NONE • Surface finishing Sanding: NONE • Grams 113.2g
		• Print successfully completed. • Support material cleaning time: 5 hours • Surface finish: acetone (2hrs) and superglue (Cyanoacrylate). • Substantial sanding done on the top of the heel tip to remove uneven surface layers. • Sanding: NONE • Grams: 35g

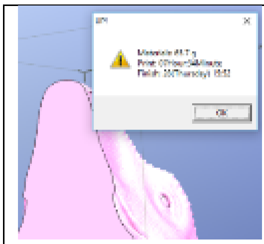
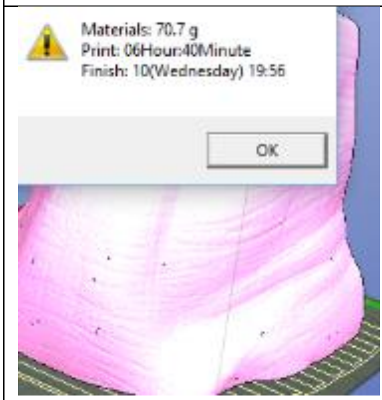
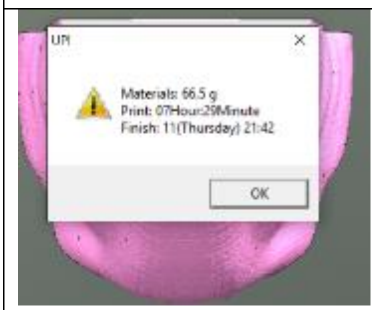
		• Print successfully completed. • Support material cleaning time: 8 hours • Surface finish: acetone (2hrs) and superglue (Cyanoacrylate). • Sanding 2hours • Grams103.6g
		• Printed successfully but with strong step layers visible due to the printing orientation underneath the top of the heel. • Support material cleaning 6 hours • Surface finish: acetone (2hrs) and superglue (Cyanoacrylate) • Sanding 2hours. • Grams: 87g
		• Print successfully completed. • However a large sections had burn scars leaving the part too dirty to finish and use. • Support material cleaning time: 5 hours • Surface finish: NONE • Sanding: NONE • Grams: 110.8g

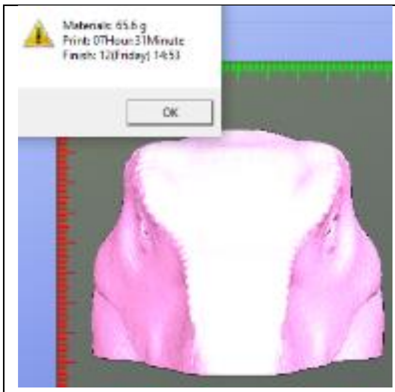
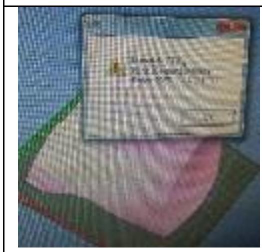
		• Print successfully completed. • Support material cleaning time: 2 hours • Surface finish: acetone (2hrs) and superglue (Cyanoacrylate). • Sanding: NONE • Grams: 35g
		• Print successfully completed. • Support material cleaning time: 5 hours • Surface finish: acetone (2hrs) and superglue (Cyanoacrylate). • Substantial sanding done on the top of the heel tip to remove uneven surface layers. • Sanding: 2hours. • Grams: 85.2g
		• Print successfully completed. • Support material cleaning time: 5 hours • Surface finish: acetone (2hrs) and superglue (Cyanoacrylate). • Sanding: 2hours • Grams: 120.3g

		• Print successfully completed. • Support material cleaning time: 5 hours • Surface finish: acetone (2hrs) and superglue (Cyanoacrylate). • Sanding: 2hours • Grams: 110g

2.2 Respondent 3: WvdH

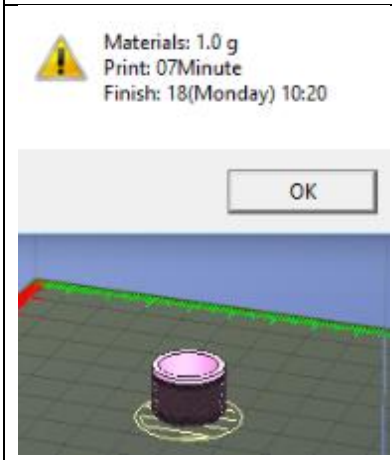
Willie van der Heever		
		• Printed successfully • Very little support material was generated. • Support material cleaning time: Less than 5 minutes. • Surface finishing: 2hours abrasive sanding followed by 3hours acetone exposure by cold vapor fuming. • Grams: 40.1g
		• First print cancelled due to warping of the raft. • No support material was generated. • Support material cleaning time: None • Surface finishing: None • Grams: 12.8g

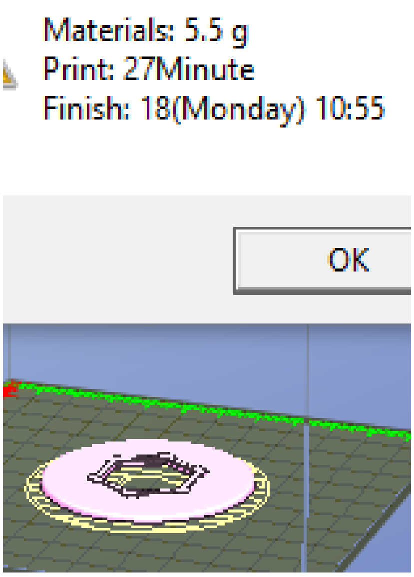
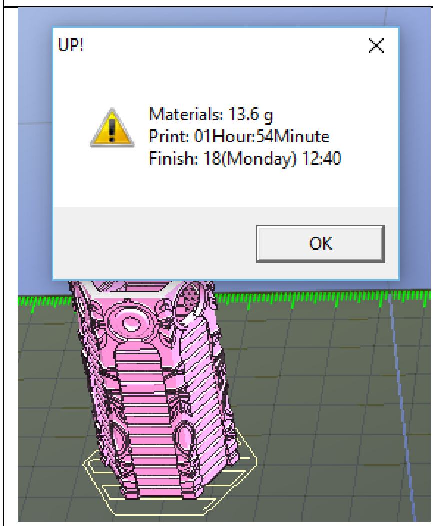
		• Printed successfully • NO support material was generated. • Support material cleaning time: 0 minutes. • Surface finishing: 2hours abrasive sanding followed by 3hours acetone exposure by cold vapor fuming. • Grams: 65.3g
	ONLY RAFT PRINTED. NOT DOCUMENTED	• Print failed due to electricity failure • No support material was generated. • Support material cleaning time: 0 minutes. • Surface finishing: None • Grams: 10.7g
		• Printed successfully • No support material was generated. • Support material cleaning time: 0 minutes. • Surface finishing: 2hours abrasive sanding followed by 3hours acetone exposure by cold vapour fuming. • Grams: 68g

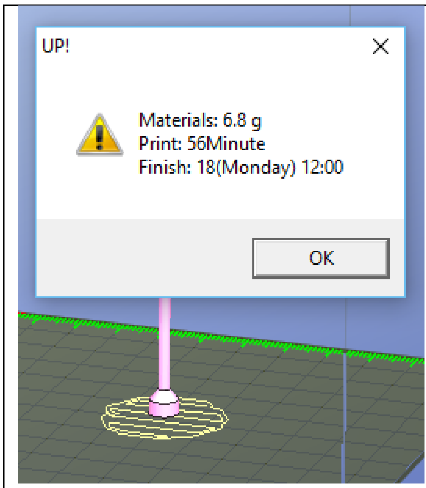
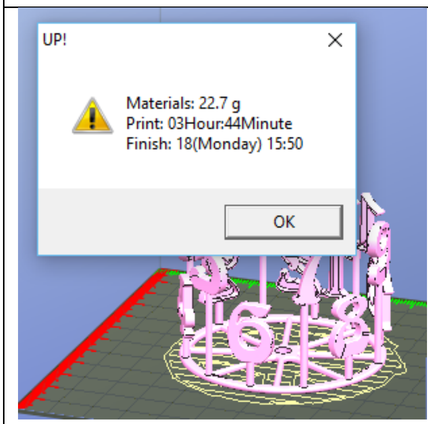
		• Printed successfully • Very little support material was generated. • Support material cleaning time: 0 minutes. • Surface finishing: 2hours abrasive sanding followed by 3hours acetone exposure by cold vapour fuming. • Grams: 67.7g
		• Printed successfully • No support material was generated. • Support material cleaning time: 0 minutes. • Surface finishing: 2hours abrasive sanding followed by 3hours acetone exposure by cold vapour fuming. • Grams: 64.3g
		• Printed successfully • No support material was generated. • Support material cleaning time: 0 minutes. • Surface finishing: 2hours abrasive sanding followed by 3hours acetone exposure by cold vapour fuming. • Grams: 61.8g

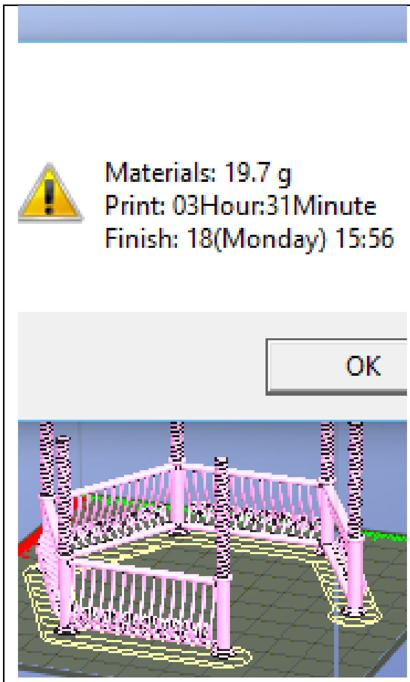
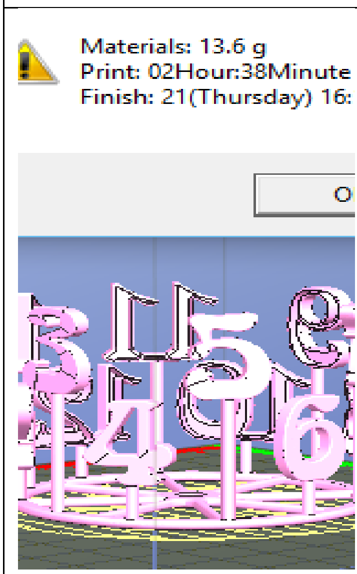
		• Printed successfully • No support material was generated. • Support material cleaning time: 0 minutes. • Surface finishing: 2hours abrasive sanding followed by 3hours acetone exposure by cold vapour fuming. • Grams: 65.2g

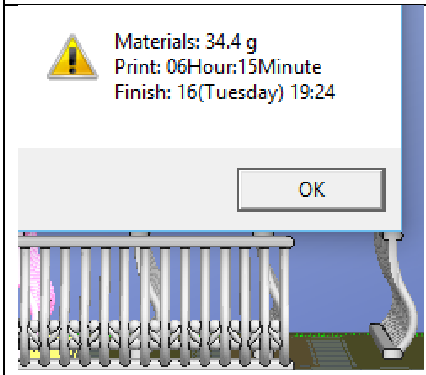
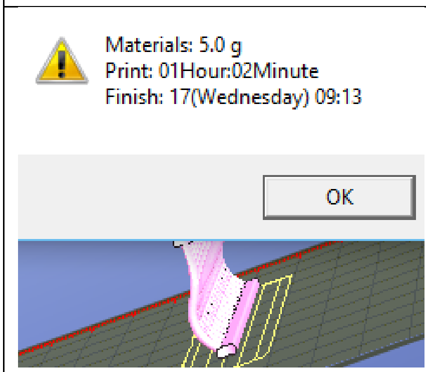
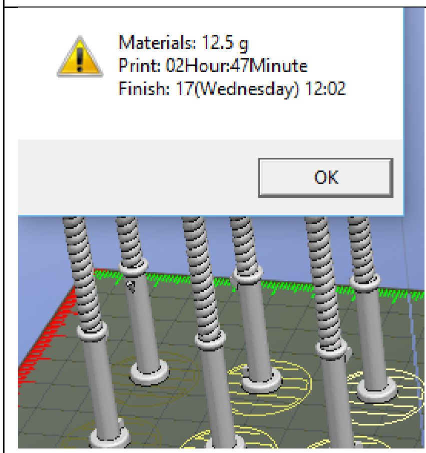
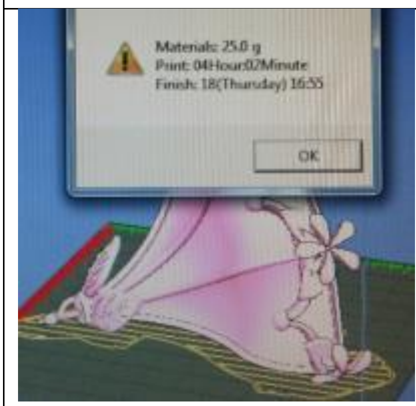
2.3 Respondent 4: JB

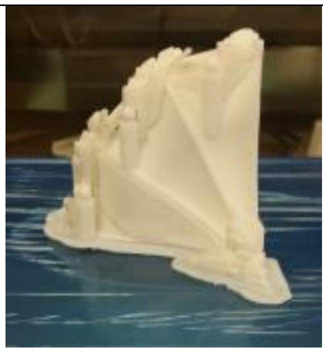
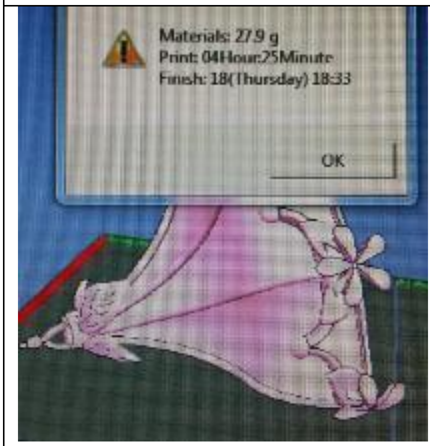
Jeane Bresler:		
	Visual documentation was not collected as specimens were never used.	• No support material was generated but slight Z-height deformation caused by compression of the part. • Support material cleaning time: NONE. • Surface finishing: Acetone. Cold exposure of 10ml over 1 hours. • GRAMS: 1g • Part of first specimen set, not completed for study due to poor print quality

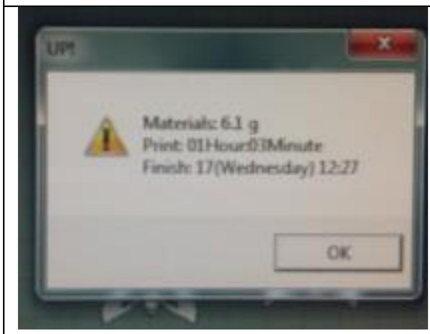
	Visual documentation was not collected as specimens were never used.	• No support material was generated. Raft delaminated without any problems. It can be speculated that the G-code generated slight deformation in print at the top as there are one layer missing. • Support material cleaning time: None • Surface finishing: Acetone. Cold exposure of 10ml over 1 hours • GRAMS: 5.5g • Part of first specimen set, not completed for study due to poor print quality
		• Support material was generated inside and out. Minimal support on the outside, most was on the inside to support the inside shaft structure. • Support material cleaning time: About 30 minutes • Surface finishing: Acetone. Cold exposure of 10ml over 2 hours • GRAMS:13.4g • Part of first specimen set, not completed for study due to poor print quality

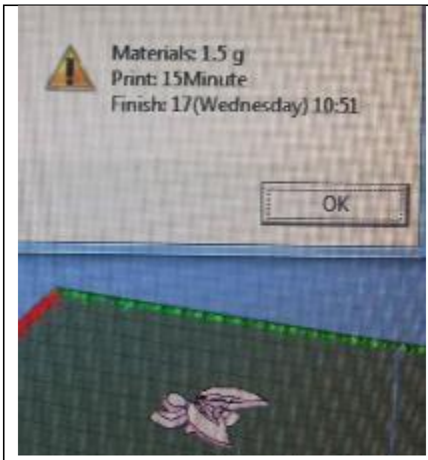
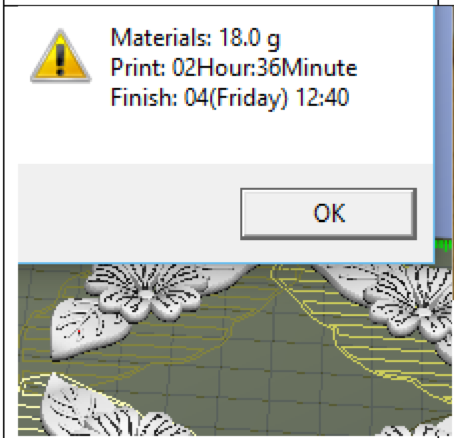
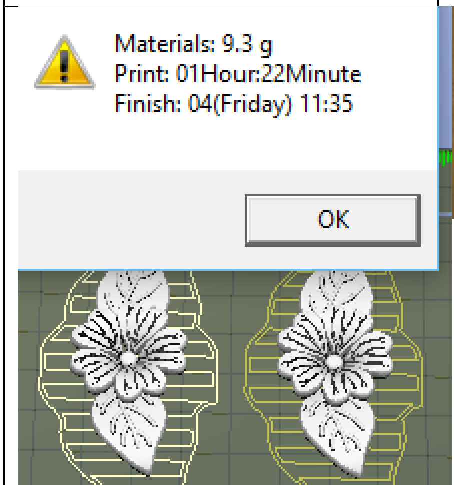
	 	• Support was generated around lettering as well as around the shaft. Shaft prints too small and breaks off. • Support material cleaning time: over two hours. • Surface finishing: Acetone and superglue (Cyanoacrylate). Cold exposure of 10ml over 1 hours • GRAMS: 6.8g • Part of first specimen set, not completed for study due to poor print quality
		• Generated a lot of support material that is very difficult to remove. The numbers kept breaking off their shafts. • Support material cleaning time: over 4 hours • Surface finish: Acetone 1hr 10ml and (Cyanoacrylate) • GRAMS: 22.5g • Part of first specimen set, not completed for study due to poor print quality

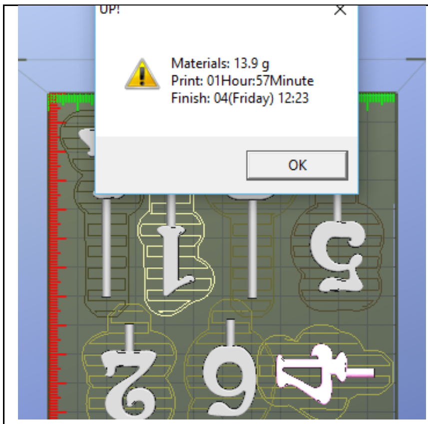
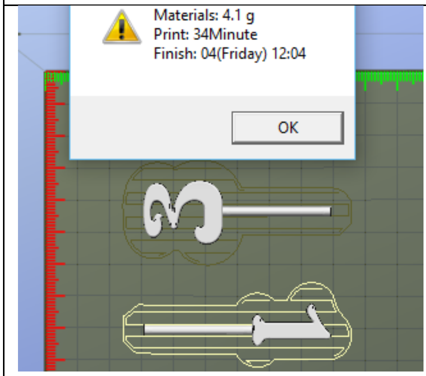
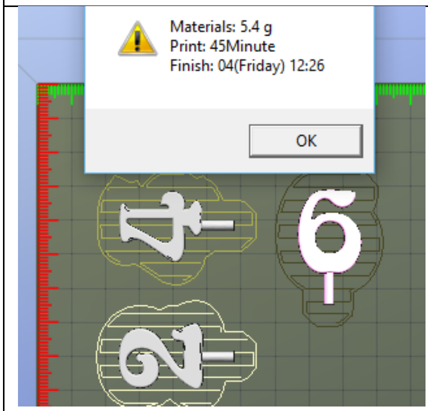
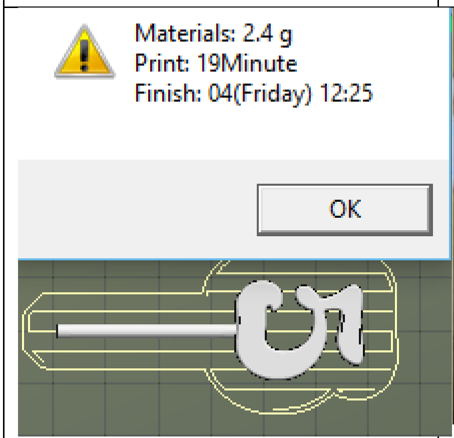
	 	• No support material generated on the top pillars. The fence at the bottom however generated support all around making it very difficult to remove. Also the support is the same size as the actual fence making removal further problematic. • Support material cleaning time: over 4 hours • Surface finish: acetone and superglue (Cyanoacrylate) Cold exposure of 10ml over 2 hours • GRAMS: 19g • Part of first specimen set, not completed for study due to poor print quality
		• Reprint experiment. Setting the support material as low as possible: Support density: 2 layers, Space: 8 lines, Area: 0mm2, Angle: 10 deg. Stable support not enabled. • Support material cleaning time: 1 hour. • Surface finish acetone and superglue (Cyanoacrylate). Cold exposure of 10ml over 2 hours • GRAMS: 13.6g • Part of first specimen set, not completed for

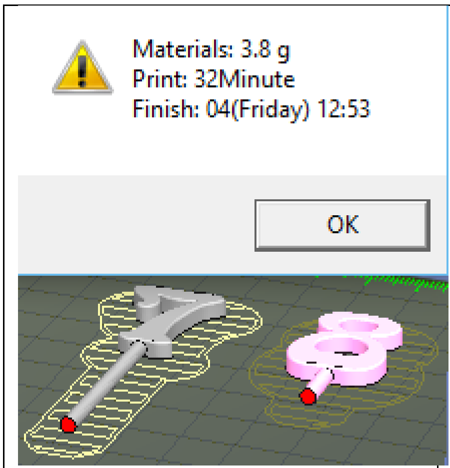
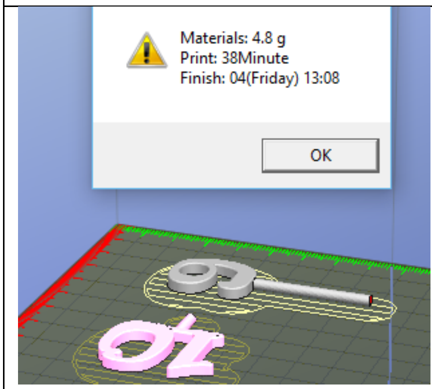
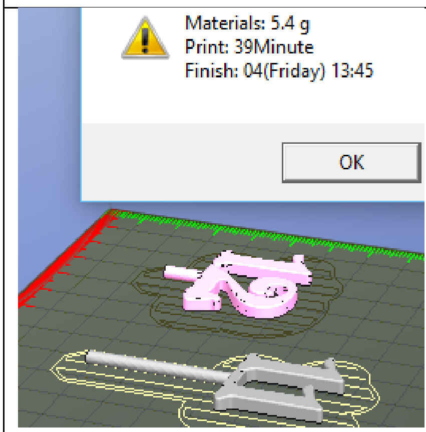
		study due to poor print quality
		• A lot of support produced. • Support material cleaning time: 6 hours • Surface finishing: Acetone exposure 2hours 10ml • Grams: 30.9g
		• A lot of support produced. • Support material cleaning time: 3 hours • Surface finishing: Acetone exposure 2hours 10ml • Grams: 5g
		• No support produced. • Support material cleaning time: None • Surface finishing: Acetone exposure 2hours 10ml • Grams: 9g
		• A lot of support generated • Support material cleaning time: 2hours • Surface finishing: 2 hours acetone exposure 10ml • Sanding: 1 hour

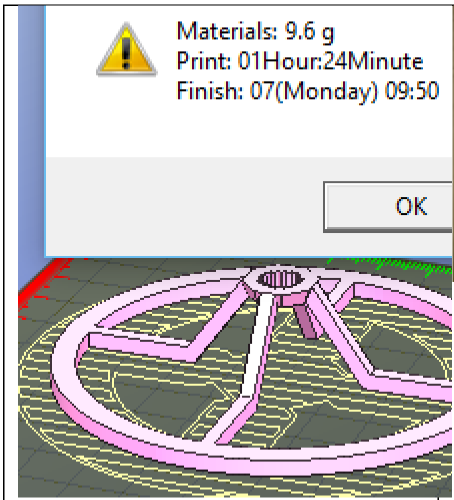
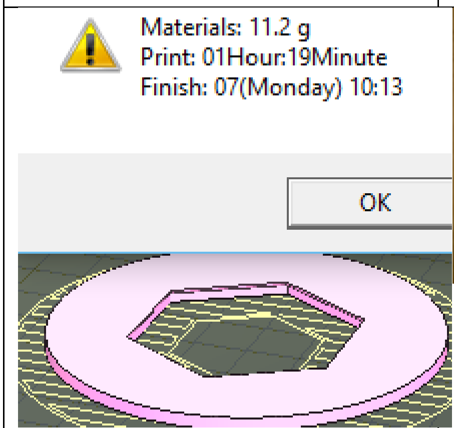
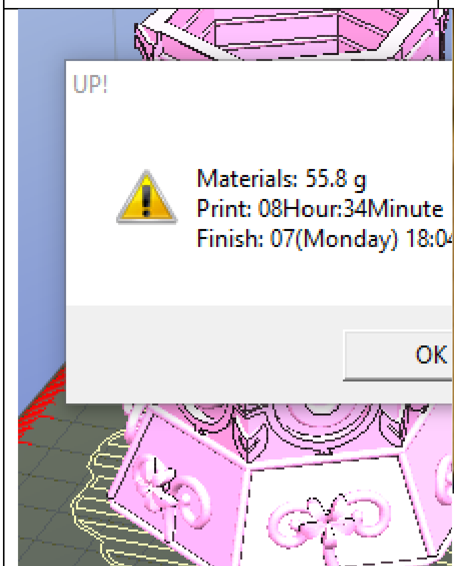
		• Grams:24.4g
		• A lot of support generated • Support material cleaning time: 2hours • Surface finishing: 2 hours acetone exposure 10ml • Sanding: 1 hour • Grams: 28.8g
		• A lot of support generated • Support material cleaning time: 2hours • Surface finishing: 2 hours acetone exposure 10ml • Sanding: 1 hour • Grams:23g
		• A lot of support generated • Support material cleaning time: 2hours • Surface finishing: 2 hours acetone exposure 10ml • Sanding: 1 hour • Grams:29g

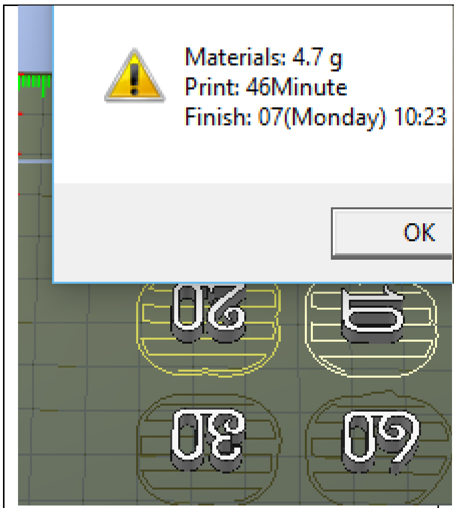
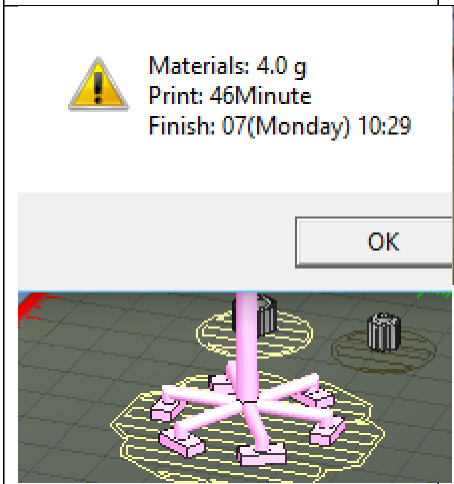
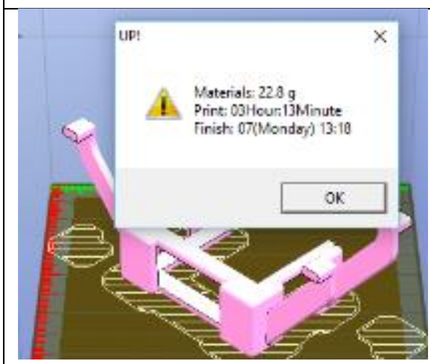
		• Little support generated but components were weak. • Support material cleaning time: 1 hour • Surface finishing: 2 hours acetone exposure 10ml and superglue • Sanding: None • Grams:6.2g
		• Little support generated but components were weak. • Support material cleaning time: 1 hour • Surface finishing: 2 hours acetone exposure 10ml and superglue • Sanding: None • Grams:6.2g
		• A lot of support generated. • Support material cleaning time: 2 hour • Surface finishing: 2 hours acetone exposure 10ml and superglue • Sanding: 1hour • Grams:43.6g

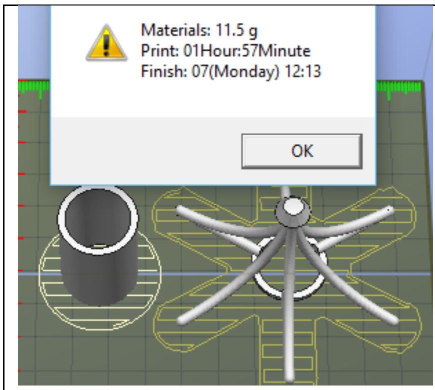
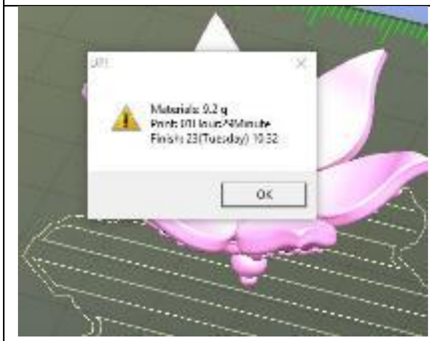
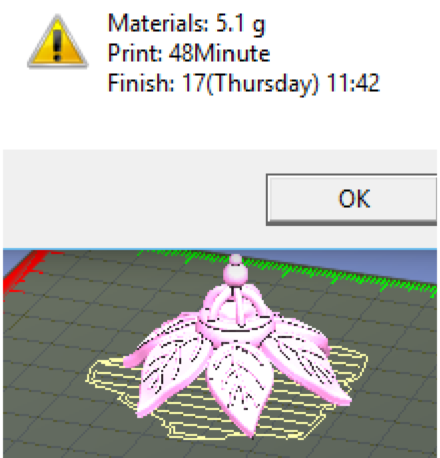
		• Reprint due to acetone overexposure • Little support material • Support material cleaning time: 30min • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 1.2g
		• Printed successfully • Little support material • Support material cleaning time: 1 hour • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 18g
		• Printed successfully • Little support material • Support material cleaning time: 30min • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 9g

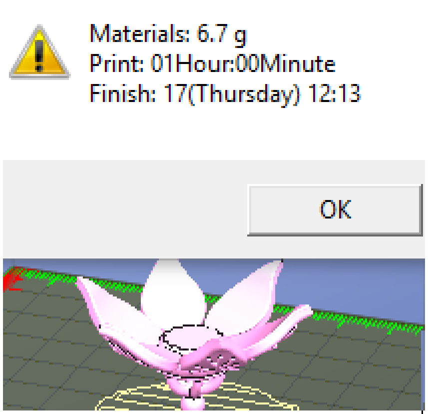
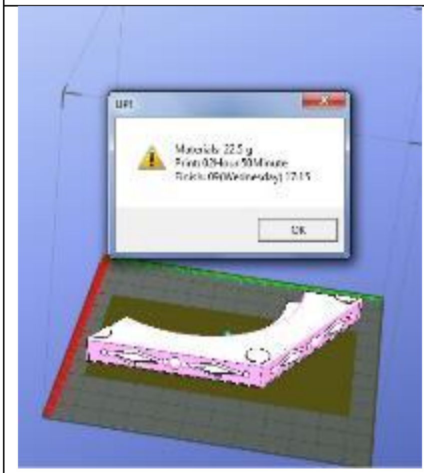
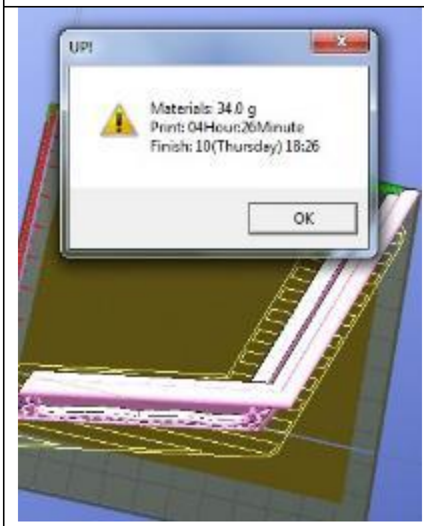
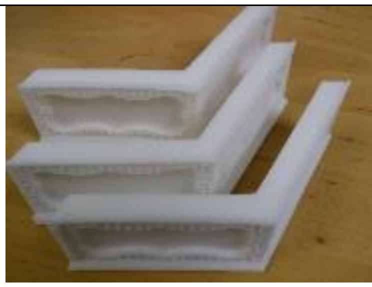
		• Printed successfully. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 13.5g
		• Printed successfully. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 4g
		• Printed successfully. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 5g
		• Reprint as previous 5 warped. Print successful. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 2.4g

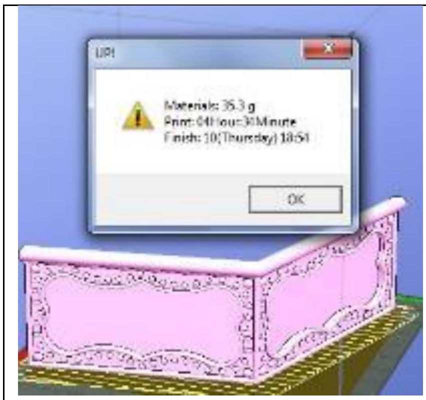
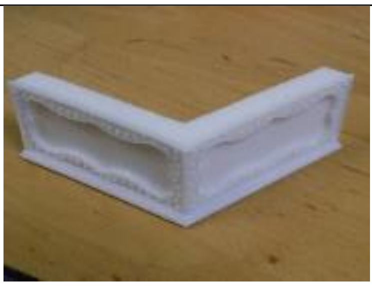
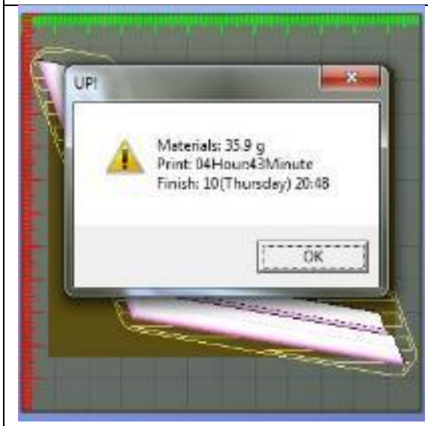
		• Printed successfully. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 3.8g
		• Printed successfully. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 4.7g
		• Printed successfully. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 5.2g

		• Printed partially successfully. Tolerance of gear teeth on the inside ring deformed, rendering the gear wheel inoperable. • Support material produced were minimal. • Support material cleaning time: 2 minutes • Surface finishing: No surface finishing was performed. • Grams: 9.6g
		• Printed successfully. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 11g
		• Printed successfully. • Support material generated on the inside and sides. • Support material cleaning time: 1hour • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 55g

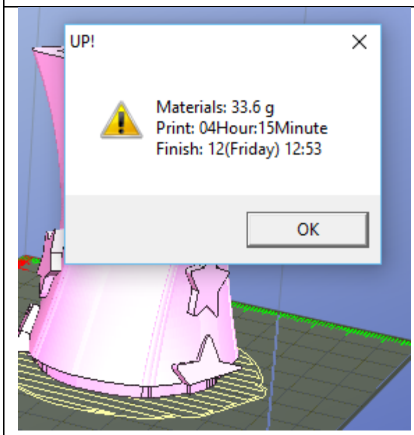
		• Printed successfully. • No support material • Support material cleaning time: NONE • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 4.7g
		• Printed successfully. • Little support material • Support material cleaning time: 1 hour • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 4g
		• Printed successfully. • Little support material • Support material cleaning time: 30 minutes • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 23g

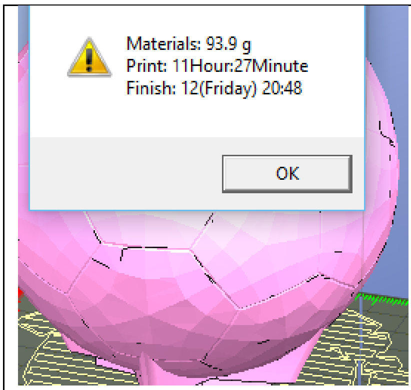
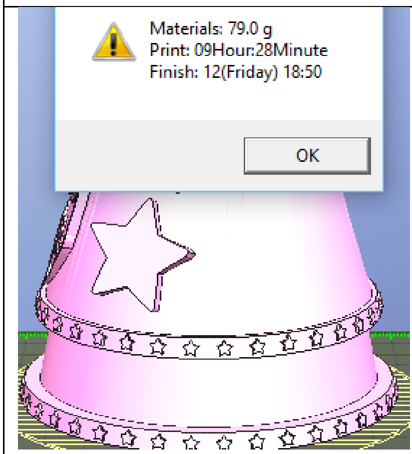
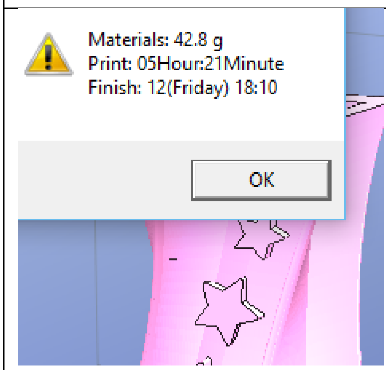
		• Printed successfully. • Little support material • Support material cleaning time: 30 minutes • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 9.3g
		• Print successfully but material contamination during the finishing • Support material cleaning time: 10 minutes • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 9.2g
	No documentation as print failed on fourth layer	• Print fail on fourth layer • Support material was not generated • Support material cleaning time: 0 hours • Surface finishing: None • Grams: Less than a gram

		• Printed successfully. • Bottom support material • Support material cleaning time: 10 minutes • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 6.5g
		• Printed successfully. • Some support material • Support material cleaning time: 2 hours • Surface finishing: 1hour acetone exposure 10ml and superglue • Grams: 22.8g
		• Printed successfully with slight warping • Some support material • Support material cleaning time: 2 hours • Surface finishing: 1hour acetone exposure 10ml and superglue • Sanding: 1 hour • Grams: 30.2g

		• Printed successfully. • Some support material • Support material cleaning time: 2 hours • Surface finishing: 1hour acetone exposure 10ml and superglue • Sanding: 1 hour • Grams: 34.8g
		• Printed successfully. • Some support material • Support material cleaning time: 2 hours • Surface finishing: 1hour acetone exposure 10ml and superglue • Sanding: 1 hour • Grams: 34g

2.4 Respondent 5: JL

Jason Laing		
		• Printed successfully • Very little support material was generated. • Support material cleaning time: Less than 5 minutes. • Surface finishing: 10 Minutes abrasive sanding followed by 3hours acetone exposure by cold vapor fuming. • Grams: 33.6g

		• Print failure due to new material that does not want to extrude. • No support documented • Support material cleaning time: None • Surface finishing: None • Grams: 25.4g
		• Print failure due to material extrusion. • No Support documented. • Support material cleaning time: None • Surface finishing: None • Grams: 8.2g
		• Print was completed successful • Very little support material was generated. • Support material cleaning time: Less than 5 minutes. • Surface finishing: 10 Minutes abrasive sanding followed by 3hours acetone exposure by cold vapor fuming. • Grams: 42.2g

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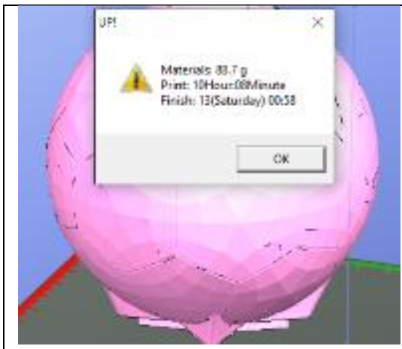
<td></td>
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- Print fail.
- Stopped extruding 90% through print
- No support documented
- Support material cleaning time: None
- Surface finishing: None
- Grams: 70g

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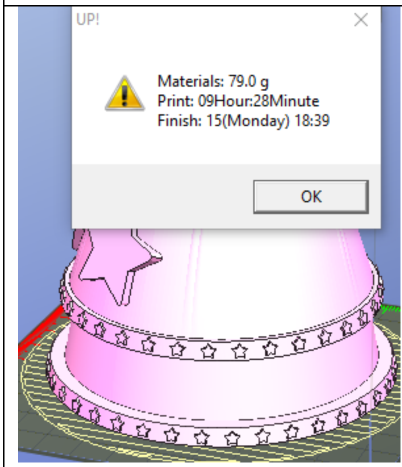
<td>
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- Component printed successfully.
- Very little support material was generated.
- Support material cleaning time: Less than 5 minutes.
- Surface finishing: 20 Minutes abrasive sanding followed by 3hours acetone exposure by cold vapor fuming.
- Grams: 70.6g

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- Print fail due to electricity being switched off
- No support
- Support material cleaning time: none.
- Surface finishing: none.
- Grams: 80.4g

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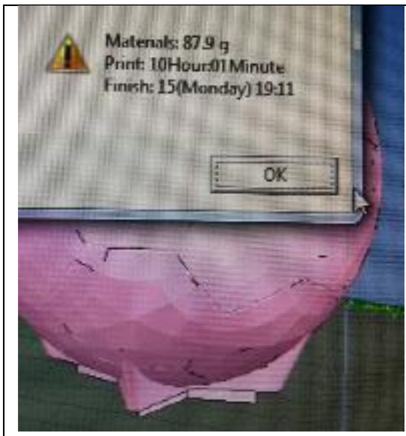
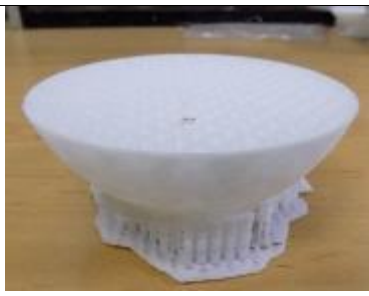
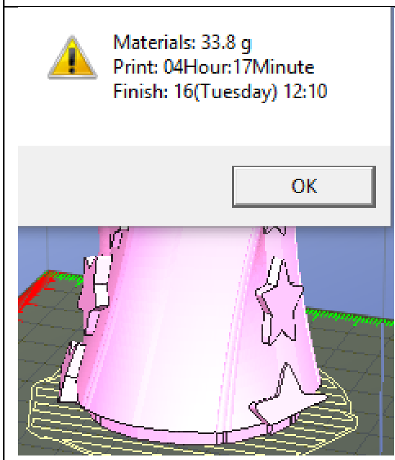
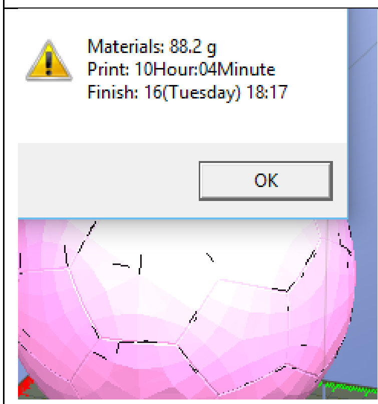
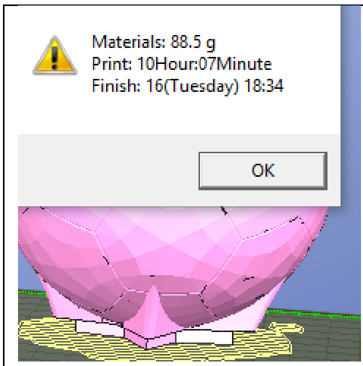
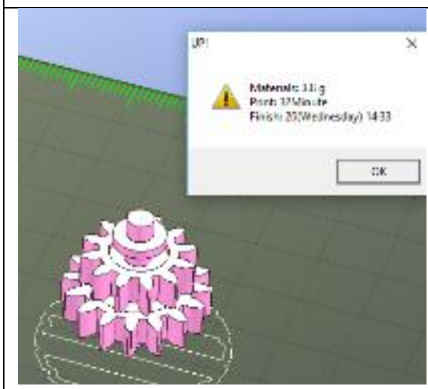
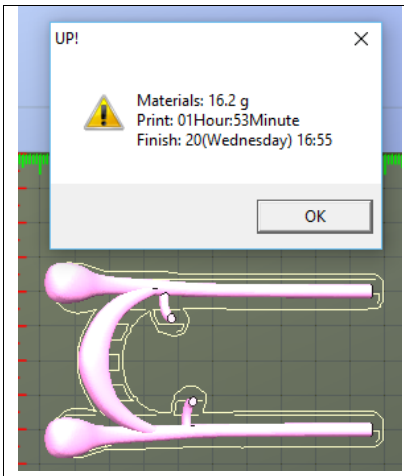
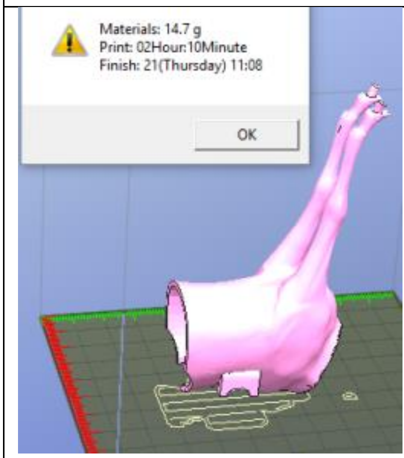
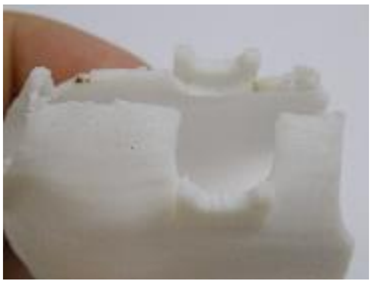
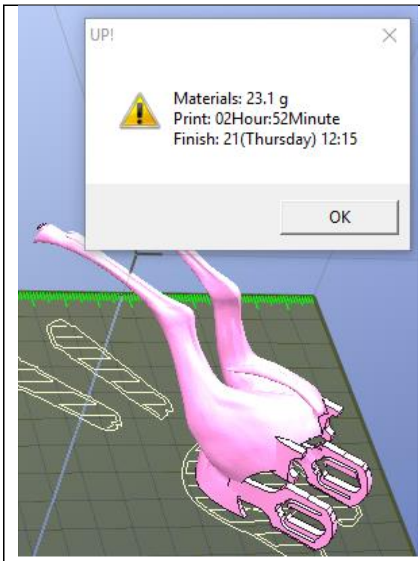
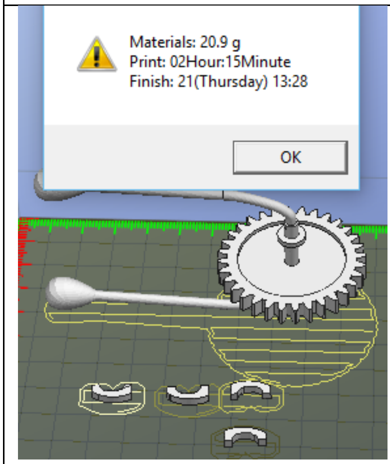
		• Print fail due to electricity being switched off. • No support • Support material cleaning time: none. • Surface finishing: none. • 36.4grams
		• Part printed successfully • Very little support material was generated. • Support material cleaning time: Less than 10 minutes. • Surface finishing: 5 Minutes abrasive sanding followed by 3hours acetone exposure by cold vapour fuming. • Grams: 33.7g
		• Part printed partially. • Support not documented • Support material cleaning time: none • Surface finishing: none • Grams: 24.4g

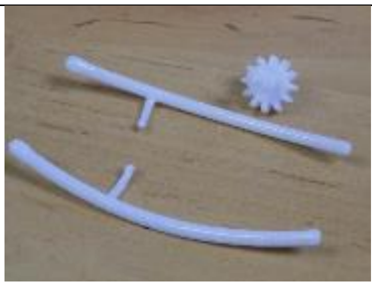
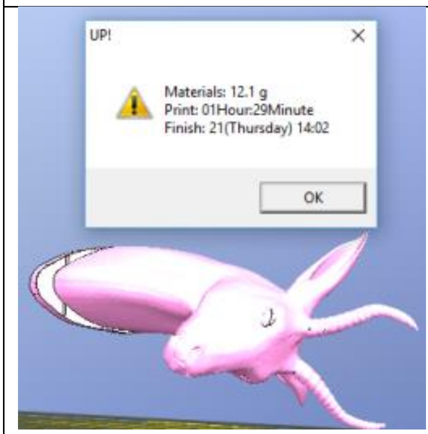
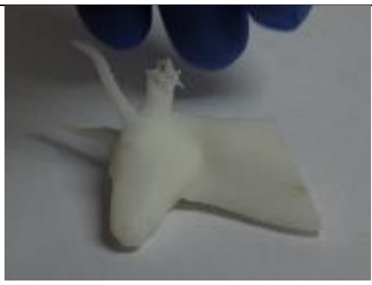
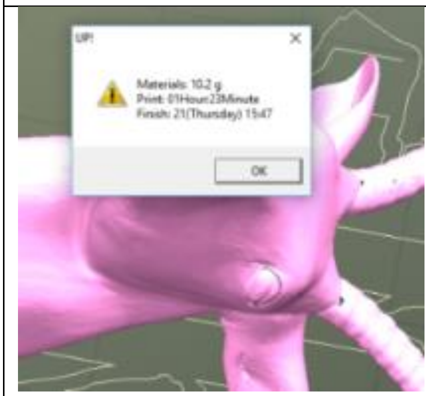
		• Part printed successfully • Very little support material was generated. • Support material cleaning time: Less than 5 minutes • Surface finishing: 5 Minutes abrasive sanding followed by 3hours acetone exposure by cold vapour fuming. • Grams: 82g

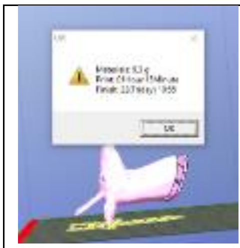
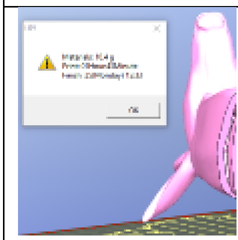
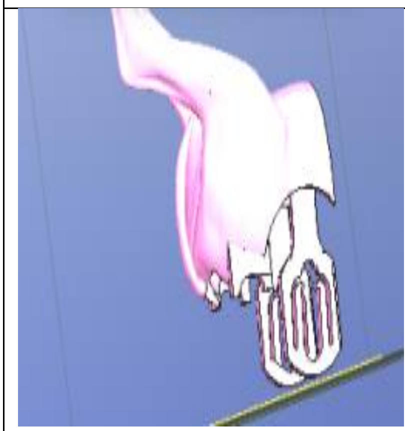
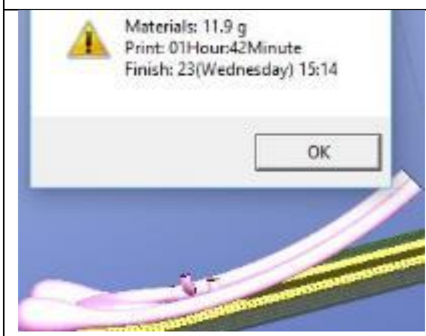
2.5 Respondent 6: MJvV

Michaella Janse van Vuuren		•
		• Support material generated on both ends of the gear, but mainly at the bottom and ends of shaft. This made gears break and had to be glued with superglue (Cyanoacrylate). • Support material cleaning time: 20 minutes. • Surface finishing: Acetone. Cold exposure of 10ml over 1 hour • Grams:3,8g

	 	• Support material generated at the bottom of the component. The footrest consist of three components in total and need assembly by application of superglue (Cyanoacrylate). • Support material cleaning time: 1 minutes. • Surface finishing: Acetone. Cold exposure of 10ml over 1 hour • Grams: 16g • ONE REPRINT DUE TO ELECTRICITY FAIL. Grams 13.7g
	 	• The legs of the component are too weak to grow downwards, making it necessary to grow upside down. This generated a lot of support material. • Support material cleaning time: 2 hours. • Surface finishing: Acetone. Cold exposure of 10ml over 2 hours. Two legs warped towards each other. • Sanding: 1hour • Grams: 14.2g

	 	• Support material generated on the inside of the component. This component delaminated the outside support easier than the previous component. However a lot of support was still generated inside the component. • Support material cleaning time: 2 hours. • Surface finishing: Acetone. Cold exposure of 10ml over 1 hour to reduce the warpage but step layers still very visible. • Sanding: 1hour • Grams: 24g
		• Print successful. • Support material generated mainly at the bottom of the gear component. Both bottom and top shafts too thin and broke during the cleaning process. • Support material cleaning time: 20 minutes. • Surface finishing: Acetone. Cold exposure of 10ml over 1 hour. • Grams: 21g

 		• Delamination of the two bottom footrest components were easy to remove and needed assembly via superglue (Cyanoacrylate). The gear generated support material at the bottom. • Support material cleaning time: 1 hours. Sanding: 1hour • Surface finishing: Acetone. Cold exposure of 10ml over 1 hour to reduce the warpage but step layers still very visible. • Grams: 7.9g
 		• Partial fail on ears. Very visible step layers on the side of the neck where the part was resting on the support material. • Support material cleaning time: 1 hour. • Surface finish: acetone: 2hrs/ 10ml. superglue(Cyanoacrylate). • Grams: 12.1g
 		• Print orientation changed to improve the quality of the ears. However print came out less successful. • Support material cleaning time: 1 minute. • Surface finish: acetone (2hrs) and superglue (Cyanoacrylate). • Grams: 10.2g

		• Print orientation changed a further 45 degrees to improve the quality of the ears. • Support material cleaning time: 1 minute • Surface finish: acetone 10ml (2hrs) and superglue (Cyanoacrylate) • Grams: 9.1g
		• Print orientation on back. • Support material cleaning time: 1 minute • Surface finish: acetone 10ml (2hrs)and superglue (Cyanoacrylate) • Grams: 10g
		• Print orientation upside down • Support material cleaning time: 2hrs • Surface finishing: 10ml acetone 2hrs and superglue (Cyanoacrylate) • Grams: 24g
		• Print successful • Support material cleaning time: 1minute • Surface finishing: 10ml acetone 2hrs and superglue (Cyanoacrylate) • Sanding 1hour • Grams: 24g

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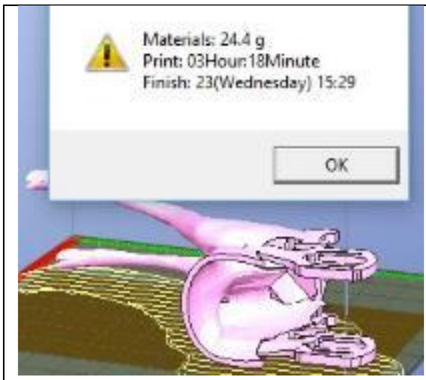
<td>
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- Print orientation sideways.
- Support material cleaning time: 2hrs
- Surface finishing: 10ml acetone 2hrs and superglue (Cyanoacrylate)
- Sanding: 1 hour
- Grams: 24g

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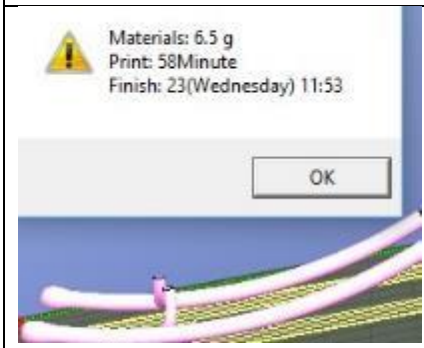
<td>
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- Print orientation upside down
- Support material cleaning time: 1minute
- Surface finishing: 10ml acetone 2hrs and superglue (Cyanoacrylate)
- Grams: 6g

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- Complete reprint was done to improve the quality of the specimen.
- Support material cleaning time: 2 hours
- Surface finishing: 10ml acetone 2hrs and superglue
- Grams: 19g

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- Print successful
- Support material cleaning time: None
- Surface finishing: 2 hours acetone exposure and superglue
- Grams: 9g

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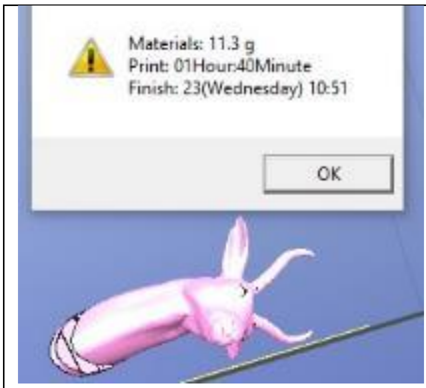
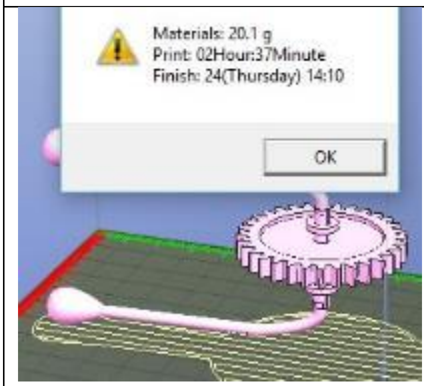
		• Printed successfully. • Support material cleaning time: 1 minute • Surface finishing: 2 hour acetone exposure. 10 ml • Grams: 11.3g
		• Printed successful • Support material cleaning time: 1 hour • Surface finishing: 2 hour acetone cold vapour exposure. 10ml • Grams: 18.3g

Appendix 3: Respondent transcripts:

3.1 Respondent 1: PvdW

Transcript 1 of interview with Mr Philip van der Walt Interview: 31/03/2016

Legend for interview	
Questions	Are colored in RED
Important gist of the conversation	Highlighted in YELLOW
Background explanation (filler)	~~Strikethrough sentences~~
Interpretation of ideas or words	*(Italic and in brackets)*
Interviewers notes and comments	Track change comments on right side of doc

1. Introduction: Thank you once again for taking the time to partake…

~~Interviewee (I): Good day Philip. Firstly I would just like to thank you for taking the time to partake in this research study. I really appreciate it.~~
~~Respondent (R): Sure.~~

2. What is your background in 3D printing?

(I): The first question I would like to ask you is, what is your background in 3D printing?
(R): I have been involved in 3D printing since 2004. This was a result of my degree. Initially I studied graphic design but we were part of a niche group of students that did training on Rhino CAD software and we used SLS printing for jewellery purposes. And then it kind of developed from there, I got into medical design, we worked with

implants, titanium sintering and after that I started doing product development. I have been working with all kinds of printers, entry-level and high-end since 2004.

(I): Is your background in majority more towards the South African market or would you say it's more towards an international market?

(R): Well, I would say the South African market is fairly new so it didn't really exist before, so our exposure was more focused international than South African. The South African market kind of grew out of the international market. You know, they doing the same stuff on different levels. I think in the last couple of years…uhhh… because there is a lot of guys developing their own machines now so the South African market is really starting to stand on its own feet.

3. Which industry do you service in your opinion, with regards to 3D printing?

(I): You said you started from an artistic perspective, then moved into the medical field and then moved on to product development. Is that more or less the field where you find yourself in now?

(R): Product development and high end modelling I would say, I do digital sculpting…so it's a lot of difficult free form shape models. The difference between me and most other digital sculptures is that I sculpt specifically for 3D printing. So we make sure we get the files ready for production and also understanding the machines to make sure…when you do a product or model specifically for a certain technology you have to consider the machine.

(I): Right, I understand, just to finish of the question would you consider the work you do to be of an industrial nature, artistic nature or more a design nature?

(R): It's difficult to separate them, because it is all part of the same thing. Some of it is very artistic so I do a lot of digital sculpting but it is for industrial purposes and the same goes for the design. We might get an industrial type product but we need to put our creative spin on it. I can't really separate them completely but I would say it's more design creative than industrial.

4. Do you have any prior knowledge of Post-production-finishing-techniques (PPFTs)?

(I): Do you have any knowledge pertaining to PPFTs in Entry-level FDM?

(R): I have some knowledge yes, obviously seeing a lot of things over the last 10 to 12 years and I also work with a lot of 3D printing guys and finishing guys in the industry. We need to constantly tell them what kind of finish we want and then they obviously explain how these things (*techniques*) work and then obviously I've had some experience doing one or two projects myself. Not much but I have done a few things AND I know how much hard work it is

5. If YES, please elaborate…

(I): Can you elaborate more on specific techniques you have worked with?

(R): Most of it would be around finishing FDM, on the sintering side we dyed and painted the parts. On the FDM, acetone vapour chamber, we have a company that uses it to get smooth finishes. And then obviously painting and putting vinyl stickers on ABS and nylon… we struggled with that. AND then small things like filling up holes, that's always the thing, especially on FDM, because usually your platform (*build-plate*) are a bit smaller so you have to combine parts so that means there is a line (*seam*) somewhere that you have to fill up and clean.

6. If NO, explain to respondent so interview can be completed.

(I): The next question we can ignore as you responded YES in the previous questions.
(R): …

7. Would you prefer to do (PPFTs) yourself or subcontract it out and why?

(I): Now I want to ask you, in your opinion would you prefer to use PPFTs yourself or as an industrial artist would you subcontract somebody else to do that kind of finishing after you produced the artefact?

(R): Well first of all that depends on what the artefact or specimen is. If it is something I need specific detail on, I need to focus on certain areas…it really depends on the person that is doing it. I mean this is all about skill level. If I am not 100% sure that that person will do it correctly because you can damage the part and destroy it if you do not do it properly.

(I): ok so you are saying it depends on the outcome of the actual product that you are working with, you will subcontract or do it yourself.

(R): Well, that is one of the factors, my experience from the industry…I mean I work with 3D printers a lot where the guys actually tells us they have the printers but they don't have the time or capacity to do the job, so they will outsource. It comes down to whether you have time or not, you obviously would want to do it yourself, but if you do not have time you outsource it to make sure it is proper. Also you might not always have the right equipment or capacity to do it yourself. And also skill level is important here, there are very few people I would trust with it. It's a very labour intensive process and you need to spend time and make sure it is done properly because people can see if it is a rush job.

8. What is your overall impression of the artefact that was reproduced?

(I): Now to go into the next section, there are two artefacts in front of you. They are the two artefacts that you and Lionel produced. If you had to now look from an overall perspective at them, what is your impression of the artefacts that was reproduced?

(R): Well, firstly it is very impressive that the level of detail and quality has been achieved because the shoe was specifically designed for the sintering process (*high-end production*). Initially we wanted to do it directly in titanium (figure 1) *[1] (Walt, 2016), we ended up doing it in nylon and then plating it. Now if I look at the detail (*on the reproduced version*) and I look at the detail on the plated version of the shoe it is very similar because with plating you lose a little bit of the fine detail. The only thing is obviously some of the small parts didn't come out.

[1] Image courtesy of the artist https://www.linkedin.com/pulse/developing-products-via-social-media-using-3d-philip-van-der-walt

Figure 1 Divine Intervention shoe

8.1. STEP LAYERING:

(I): So now im going to break it up into four stages…firstly if you have to observe the step layers on the actual artefacts, would you firstly say that using entry-level FDM technology produce a lot of step layers and then secondly the vaporizing technique, does it successfully get rid of step layering?

(R): Well it depends on the quality that you print on, if you push up it to the highest quality, which would obviously take the longest, you don't really see that much step layering. The only area I really see problems with the step layering is in the really thin parts…it looks a bit jagged. But the bigger areas are perfect, there is actually no problem with it and after the acetone…honestly I cannot see a difference between that and the other final part. In areas like the wings I can still see some steps, but the bigger areas nothing and I think It's mainly because the acetone, if you push it too far you going to lose the detail.

(I): When you look underneath the top of the heel (figure 2), where the angels are holding on with their hands you will see there are a lot of step layers present. What is your take on that versus the outside of the top of the heel?

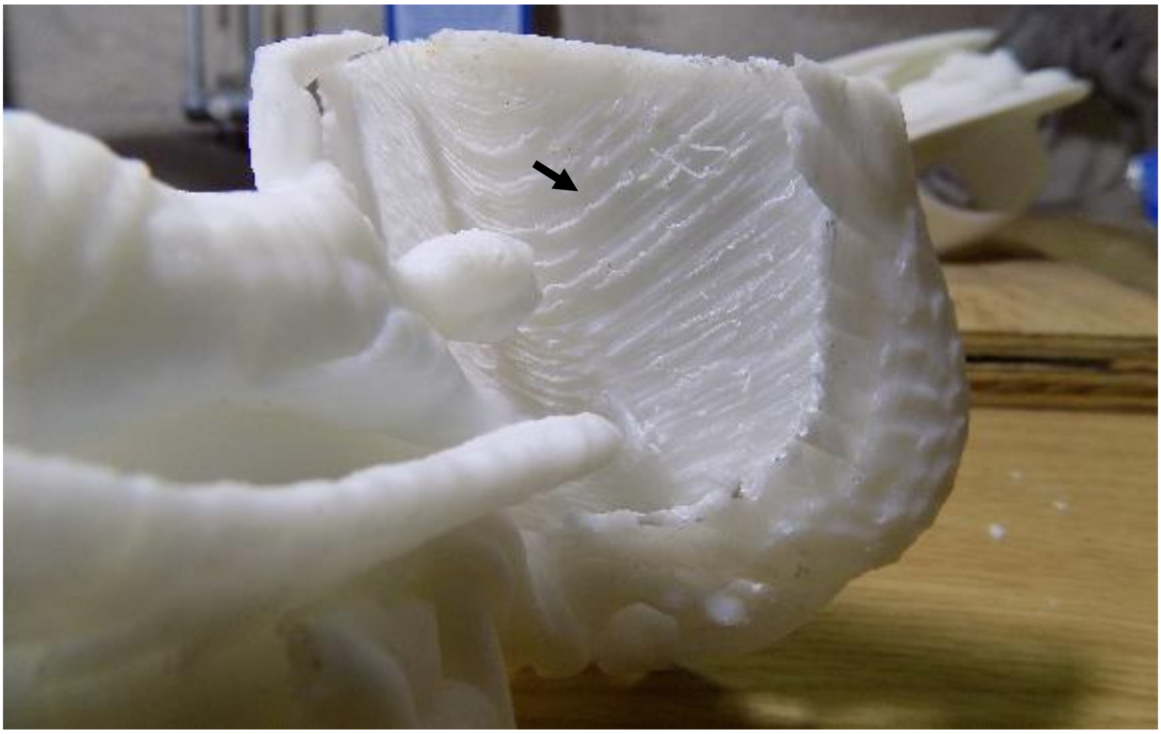


Figure 2 Prominent step layers under heel

(R): It is quite a huge difference, I would say what you are looking at there would be the original print…to me either there wasn't enough acetone on that side (*exposure to acetone*) or I do not know.

(I): Basically what happened was there was no PPFTs post-production surface finishing treatment done on the inside bottom part of the heel whereas on the top there was. So when you compare the two can you see a clear difference between them?

(R): Yes there is a clear difference between that…obviously it is also a very difficult spot to get into, so if you do want to sand or something it is not really possible.

8.2. ASSEMBLY TECHNIQUES:

(I): Okay then for the next question, your impression on the assembly technique by fusing the different parts together? How do you feel about it?

(R): uhm… I think most areas are quite successful, it's unfortunate that there are some spots that you do notice there is a line, but I have seen that with enough work you can get it done perfectly. It is just a very time consuming thing, but I think you can really notice it on the under part of the shoe but other areas you do not even see it, for example on the waist area of the angels (figure 3).

On that note now when you refer to the angels where the waist meet… there are two techniques that were applied here. The one was basically just a fusing technique and the other one was a fusing technique with a surface filling that was put over them. When you compare the two, which of the two techniques is more successful?

(R): I would say the one to the left (figure 4), the angels are a bit glossier so I would presume it was exposed to more acetone the other one is more matt. You can see the lines but there are more details. If I look closely I can see the fine line s but the lines do not bother me.

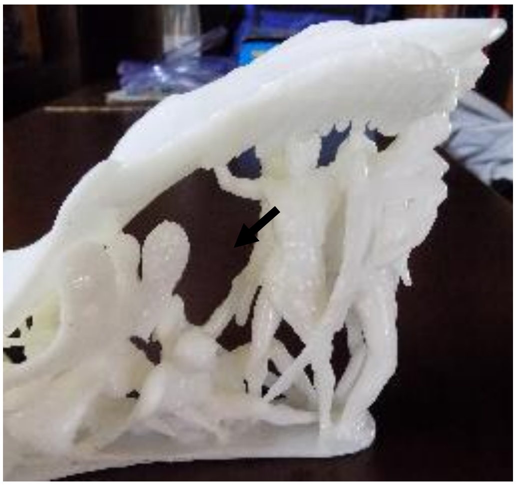


Figure 3 waist joint seam

Figure 4 sample one (interview screen grab)

8.3. SURFACE TEXTURE:

(I): Then the overall surface texture, in your opinion…you have worked with entry level FDM objects before that were created on the UP MINI printer, when you compare a model that has had no surface finishing done to them and compare it with these (s*amples*) would you say the surface texture is better or worse off after treatment?

(R): I don't know, I guess it depends on what the model is supposed to be or do…You know everything has got its own purpose. If you look at the handle in the front of the shoe you can see its very smooth, it is almost like a perfect surface, but I know it is a lot of work to get it there and the problem on especially the small stuff is you just cannot spend so much time or energy to get it to that level. So most of the time unfinished product is acceptable especially if it's basic shapes you get beautiful prints but again that depends on what the client wants or what the purpose of the product is

8.4. AESTHETIC VALUE OUTPUT:

(I): Lastly for the overall impression, when you look at the objects in front of you, would you say that the aesthetic value output has increase… in other words…from a more artistic point of view do you feel it is successful versus a more technical output? What I mean is an industrial person will look more at the technical aspects and getting everything precisely (*correct*). BUT Aesthetic value from an artistic point of view can include something like "happy accidents". SO the shoe closest to you, you will see the angel right at the back at the top of the heel, the one arm has been broken off (figure 5). Now if you look at that sample it almost gives you a Romanesque statue kind of feel…if I can compare it to that, which from an artistic point of view makes it almost like a little sculpture that is sitting on the shoe. Do you think this kind of finishing on this kind of technology makes that a successful aesthetic object or would you rather prefer a more technical and precise outcome?

(R): Well uhhh…we do everything purposefully, so if I did it with broken arms specifically like the sculptures, I would sculpt it like that. The thing is, the shoe is a product. Something made to look specifically in a certain way. Which means everything is planned like that, it is made for SLS process and that is why we do certain things. Aesthetically I really like this, but if I need to go put this down on a table for a presentation for a company that wants to manufacture the shoe, that (*happy accidents-inconsistencies)* might cause problems because whatever I represent in the renderings need to be the same in the physical form. I would definitely use it for testing but for the final product it will be too much work to get it to the right level.

Figure 5 Angel arm broken during Post-processing

9. Which part would you consider most successful?

(I): When you take all the above into consideration, which part of the shoe do you consider most successful?

(R): Aesthetically when looking at the angels I would say the heels and then also the upper bridge area of the sandal because this is the kind of finish that you want all over.

(I): Is it because of the step layers that are not present, the nice smooth texture?

(R): I think it's more an issue that everything is not the same. If the surface finish was followed through then people would not focus on the production issues but see it as a successful product

10. Has these finishing techniques improved or made worse the quality of the artefact?

~~(I): Has these finishing techniques improved or made worse the quality of the artefact?~~

~~(R): When it comes to the quality I cannot say, I'm sure chemically there is a lot of changes happening. There are areas where it became thinner and the blending is not so good between the seams, especially if it's a fine part going into another part. Once~~

~~these parts blend into each other it does become a little stronger when it comes to tensile strength.~~

(I): Ok, let me rephrase it, when you take into consideration the finishing technique… before the finishing was done to this component…would you say it's less or more successful than after the finishing was done?

(R): For this it is definitely more successful after.

11. Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM?

(I): Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM?

(R): Again I think it depends on the purpose, the reason why we used high-end sintering was because this is the final product meaning it can carry the weight and the detail we can get without any assembly. It is also a time factor where the ABS is not strong enough and you have to put it together, it is very labour intensive. There is a lot of new material available for FDM which could definitely improve strength, I actually have seen metal parts being printed by FDM, which has got the wait and feel. I do not know how strong that is but, we definitely moving towards that fast. BUT the biggest issue is the size of the printers, although you do get very big FDM printers. Detail like this cannot be printed in one go, it needs to be done in different parts to get the specific details. However that said I know shoe designers that use FDM printing specifically for manufacturing, they print in rubbers and they get beautiful fine shoes and the shoes work. But obviously you design for your machine.

12. Do you feel the tech is successful or does the technical ability of the artist/ designer play a role?

(I): Do you feel the techniques are successful in the sense that when you compare applying this technique vs the skill of the artist or design, which one is more important?

(R): Your skill is going to play a big role, especially with something like this, it is an artistic piece, and you need to be able to make decisions while finishing… I mean it is like anything, if you are going to polish something you need to make sure certain areas you want more attention on and on other areas you want to be more careful. It's not something you can just take and do the same finishing across the board. I see that when people break things by accident and didn't think ahead. Also you need to know more than one technique, you need to know if that part is more fragile maybe we should try and do something else and still get the same look.

(I): So in your opinion basically we can say that even if the same technique is applied by two different people, the skill of that operator will definitely have an influence on the outcome of the part?

(R): Ohhh, absolutely, it is like painting a house…it sounds simple but you know two people do it and it might look different because it is an attention to detail and that is what you want. You want to make sure your detail is preserved. It has a lot to do with technical skill, you need to have the skill to do that also understand the product and 3D printing. Making the right decisions.

(I): No to look back at what you said earlier about subcontracting, whether you as an artist specifically would subcontract somebody else from outside to do your post-processing for your artefact or whether you would do it yourself. Now regarding that, where the skill comes in, do you still feel the same, would you subcontract or do you feel for you as an artist there is a connection between you and the artefact, because you designed the CAD file for this technology. You know where all the sensitive areas are that can break etc. Can you really trust somebody else with this?

(R): You can never really trust anyone. Look you do have a relationship with your product, it is always the case and like I said in the ideal world you would always want to do your own thing. The little stuff I have done that I finished by myself I did myself because I wasn't sure that I could trust anyone wanting to do it the correct way. We have had projects that has been send out in the past, not necessarily what we wanted…in the time frame we had…that was what we could produce. Ideally you would want to do it yourself, but you might not always have the skills, I mean my skills are very limited because of the stuff I was exposed to. I know what I can do and what I can achieve and I am happy with that, but I might not have all the equipment, so I do outsource to people that I am okay with. Nowadays I focus more on the CAD and sculpting, not really the printing, so that part is taken care off by the company that prints it for me

13. Are there areas where these techniques can be improved?

(I): **INTRO TO QUESTION SKIPPED**

(R):

13.1. STEP LAYERING:

(I): When you think of these techniques (*vapour treatment, acetone brushing, etc*.) where do you think it can improve step layering or what can be done to improve the step layering?

(R): Well the step layering is a direct result of how the machine works. I think obviously the first improvement would be to do finer detail from the machine side. That is a technical thing. Honestly I do think they will get to a level where they print finer resolution.

(I): So can I assume you mean that the hardware and software of the printer is more at play here than at looking for a solution from a post-processing perspective.

(R): That is just one component, because that is where it all starts, a lot of improvements are evident and it is happening quicker because it's no longer just two companies that does this but thousands and thousands of people around the world, fine tuning and improving them. Once that is done then obviously there is room for improvement through post-processing…it's a continuous thing for example the vapour chamber…I've seen people that chuck their parts into a pot and then some companies that build expensive chambers where you really can control it. Now if I look at the shoe you not even then going to get an even finish on this technology because it was not created for this platform originally.

13.2. ASSEMBLY TECHNIQUE:

(I):…

(R): Then you also need to look at your splitting. I mean the shoe is cut right through in certain instances (figure 6)…on any product you have to look at where you are going to split it, where would this splitting line not be an issue…you obviously trying to hide these as far as possible. That is also a skill, if you do it properly people will not even notice it. There are a lot of factors to consider for example the orientation of the print in relation to the splitting line.

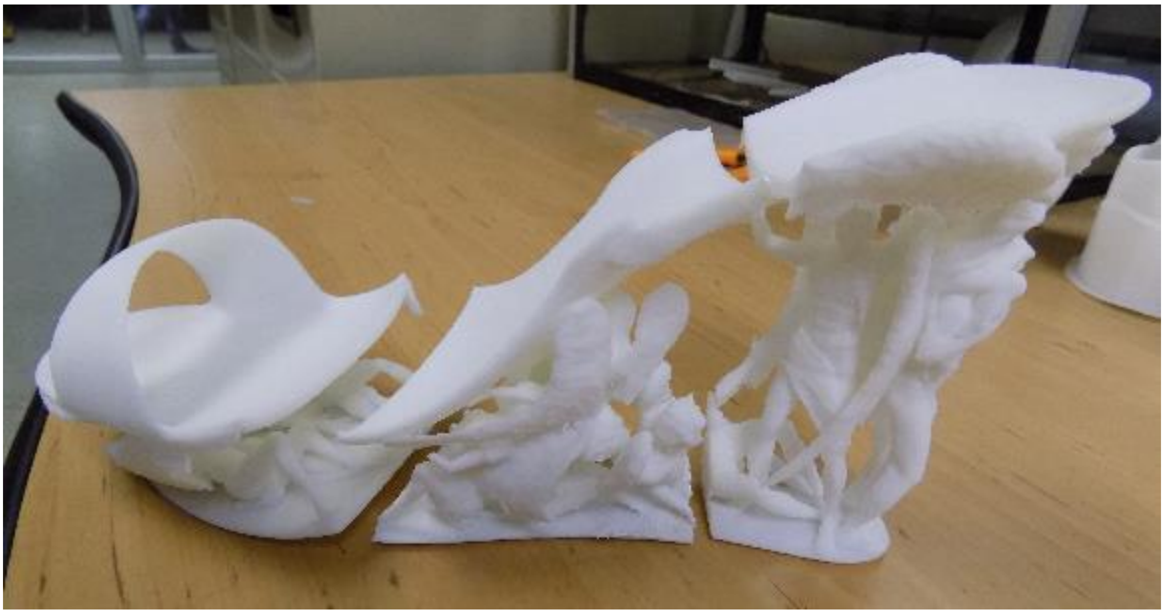


Figure 6 Splitting lines

(I): Okay thank you, in regards to the assembly techniques…when you look at the way it has been fused together, do you feel there are areas where it can be improved in regards to acetone finishing and ABS cement?

(R): The acetone I would presume is one of your last steps you would do, there are some bumps, maybe smooth it out more before acetone finishing. On the other shoe you do not even see it. I can see there has been more time spend on the one shoe, even though the printing is not always exactly the same, with warpage you might get a little clearance here and there. They are all unique.

(I): You actually answered the following question now… let me ask you… specifically the acetone glue (*ABS cement*), when you look at the areas that have been assembled together, do you feel there is another way it can be used, was it used successfully, do you have any suggestions?

(R): Well if I compare the two shoes (Figure 7)[2], the one on the right, especially on the bottom, I don't even really see it. The one on the left does have some bumps, and that is obviously the glue. The thing with the glue, and I have worked with it myself. It is a very tedious process, you cannot put too much glue in at once and you have to layer it. It all depends on the amount of time you have because you are going to glue then sand and then repeat. It could also depend on the consistency of the glue as that is not always the same because the way the glue is made. Could mean it will end up

[2] Camera back up recording number DSCN1151 Still image insert from 12min49seconds.

being thicker or runnier, which could change the outcome. That could be an area of focus, to get the ideal consistency of the glue.

Figure 7 Image still of different shoes

That is just one aspect, another would be the use of ear buds to smooth out the surface, maybe there is something out there already that might give a smoother and overall finish or blend.

13.3. SURFACE FINISH:

(I): QUESTION HAS ALREADY BEEN ANSWERED ABOVE:

(R): *The acetone I would presume is one of your last steps you would do, there are some bumps, maybe smooth it out more before acetone finishing. On the other shoe you do not even see it. I can see there has been more time spend on the one shoe, even though the printing is not always exactly the same, with warpage you might get a little clearance here and there. They are all unique.*

13.4. AESTHETIC VALUE OUTPUT:

(I): Okay, now with regards to improving, do you think there is something that can be done, using acetone or acetone glue to improve the aesthetic value output of objects like these shoes in front of you?

(R): Well I would like to be able to use the glue, maybe a different consistency, to rebuild some of the things, or add or edit the artefact. When you are working with something like this that is very sculptural, there are problematic areas or missing areas, you might want to rebuild it.

14. Do you have any other suggestions of techniques that can be beneficial for PPFTS?

(I): When compare acetone finishing to processes like chrome plating that is done on high-end production, like the shoe that is seen on the right hand side (Figure 7), do you think it is more successful than acetone finishing or would it roughly have the same outcome?

(R): Well, the plating depends heavily on the process and who is doing it…there is a definite skill thing there. This plating was horrible and just a test. The plating picks up all the mistakes, it will pick up lines and bubbles and things like that. When I compare the plated shoe and the ABS printed shoe, the detail is very similar. Because you do lose some detail on the sintered parts when they are plated. But that is usually considered into the design. You know the plating will add a certain amount of layers, so you design slightly smaller to compensate for it…make room for that thickness.

(I): Okay fantastic… can you think of any other suggestions or techniques that can be beneficial for PPFTs by using acetone or other ways the acetone can be used?

(R): Well uhm…from the way we have done it firstly the planning, where you split parts etc. plays a big role so that it for example can fit together. I never use plain cuts, I use plugs. If I have to consider the entry level technology I would print the angels separately and then finishing them separately before assembly. This will allow me to get into spaces which I otherwise would not have been able to access. Another way would be to adjust the design for this technology. I cannot confirm it but it does seem that with the acetone vapour the arms become a little thinner, so making the walls slightly thicker might compensate for that.

15. What do you think will the future hold for PPFTS in the AM industry as well as other industries?

(I): What do you think is the future for PPFTs and does it have a place in the industry or do you think it will steer in a completely different direction in the future?

(R): Well I have always been a very big advocate of surface finishing, for some reason in South Africa, it is still very lacking. Especially the bigger labs, they print left and right but finishing is never even looked at. When you go to company like Materialize you will see a whole section of their company is finishing. At the end of the day: if the product is not finished, it is not a finished product, then it stays a prototype, but the moment you add finishing to it you can create a finished product, so by using these techniques you create a final usable product. **THE FINISHING IS ACTUALLY THE KEY OF TAKING 3D PRINTING FROM JUST DOING PROTOTYPES TO SELLING PRODUCTS IN THE MARKET.** South African companies really need to wake up and spend more time on it to get specialists in that field. There needs to be a development in this so that there are companies that focus on production and other that focus on finishing.

(I): So basically you are saying we should outsources all the different functions to different specialists.

(R): Yes, again it's a specialised kind of thing. For instance larger companies print a lot of things and do not have time to focus on surface finishing.

16. Any last comments?

(I): Are there any other comments that you can add in regards to the shoes or the vapour chamber or acetone?

(R): I don't really think there is really anything. Look for me it comes down to how it is used in the industry for the purpose of the project. It comes down always to time and money. These budget constraints pushes you into using specific technologies. That's always the big one, if for example we do not have money to laser sinter then we have to use other processes. Now sintering isn't always the best option but that depends on what the product needs to be, in this case the shoe… we needed something that is very strong that an actual person could be able to wear so sintering was our only option, but for display purposes for instance the ABS model would work. Again it also depends on how much time we have, if we don't have the time…we…because although it might be a cheaper option, it does take a lot longer to finish, where with the sintering…when it's done, it's done. You don't have to do any post-processing. I for one want to print a bigger version of the shoe to show off the detail to companies and for that we can definitely use FDM technology. It would be a lot cheaper than sintering it.

17. Any suggestions or recommendations you would like to add to the interview?

(I): Any other thing you can think of to improve this kind of process, finishing or technology?

(R): Well I'm not really in that industry so cannot really say…not specifically but I would advise for anybody playing or developing this technology to not stop. To continuously try new things...I have seen in the last year or two material development of new materials…uhmm what's the material called now???

(I): PLA?

(R): the PLA…there is a company I'm working with that managed to get the same finishing results like the acetone on ABS by using other materials (*chemicals*). Stuff that nobody even thought about.

18. THANK YOU FOR YOU TIME AND VALUEBLE INPUT

(I): Okay that is basically it for the interview. I would just like to thank you again for your time and valuable input and that you took the time in your busy schedule. Lastly also availing the wonderful artefact that you and Lionel designed. I really do appreciate it

(R): No, it's a pleasure

3.2 Respondent 2: LTD

Transcript 2 of interview with Lionel T. Dean Interview: 2016-03-31 09-44-50

Legend for interview	
Questions	Are colored in RED
Important gist of the conversation	Highlighted in YELLOW
Background explanation (filler)	~~Strikethrough sentences~~
Interpretation of ideas or words	*(Italic and in brackets)*
Interviewers notes and comments	Track change comments on right side of doc

1. Introduction: Thank you once again for taking the time to partake…

~~Interviewee (I): Firstly, I would just like to thank you again for partaking in the study and I really appreciate that you availed your work so that we can actually reproduce it~~
~~Respondent (R): (*No response*)~~

2. What is your background in 3D printing?

(I): What is your background in 3D printing?

(R): Okay… so I've been working exclusively in 3D printing since 2003, my first research project was in 2003, and that took over my work, so all my work was focused on 3D printing since rapid prototyping in 2003.

(I): Okay so you have been in Rapid prototyping since 2003, so that's roughly around 13 years?

(R): Yes.

3. Which industry do you service in your opinion, with regards to 3D printing?

(I): Which industry specifically did you service? Is it more towards industrial design, design, art, architecture, which area specifically have you been working since then?

(R): Ok. It is a blend between industrial design and art, so in fact these are industrial design artefacts but because of their nature they are customized and become art objects. But essentially it is industrial design.

4. Do you have any prior knowledge of Post-production-finishing-techniques (PPFTs)?

(I): Do you have any knowledge of any post processing finishing techniques PPFTs?

(R): Yes, I do.

5. If YES, please elaborate…

(I): If yes, please elaborate?

(R): Well, a range of techniques and technologies, not very much to do with FDM. Not much to do with vapour (*limited*), but hand finishing, electro-forming.

(I): So you have worked with abrasive finishing techniques?

(R): Yes.

6. If NO, explain to respondent so interview can be completed.

~~(I): Please ignore the next question as you carry knowledge of PPFTs.~~

~~(R): …*silence*~~

7. Would you prefer to do (PPFTs) yourself or subcontract it out and why?

(I): From your experience between the industrial design and art worlds, would you say as an artist yourself, would you prefer to use post-processing yourself or would you usually subcontract it out to another person and why?

(R): I usually do it myself, because it's very difficult to get the quality you want at a reasonable price. Because one of the… it's subjective…how? How? You can always carry on with the hand finishing (meaning: continue with the finishing technique), how far would you go? I do a lot of work with electroforming and once you put the metal down you cannot go back. So if someone plates it too soon without finishing it, you are left with that marking.

8. What is your overall impression of the artefact that was reproduced?

(I): Now if we look at the artefact that was finished for this study, that specific product (*artefact*) that yourself and PVDW developed, what is your overall impression of the artefact that has been reproduced? When you look at it now?

(R): Well, given the finishing process I am actually pretty impressed because there are details on the figures I wouldn't have actually expected…uhm… so overall the impression is good.

(I): okay okay…

(R): Then again it wasn't designed for this process, so there is some of the geometry that have thin wrists (for example) that haven't formed, I wouldn't expect that had you designed it for this process you wouldn't have designed them so thin.
(I): Exactly…yes.

8.1. STEP LAYERING:

(I): When you look at the artefacts in front of you and you observe the step layering. Is it very evident? Do you think the process of Post-processing finishing techniques (PPFTs) has influenced the artefacts to improve the surface roughness reduction? (QUOTE: to make the surface smoother)?
(R): I don't think you are… you are seeing it in places that aren't of importance… when look at the underside of the sole plate, there is quite a lot of marking on there…but you have to hold it upside down to see it. From a consumer perspective they wouldn't see it at all, they would be rotating it looking at the figures that are pretty smooth.
(I): If I told you that the underside and the top had similar striations before surface finishing, would you then say the technique is successful or not?
(R): The technique is definitely successful, I mean the only place where there is some damaging is underneath the heel. It's always a problem where there is a big explosive surface, I mean if there is damage on the figures because there is complicated geometry, you don't always notice. BUT that heel…there is pitting there that you do notice.
(I): That is right. Now to give an explanation the top bit also had a lot of very serious step-layering, but that obviously could be eroded away…uhm… by abrasive sanding and then after that the vaporizing technique that was used. The problem that I, as the finisher for instance had with the object was that the bottom could not be reached, so I could not do finishing techniques. (*Researcher apologize for going off topic*).
(R): Yeah…

8.2. ASSEMBLY TECHNIQUES:

(I): Then when you look at assembly techniques, in other words fusing the parts together. Would you say that that is successful or unsuccessful or do you feel oblivious to the topic?
(R): I think that that is very successful…uhm… the only one you notice one sort of halfway down the geometry…just at the point where the ball of the foot raises into the arch (Figure1), there is a line across there and that is quite strong.

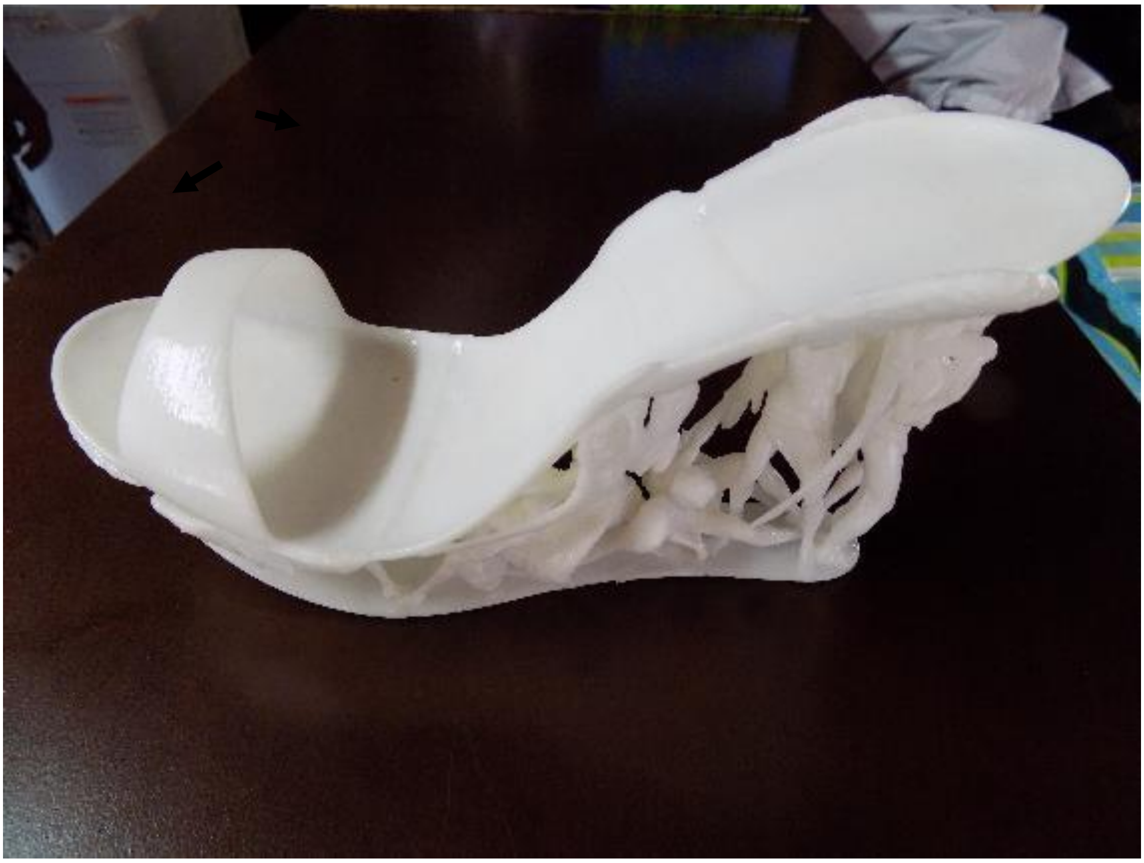


Figure 8 Assembly lines on the arch

(I): Okay okay…

(R): It is made worse by the fact that where it hits the figures at the bottom there are two limbs, lower legs of two angels come together and it literally arise on this line at a point which almost draws your eye into it. That is just an unfortunate accident, but to be honest, I am familiar with this, you divided it and stuck it together and I don't think you see it all that much.

(I): If you look at the two very last angels, male angels standing at the back (at the heels side), one of the two had a smoother surface finish (*you can see it through the waist line*), (Figure2), can you see the two parts that have been stuck together?

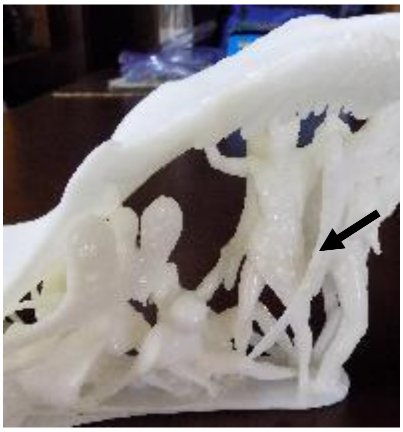


Figure 9 Seam line where parts were glued

(R): Yes I can see them, the one has a very strong line running through it and the other doesn't.

8.3. SURFACE TEXTURE:

(I): That is right. I used two different techniques, hence I am specifically asking for that section. The one was basically just a fusing technique and the other was a fusing and eroding (*smoothing*) technique where the acetone glue was added onto the surface. Now when you look at the two artefact in front of you would you say this is a technique that could be explored? Or, do you think it doesn't really make a big difference between the two artefacts?
(R): There is a mild difference between the two pieces, I'm assuming the glossier one is the one with the finishing?
(I): Correct.
(R): Yeah and that is more successful. The gloss is great in that it gives a smoother finish, but it is slightly distracting that it is almost too glossy. It is just one of those things.

8.4. AESTHETIC VALUE OUTPUT:

(I): Do you feel that the object (*artefact*) has been improved aesthetically by applying this technique with this specific technology or do you feel aesthetically it is not a pleasing object?
(R): I think that is a tricky question because it's been improved because the aesthetic is less disturbed by the manufacturing, both from an industrial and artistic point of view.

9. Which part would you consider most successful?

(I): Which part of the overall artefact would you consider most successful?
(R): I should think the bridge in the front that is working very well (figure3).

Figure 10 Bridge area

(I): Right, so that would be the area where the foot slips under?
(R): Yes.

10. Has these finishing techniques improved or made worse the quality of the artefact?

(I): Has these finishing techniques improved or made worse the quality of the artefact, in your opinion?
(R): yeah it has improved. I mean I don't think you can show the untreated parts if you just printed and stuck them together, where with this one you can almost get away with showing it. For me there unfortunately is a little too much missing from the parts that didn't form but generally it is not that disturbing.
(I): Now im going to deviate slightly from the questions in regards to your above answer. From an artistic point of with sometime you will get what is called the "happy accident" whereby a certain area didn't print but from an aesthetic viewpoint it can be rendered useful. If you look at the back of the heel all the way at the top one of the angels have an arm that broke off and it almost makes me feel like it looks like a Romanesque sculpture… So from an artist point of view, do you think that these kind of "happy accidents" with the technology can be used successful or not?
(R): Mmm, I am not a fan of the "happy accident" as a principle. I do agree that the angel at the back is quite nice.
(I): So you wouldn't compromise the technical aspect over the aesthetical artistic?
(R): No.

11. Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM?

(I): 11. Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM processes?
(R): Yeah, yes simply on cost.
(I): And quality? Do you think it still has some way to go?
(R): Well you can't really separate those two, if the cost for example was the same as SLS I would say no and go with the high end option, because the resolution is better and you're not dividing the artefact into pieces, but a friend of mine that sells shoes compromises the quality slightly for a cheaper cost.

12. Do you feel the tech is successful or does the technical ability of the artist/ designer play a role?

(I): Do you feel the tech is successful or does the technical ability of the artist/ designer play a role? In other words the techniques that was used in itself, the vapour technique, is that successful by itself or do you think that OR do you the think the artist or designer that does the actual post-processing play a big role in how the quality comes out?
(R): That is a very tricky question as I didn't see the process unfolding. I am not sure if the results are down to the skill of whomever did it or whether that was just an automated process. It is quite hard to judge that question. I think the finisher has quite a big role because looking at the part I can see that some areas have had more attention than others, so when we talked about the stair stepping in the beginning it has been dealt with in the more critical areas.

13. Are there areas where these techniques can be improved?

(I): Are there areas where these techniques can be improved…uhm that have been used on these specific objects now? Do you feel there are areas where these post-processing technologies can be improved?

(R): Oh yes I would assume so. There is a difference between the two pieces in front of me, I assume if you continue with this it would improve further.

13.1. STEP LAYERING:

(I): When you look at the step layering specifically, in your opinion, where do you think it can be improved

(R): Okay, I think it is consistency because the stepping itself is not such a problem, If you look at the underside of the sole it's almost like the grooves are a record, were they are uniform it would have been nice, the problem is every now and then the machine is jumping and you get bigger gaps and that's where the disturbing bit originate.

(I): Do you think improvement to hardware would solve this problem or more the development of these post-processing techniques?

(R): I would say hardware.

13.2. ASSEMBLY TECHNIQUE:

(I): For the assembly techniques, what do you think can improve?

(R): I think that links back to what you asked previously about the skill of the operator, yeah I'm sure they can improve still further

13.3. SURFACE FINISH:

(I): Surface finishing overall?

(R): It's pretty good, I don't think you going to get much better.

13.4. AESTHETIC VALUE OUTPUT:

(I): Are there areas where the aesthetic value output can be improved by using these techniques?

(R): You have to limit the flaws. Design the artefact for the process, for example there are a few areas that are just too thin and didn't print.

14. Do you have any other suggestions of techniques that can be beneficial for PPFTS?

(I): Do you have any other suggestions of techniques that can be beneficial for PPFTS?

(R): Uhm, no, not off the top of my head.

(I): When you think of the high-end technologies you have worked with before, are there any of them that might be beneficial for entry level FDM PPFTs?

(R): I'm not sure as everyone is still fighting to discover but the biggest improvement usually would be the resolution, the accuracy of the machine, the finishing is still largely down to hand techniques.

(I): One of the techniques I have seen is chrome plating for ABS plastics. Might that be a viable addition?

(R): I think it is a very viable approach to these plastic parts as plastic is usually not seen as a high value part material

15. What do you think will the future hold for PPFTS in the AM industry as well as other industries?

(I): What do you think will be the future for PPFTs in AM and the design industry; and art, you know all the other industries? Do you think there is a future for this technology?

(R): Okay well definitely is a future for this technology, beyond any doubt. Ultimately we want to get to the situation where you go straight from the entry level to high end production, have the same quality as you see in renderings on screen.

16. Any last comments?
(I): Are there any last comments you would like to add to the interview?
(R): No, just well done. Very nicely finished part.
(I): Thank you very much.
17. Any suggestions or recommendations you would like to add to the interview?
(I): Any suggestions or recommendations you would like to add?
(R): Uhm not off the top of my head, no.

(I): Just to recap…In essence you feel there is a place for this technology from a quality and a pricing perspective and you feel that the overall techniques that were used to finish off is successful at least to a certain point
(R): yes definitely.
18. THANK YOU FOR YOU TIME AND VALUEBLE INPUT
~~(I): Thank you very much for your valuable time and input. I really appreciate it.~~
~~(R): Thank you~~

3.3 Respondent 3: WvdH

Transcript 3 of interview with Mr Willie van der Heever. Interview: 14/05/2016

Legend for interview	
Questions	Are colored in RED
Important gist of the conversation	Highlighted in YELLOW
Background explanation (filler)	~~Strikethrough sentences~~
Interpretation of ideas or words	*(Italic and in brackets)*
Interviewers notes and comments	Track change comments on right side of doc

1. Introduction: Thank you once again for taking the time to partake…
~~Interviewer (I): Good day Willie. I would just like to thank you for partaking in this interview and being part of my research…and I want to just convey my thanks to say this will really make a big difference in the 3D printing community.~~

~~Respondent (R):… okay uhm… I am glad to help.~~

(I): ~~How are you doing today?~~

(R): ~~uhm… good thanks.~~
(I): ~~okay. We are going to keep this as informal as possible, so…you don't have to stress….uhm… there is no right and no wrong answers. It's basically an opinion poll, so basically we trying to ascertain…uhm…what your opinion is, from your background and your perspective in regards to specific objects and finishing techniques, etc. in entry level 3D printing.~~
(R): ~~Okay.~~

2. What is your background in 3D printing?
(I): I am going to start off by..uhm… question 2 on the question sheet…you will see it says: What is your background in 3D printing? Can you please give us feedback on that?

- (R): Uhm… my background is…uhm… theres not a lot because I am new to it…because I only started like two years ago with doing it in my work.
- (I): ~~And uhm…(interruption)~~
- ~~(R):…so I would say…~~
- ~~(I): sorry, continue.~~
- ~~(R): No, I would say it is fairly~~ still growing.
- (I): okay, okay, but you have done some 3D printing work for the last couple of years?
- (R): Yes, I have.

3. Which industry do you service in your opinion, with regards to 3D printing?

- (I): Now just to elaborate in regards to the question, when I say industry, I mean are you from the art sector, are you from design, are you from architecture, are you from engineering…from which perspective do you come from in regards to 3D printing?
- (R): I come from Fine art
- (I): Okay and for what application did you use 3D printing in fine arts?
- (R): I used it in sculpture.

4. Do you have any prior knowledge of Post-production-finishing-techniques (PPFTs)?

- (I): Do you have any prior knowledge of Post-production-finishing-techniques?
- (R): No, the only one I know of is vapour treatment.

5. If YES, please elaborate…

- (I): …
- (R): …

6. If NO, explain to respondent so interview can be completed.

- (I): So you do have some knowledge in regards to some of them but not ALL of them?
- (R): Yes, that is correct.
- (I): Now this specific study went into more depth in regards to vapour treatment by the form of acetone as well as acetone cement. Acetone cement is basically a concept where you take your support and raft material (*ABS*) that is left over, and you mix that with acetone to create a thick substance that is almost like glue. When you apply that then directly to two parts, you can basically fuse them together. Have you had any prior experience using these techniques?
- (R): Yes, a little bit…uhm…but..uhm..I still had to experiment because at first it did not work out, so… uhm I am still learning.
- ~~(I): Now in regards to the PPFTS there are also a whole array of different techniques you can use. Some other ones are abrasive sanding, so obviously in between you sand layers. Then you put more of the acetone layers on top of it and then sand it down again. That's another finishing technique. You get techniques like…we will discuss this in a little bit, where, when you have holes or cracks, you basically have different techniques to fill it up with, like POLYFILLA, that kind of thing.~~

7. Would you prefer to do (PPFTs) yourself or subcontract it out and why?

- (I): OKAY, so basically what I want to say is, when you consider all these kinds of post-production-finishing techniques, in your opinion do you think you would prefer to do it yourself on the artefacts that you create or would you rather subcontract it to a specialist that specialises in finishing techniques?

- (R): I think I would try to do it myself to gain the knowledge and experience from doing that.
- (I): Okay, and from the little bit that you have done in the past, do you feel that it is very time consuming or do you think you got it right very quickly?
- (R): Uhh…I did not get it right very quickly, but I wouldn't call it time consuming, maybe that's my own…(*MISSING REPLY BY FORM OF SILENCE-PAUSE*)… I like doing things like this.

8. What is your overall impression of the artefact that was reproduced?

- (I): What was your overall impression of the artefact that was reproduced, when you have the specimens infront of you, uhm can you just have a quick look at specimen a (1) and specimen b (2) for the moment ignore the last one…the small one for the moment. If you had to look at them, let me first explain what happened. Okay the components were obviously too large to print on a 12x12cm platform or like they call it in the industry a 120mm cubed platform. So basically the component had to be subdivided into 4 sections and then had to be assembled. And as you can also see, it also went through vapour treatment, so the surface has become smoother. Then I have indicated a couple of areas with markings…an A, B, C, etc that we will discuss now, but overall when you look at the objects, what is your opinion?
- (R):uhm… it is interesting. I would say I like specimen one (figure 1) better.

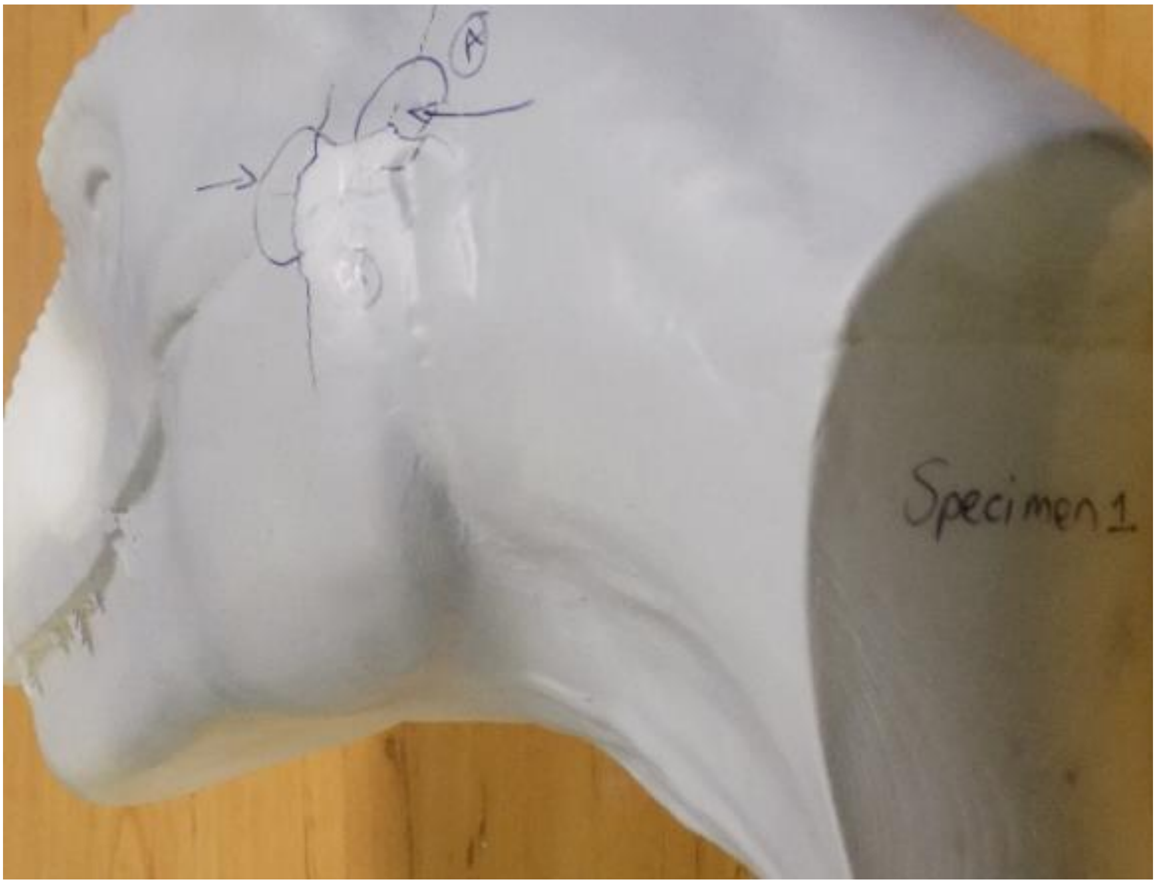


Figure 11 Specimen 1

(I): For what reason?

(R): The specimen 2 (figure 2) looks dirty at the seams where it was clued together…

Figure 12 Specimen 2

(I): So from a visual perspective it is quit dirty?

(R): YES

~~(I): Okay, then you will see it subdivided into a number one, two, three and four…okay, so we will go into a little more depth there…~~

8.1. STEP LAYERING:

~~(I): When you look at the two specimens…firstly, are you familiar with the concept of step layering?~~

~~(R): Uhm…that is…is that in regard to the…just quickly uhm (*talk over each other)*~~

~~(I): I can quickly explain it to you if you are not sure… In short, Step layering is, you know the concept of this kind of 3D printing is called Fused Deposition Modelling (FDM), so basically layers are fused together, while depositing plastic and it's a modelling process. Now when you create this layer upon layer effect, you see little striations or steps that is created that sometimes is visible to the eye, in between the layers. So if you feel over the surface it feels like little layers that you can see. Now those are called step layers. Now sometimes when the printers are not synchronized *(meant calibrated)* correctly those step layers become more prominent, does this make sense?~~

(R): Specimen two I can see a lot of steps, although the vapour has smoothed it out, I can still see even though it has been smoothed, but specimen one is less visible (*meaning the steps are less visible).*

8.2. ASSEMBLY TECHNIQUES:

(I): Yes, okay, we can move on then from that (*question*) to the 8.2 question which is assembly techniques. Now the assembly technique that was used on both specimens was acetone cement or acetone glue… would you say in your opinion it's a successful technique, partial successful or not successful at all, how do you feel?
(R): I would say that it is maybe partially successful, because I can see the cracks in it.
(I): Are you now referring to the cracks demarcated as number A (figure 3) on specimen 1? Or do you mean… (*Interruption)…*

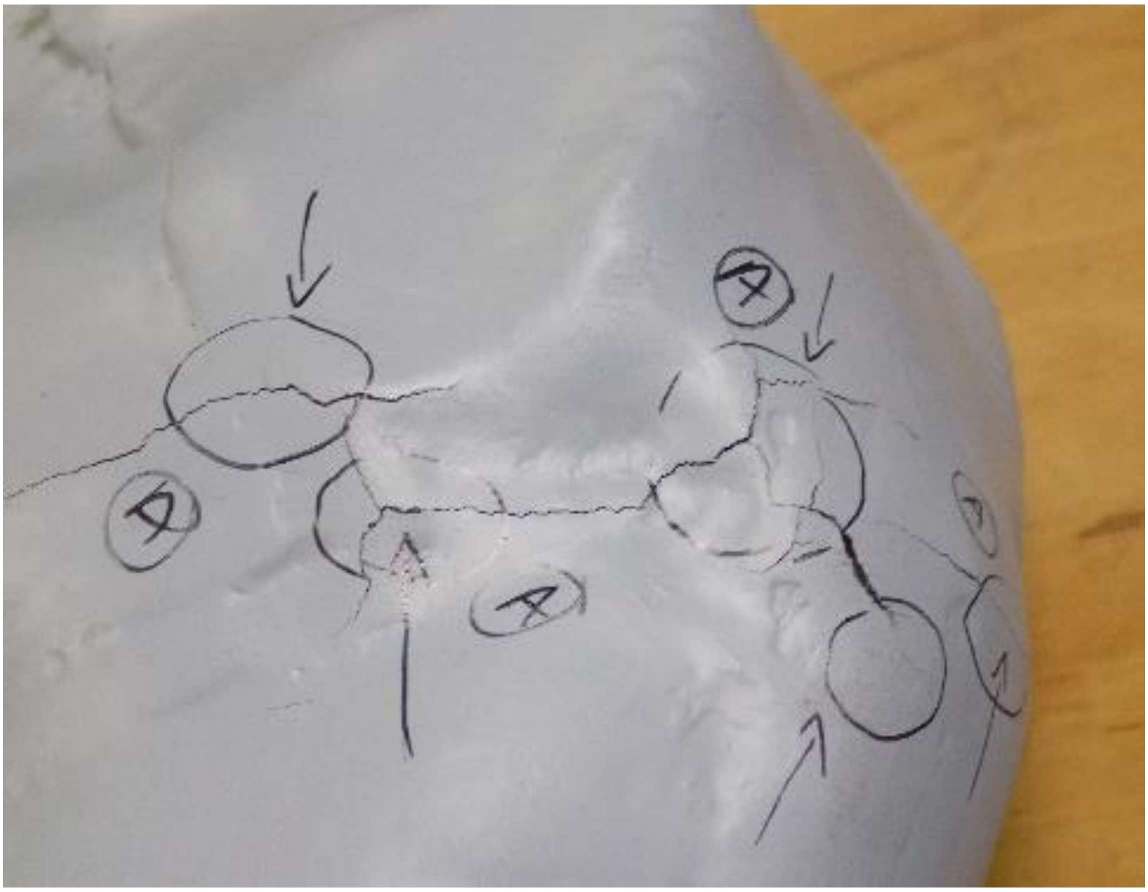


Figure 13 Cracks on surface of specimen 1

(R): Yes
(I): okay when you look at specimen 1 for example look where it says "SPECIMEN1"…right? Where it is written "SPECIMEN1"…
(R): Yes…
(I): When you look at that section, im just trying to open it on my side so I can see as well…You see on top of it where the line is…the joined section…right?
(R): Yes

(I): But, towards the edge on the (S) side where it says "SPECIMEN" (figure 4). That edge where it goes around the corner, you can see in the grey area that it has quit a smooth section where the joined area almost disappears?

Figure 14 Specimen one EDGE

(R): Ja ja, I see it...
(I): So what I am saying is, there obviously are areas that I finished off further on purpose and there are areas that I did not so that we can see the difference. Now when you take this into consideration and you look at all the areas… do you feel that this kind of technique with the right kind of practice can be successful or it might cause a lot of problems?
(R): I would say it is successful and it gives a nice texture.

8.3. SURFACE TEXTURE:

(I): That brings us then to the next one … the surface texture… the overall surface texture on the two specimens, what is your overall impression from what you expected maybe beforehand and what you actually see now
(R): I would say… uhm… if I had to…I would say im in favour of specimen ones surface texture
(I): Okay
(R): Two not so much because it is not…it's only smooth and the cement surface finishing gives an interesting texture.

8.4. AESTHETIC VALUE OUTPUT:

~~(I): You understand the concept of aesthetic value output? The visual aesthetics of an object, obviously as an artist you have dealt with that concept before?~~
~~(R): Yes, I have.~~
~~(I): Okay, so it means how visually appealing that object might be for various reasons to a specific person or group of people… right?~~
~~(R): Yes…~~
(I): When you look at these two specimens, what would you feel is the aesthetic value output from an artistic perspective… from your specific perspective…which one of the two in your opinion would be more successful?
(R): Definitely specimen 1
(I): Okay, can you elaborate why you feel this way?
(R): Uhm…can I bring in the cracks and stuff?
(I): Yeah, you welcome to bring in anything into the discussion.
(R): ugh…I was thinking…even though it is there (the cracks)… you might think it does not contribute to the positive aesthetic…I think if you use it to your advantage maybe it can be more positively aesthetic…you could create interesting things with it.
(I): I completely agree with you. Now obviously the different industries will differ for example somebody from architecture or graphic design or engineering might not necessarily agree with that but definitely in the artistic sphere…you know like we call it "happy accidents" ending up more interesting and makes the object more appealing.
(R): Talk over: YES YES…uhm yeah
(I): So that is basically where you are going with this (*discussion*) because of that section that is demarcated (A) (see figure 3 above). You actually think that makes the object more interesting?
(R): Yes, I do.
(I): Perfect, that moves us then into the next section… you can take specimen A now and we can start off with those sections now and just see…that section numbered as A…what happened there was that on the joint where the two pieces are fused together by the ABS acetone cement (glue), there was basically infiltration of the acetone, which caused entrapment. The vapour is isolated on the outside…it dries off on the outside and there is still the vapour on the inside and over time the object will crack open. So from an artistic point of view, in your opinion, you are saying that is not a flaw…you say as an artistic technique this can work in your advantage, right?
(R): Yes.
(I): Okay, is there anything else you can add to that?
(R): I think that if you use it on an objects whole surface…if you implement it in the right way it can give an antique look.
(I): So basically the finishing technique…what you are saying is…can have a visual appeal as well as a functional… (*outcome*)… it can actually give a good texture that you can use for a specific technique.
(R): Yes, I would try to implement it deliberately.

(I): Then if we go over to section B (figure 5) on specimen one. That would be the nose section, you can see the joint section there right in the front, on the nose. When you look at that would you say that it is a successful joint or do you think it needed to be a bit ~~more~~ smoother?

(R): I think maybe…I don't think the smoothness…it's almost like if you feel over the surface it creates like a bump.
(I): Okay, so it doesn't really bother you?
(R): No, not all that much.
(I): Okay, then we can move on to the next section that says C (figure 6), that's on the right jaw.

Figure 15 Specimen 1 Nose joint

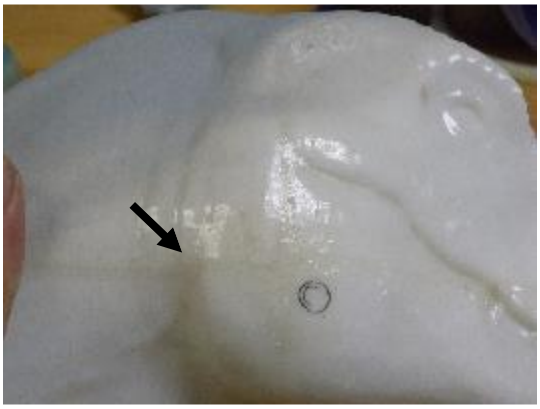


Figure 16 Specimen 1 joint- Right jaw

On that jaw line you can clearly see where the four pieces came together… where they are fused.
(I): Now if you look at the top of that little X (*meaning where the four lines meet*) where it is fused you will see there is almost like a little bubble (hole beneath the surface). Now again from your perspective, if you look at the eye section and you see how smooth that area is… and now look back to just above and left from where the C is, where the little joint is. Would you consider the joining as a rough joint, is it smooth enough or do you feel the same as before in regards to "happy accidents" through aesthetic value?
(R): It almost create like a skin texture, it looks like pores.
(I): Okay let me ask you…what was the objects intended to be used for?
(R): uhm this was just a quick creation…I was basically fooling around.
(I): So you didn't want to use this in a specific exhibition or work?
(R): No…

~~(I): Okay, we can move on to specimen 2. Now to just give you a quick idea, numbers A (figure 7) and B (Figure 8)… A would on the side of the head, the left jaw and B would be around the nose area again. You see the black marks inserted there, now just to explain the black marks were just a decolouration that I put in on purpose so you can see the areas clearly where the surface didn't bond properly. The ABS cement (glue) shrunk into the joint at number A and B there actually was a crack that formed. I filled it up with something called spot putty and then you sand it down again so you can see the areas that are flawed…that needs to be filled up or closed off.~~ Now when you take that into consideration would you say that this gluing technique is successful or do you think it can improve, do you think it has to do with the artist (*technical ability*) that's working or is it the technique that is a little flawed?
(R): I would say that it's more the technique than the artist I think.

(I): Now if you think if the artist for example improves on the technique, in other words like a fine artist, a painter, the more you paint the better you will get, so basically the more you use the technique the better you will get. Do you think this is a situation like that?
(R): Yeah, I think it is.
(I): Can you as an artist really control the outcome of the technique or do you think it is based in the chemicals (*process*) of the technique?
(R): I guess it is in the chemicals.

Figure 17 left jaw joint

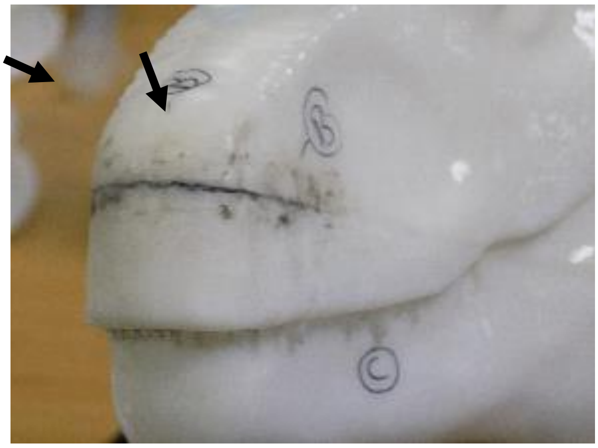


Figure 18 nose joint

(I): Alright then I'm going to move over to the section that says B. There are two areas marked B with lines pointing down to certain sections. Now if you look very closely you there where those two B's are you will see little cracks on the surface?
(R): Yes I see it.
(I): Okay, now it's the same kind of infiltration that happened there and then you have that cracked section on the nose. I am diverting back to the previous question where I asked do this kind of "happy accidents" work for the artefact or do you think it is bringing the quality of the work down?
(R): In my opinion not so much, I do not like the way it looks so much. I would not use it to further the aesthetic quality.
(I): So in specimen 1 it was aesthetically pleasing but not here on specimen 2?
(R): Yeah.
(I): If you had to ignore the big line that goes across the nose section and keep the two cracked areas that's marked B (Figure 8 above), do you feel those could give you an interesting texture to the artefact? Is it basically the big crack that is bothering you, is what I am trying to find out?
(R): I think…the coloration is not supposed to be there?
~~(I): Yes, I completely agree, however if you had to spray over that now in other words it doesn't look dirty… I mean if you ignore the fact that it looks dirty and spray over it like I did with specimen 1 where the cracks are (figure 9). I did this on purpose. On specimen one the cracks looked almost the same as these cracks on specimen 2. Then I sprayed over it to have a neutral color over it to see whether the dirty marks would be distracting.~~
~~(R): ahh yes, now I understand.~~

(I): Okay now if we go back to the question, if you ignore the big crack in the middle of the nose and look at the two B section cracks that are there, do you think that can be used in the aesthetic output of the work or do you feel it should not be there?
(R): I would say that I would regard it as a way to do that positively, yes…but again in a more overall finish…you can use it in certain areas depending on the model that you are trying to convey it in but I would say more overall.

Figure 19 spot putty and aerosol spray grey

Figure 20 Air bubble entrapped

(I): Then when we move on to section C…I am focusing specifically on the teeth now. When you look at the teeth on specimen 2 and then on 1, which do you feel is more successful. One had a longer exposure and was printed in different settings.
(R): I prefer specimen 1, especially on the grey part, the teeth on specimen 2 looks brittle to me.
(I): Okay, then if you go to section D (figure 10 above), on the side of the chin, I think it is the right chin if I am not mistaken, there are also a spot where there is a thinning of the wall where you can almost see into the bubble. Do you feel this is a successful or not successful area?
(R): I would say that it's not that successful, I wouldn't regard it as successful.

9. Which part would you consider most successful?

(I): Then I would like to ask you, which part would you consider most successful of the two specimens you have in front of you?
(R): Specimen 1 I like better, I prefer the part marked C.
(I): What is making it appealing to you?
(R): The texture it gives, it looks like skin pores almost and the kind of model it is, it kind of compliments it.
(I): Right, because it's a dinosaur it goes with the subject matter.

10. Has these finishing techniques improved or made worse the quality of the artefact?

(I): In your opinion has these finishing techniques improved or made worse the quality of the artefact? If you would like to know what it looked like beforehand, I would like to ask you now to take specimen 3 and hold the head towards you fingers and the part where it says section3 towards your face. If you hold it like this you see all the step layers. This object has been glued but not surface finished, now when you compare this one to the other previous two, would you say these techniques improved or made worse the specimens?

(R): In my opinion it improved it because usually a favourable 3D print is seen where the layers are not visible any more

11. Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM?

(I): Do you think applying these finishing techniques and developing them on entry level can be seen as a viable option to compete in the high end market?

(R): Yes, I think it can.

(I): What do you think will help it get there?

(R): Well, firstly…definitely experimenting more…(*Respondent left answer here*).

12. Do you feel the tech is successful or does the technical ability of the artist/ designer play a role?

~~(I): In other words, can anybody take this technique and apply it on (*post*) 3D printing and it will come out good or do you think the artist plays a big role.~~

~~(R): In printing the model?~~

~~(I): No not in printing the model but in post-production finishing techniques afterwards.~~

(R): Uhm…in vapour treating I think it is successful and there might play a role in the artist using it but not that much I would say. BUT, may I say…that maybe in the process of painting the part the artist role becomes more important because of their knowledge (*prior artistic knowledge*).

(I): In that case then, do you think, if you have the same technique and object…and you put somebody without an artistic background and have them surface finish AND then do the same with someone that does have a good artistic background…which one in your opinion would come out more favourable?

(R): They would probably come out the same… (*pause for a moment*)… because it is steps that you follow and it is not completely only the knowledge you have acquired as an artist.

(I): Okay and what about the "happy accidents"? The artist or finisher is not in control of that process even if taking the right steps. Should these be worked away or incorporated into the artefact?

(R): I think it depends on the artist but something like that you cannot control so neither of them can control it in a major sense.

~~(I): Let me say: an engineer and an artist applies the same techniques in post-production to an artefact but they THINK differently…they get to a point where they have this kind of infiltration happening resulting in cracks…if it makes no difference then they both should think in the same direction and finish off the artefact in the same way.. Do you think this kind of technique controls you as the artist or do you think you as an artist control the technique or is it a symbioses?~~

(R): I would say you control it to a certain degree but it might lead you to create it for certain applications but I think the artist might use it deliberately but the engineer would steer away from it because it is not what he wants to create.

13. Are there areas where these techniques can be improved?

(I): *(Skipped the general question and moved directly to 13.1)*

(R):

13.1. STEP LAYERING:

(I): When you look at the specimens are there areas where the step layers can be improved?
(R): I would say it is successful for example in specimen 1…you cannot almost see it (*step layers*) at all.
(I): Are there areas where it can be improved?
(R): Yes, I guess so.
(I): Can you please specify.
(R): Now that I look at it…I would …I don't know what to say.

13.2. ASSEMBLY TECHNIQUE:

(I): That is now by looking at the parts that were fused together by the ABS cement glue. What would say can be improved?
(R): Specimen 2…this part D? It is part of the glue where the hole was made?
(I): That is correct a little bubble got trapped inside and before it could reach the surface, the surface sealed off.
(R): The glue on specimen 2 is rather rough and could be sanded off more.

13.3. SURFACE FINISH:

(I): Okay overall when looking at the surface finish, do you think there is any area that can be imporved?
(R): I am quite satisfied with specimen 1 but specimen 2 needs sanding.

13.4. AESTHETIC VALUE OUTPUT:

(I): Between the two objects which is more aesthetically pleasing, specimen 1 or specimen 2?
(R): Definitely specimen 1.

14. Do you have any other suggestions of techniques that can be beneficial for PPFTS?

(I): Do you have any other suggestions that will be beneficial for PPFTs?
(R): Uhm… I'm not that knowledgeable in that area…. I can't think of any.

15. What do you think will the future hold for PPFTS in the AM industry as well as other industries?

(I): So that means for architecture, for design for engineering and fine arts? What do you think the future will hold?
(R): Yeah I think there is, especially in covering up parts… the seams. Look if it is maybe something that is sold to the consumer it could be MORE aesthetically pleasing (*finished more completely*)…be more presentable.
(I): Do you think this industry will grow, become more prominent or just steadily stay in the background?
(R): I think it will grow…its not something that is that widely used yet so there is space for it to grow

~~16. Any last comments?~~
~~(I): Any last comments?~~
~~(R): I don't think so.~~
~~17. Any suggestions or recommendations you would like to add to the interview?~~
~~(I): Any suggestions or questions or things I didn't discuss?~~
~~(R): No I don't have any?~~
~~18. THANK YOU FOR YOU TIME AND VALUEBLE INPUT~~
~~(I): Thank you very much for you time.~~

~~(R): okay…it was a pleasure to help out.~~

3.4 Respondent 4: JB

Transcript of interview with Jeanè Bresler Interview: 2016-05-14 16-18-43

Legend for interview	
Questions	Are colored in RED
Important gist of the conversation	Highlighted in YELLOW
Background explanation (filler)	~~Strikethrough sentences~~
Interpretation of ideas or words	*(Italic and in brackets)*
Interviewers notes and comments	Track change comments on right side of doc

1. Introduction: Thank you once again for taking the time to partake…

Interviewee (I): Okay welcome Jeane, I would just like to thank you for taking part. I really appreciate it

Respondent (R): Thank you, it's a pleasure

2. What is your background in 3D printing?

(I): Okay we can jump into question one, can you in short tell us what your background in 3D printing is.
(R): Well I studied graphic design and from there I got into 3D design using Rhino software. Then I started working at the technology station where I learned about 3D printing and it kind of went from there. So that is my background and how I got into it.

3. Which industry do you service in your opinion, with regards to 3D printing?

(I): So which industry do you service in your opinion, when I say industry I mean…so you see yourself come from an artistic, design, engineering or architecture background. Which industry specifically?
(R): Mmm I would say more design, sometimes we make architecture and engineering stuff look more good through design.

4. Do you have any prior knowledge of Post-production-finishing-techniques (PPFTs)?

(I): Do you have any prior knowledge of Post-production-finishing-techniques? So that would mean after the artefact has been created and it has been surface finished do you have any knowledge about them?
(R): No, not really apart from the stuff that you showed me. Nothing else no. I know about it, for example techniques used on the EOS machines. But I do not know how it is done.
(I): Okay so you do have prior knowledge, you just haven't done it yourself yet.
(R: YES

5. If YES, please elaborate…

~~(I): The reason I'm asking that specific question is it will set us up for the rest of the interview, for example if you said you have no prior knowledge I first will have had to explain what is acetone vaporising, but now I know you know already I don't have to explain it to you.~~
~~(R): Oh yes, I understand.~~

6. ~~If NO, explain to respondent so interview can be completed.~~

~~(I): Omitted from discussion~~

~~(R): Omitted from discussion~~

7. Would you prefer to do (PPFTs) yourself or subcontract it out and why?

(I): So this study mainly focused on the use of acetone finishing on the one side and on the other the use of acetone glue (*ABS cement*) to basically assemble components. In your opinion when you look at the type of designs you have done in the past, would you say that you prefer to do finishing techniques yourself or would you rather subcontract it to somebody else?

(R): I would NOT want to do it myself, it looks like a lot of work so…

(I): Is there a more technical reason why you feel this way? In What sense do you mean?

(R): I think it is just very time consuming especially because I like designing small and intricate parts. To finish all of those and then glue them together, I just think that I would rather pay someone else to do it.

8. What is your overall impression of the artefact that was reproduced?

(I): Now when you look at the artefact that we reproduced for you, overall what is the impression that you have of the artefact when you just look at it, let's say when you compare it to the high-end EOS parts that were grown before for you. What is your overall impression?

(R): Well, I honestly love the parts, it's just…it obviously needed to be bigger than the original parts for it to actually print and come out. But I do not have a problem with that or anything. I like the fact that it is smooth and it doesn't look like a 3D printed part.

8.1. STEP LAYERING:

(I): What would you say is your impression regarding step layering when you look at this artefact? Would you say it is visible or not visible?

(R): Well if you go into it and really look at the part you will be able to see it but from about 30cm away you can't really see anything.

8.2. ASSEMBLY TECHNIQUES:

(I): And the assembly techniques? If you look at the roof for example. What is your opinion about how the roof sections. The roof was obviously split into four sections and then glued together. What is your overall impression of that?

(R): You really cannot see it, it looks like it was done in one (*meaning grown in one part*)

8.3. SURFACE TEXTURE:

(I): What is your overall impression of the surface texture?

(R): I like the texture, I think if the design wasn't meant to be shiny it would be a problem maybe but in this case it works well with the design.

8.4. AESTHETIC VALUE OUTPUT:

(I): Do you know what aesthetic value outputs are?

(R): Uhm I know what aesthetic values are, I guess…uhm no I don't.

(I): In this context what I am asking is, is this artefact visually pleasing?

(R): Well I designed it and if it looked bad I would be upset because I gave it so much…so looking at it now I find it visually appealing. I think the aesthetic value output is fantastic.

(I): Without applying these techniques to the objects would it have been visually more pleasing or do you think its more pleasing after the finishing techniques were applied.

(R): I honestly do not think it would have been possible if the (*finishing techniques*) did not take place. If I look at the roof, I do not know how it would have been possible to assemble without this technique.

9. Which part would you consider most successful?

(I): Which part would you consider most successful? Are there any areas that stood out very much?

(R): honestly I like the roof the most because of the curves and the shine (Figure1). Grabs attention.

Figure 21 Roof assembled

But I am also impressed by the finer detail like the flowers and the railings that came out as pretty as they did. Those are the parts I am most impressed with.

(I): In regards to the little pillars and the railings (figure2) and using vaporizing, do you think there is anything else that could have worked better to assemble them for example? Or is it a viable option?

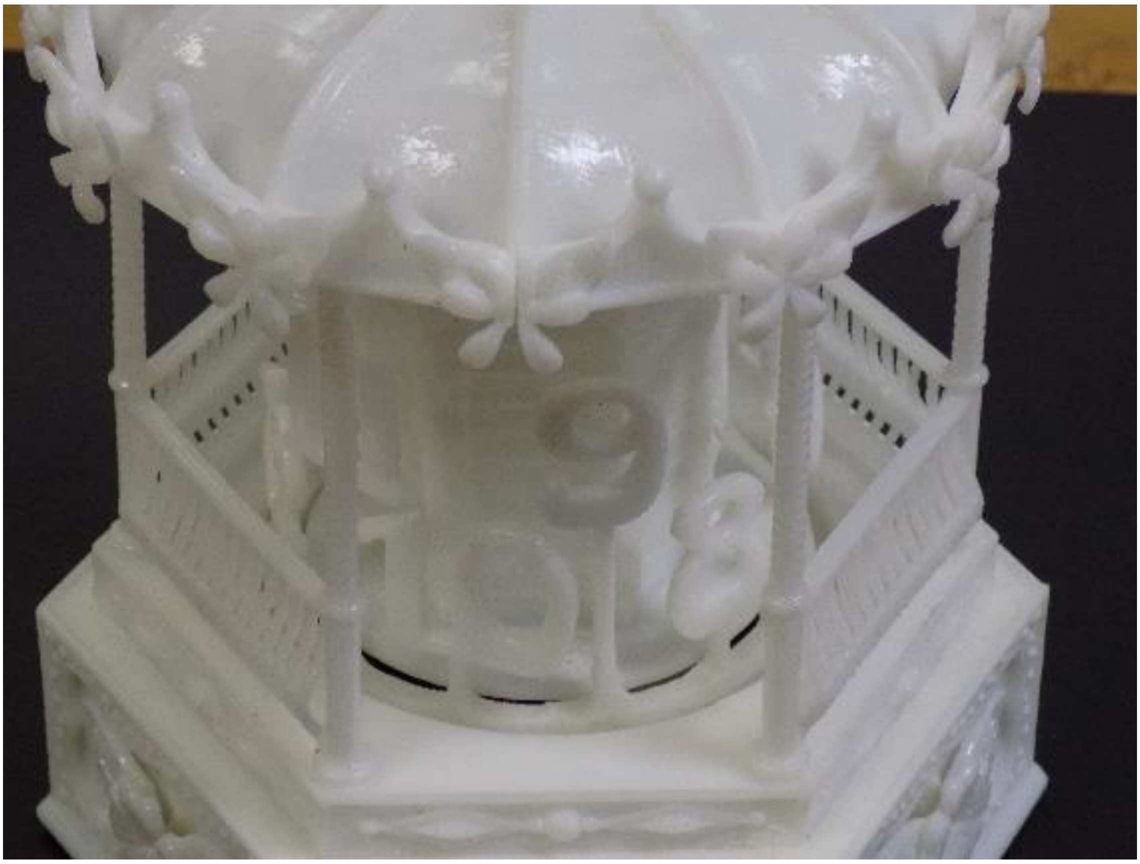


Figure 22 Pillars and railings

(R): No I think it is very viable, just to get them smooth the only other way I can think of is sanding it and that would break it and make it all dirty and sandy. That wouldn't work at all.

10. Has these finishing techniques improved or made worse the quality of the artefact?

(I): Has these finishing techniques improved or made worse the quality of the artefact?

(R): Definitely improved it.

11. Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM?

(I): Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM?

(R): Yes because of the costing point of view. I get a bigger model for so much less than the original EOS print. But like all additive manufacturing processes you design for it, so if you know beforehand this is what you have to do then you include it in your design process, then that is fine. SO it definitely can compete if you design for it.

12. Do you feel the tech is successful or does the technical ability of the artist/ designer play a role?

(I): What I am asking with this question is, when we use these techniques are the techniques successful by themselves alone or do you think the ability of the finisher or artist or designer in post-production plays a role?

(R): If I spend more time with you during the post-processing phase I would know better how to answer that but from just the knowledge I have I would say it does play role. If you leave it in too long it will be a mush or if you use too much or too little

(*acetone*) and the way you apply it might cause a dent or some other unwanted feature in the original design, so I think it definitely plays a part.
(I): Okay so technical ability does play a role?
(R): Yes

13. Are there areas where these techniques can be improved?

(I): when we look back at the object again are there areas where the techniques can be improved?
(R): *silence*

13.1. STEP LAYERING:

(I): When you look at the step layering do you think there are areas that can improve?
(R): In parts maybe but I don't think it can improve that much… the only thing that I would say maybe is also like the fine details on the leaves are taken away. If the detail can somehow be improved that would be great.
(I): Thank you, this answers the surface finishing bit nicely, so can we say that you feel the surface finishing technique successfully removed the step layers?
(R): Yes.

13.2. ASSEMBLY TECHNIQUE:

(I): In regards to the assembly of the components, are there any areas where it could have been improved?
(R): It is just parts like the flowers that are rough where they are joined, but nobody is really going to look into it. The rest, everywhere else is fine.

13.3. SURFACE FINISH:

(I): …
(R): …

13.4. AESTHETIC VALUE OUTPUT:

(I): What could have made it even nicer? Is there anything that could improve the aesthetic value?
(R): No

14. Do you have any other suggestions of techniques that can be beneficial for PPFTS?

(I): Do you have any other suggestions of techniques that can be beneficial for PPFTs that you think might work better than PPFTs?
(R): I don't know of any techniques that could work but if there might be a way of incorporating colouring into the prints. It's one thing to print one colour filament at a time but it would be interesting to incorporate graphics into it. It could be cool.

15. What do you think will the future hold for PPFTS in the AM industry as well as other industries?

(I): What do you think will the future hold for PPFTS in the AM industry as well as other industries? What is the future for these kind of techniques?
(R): I think it will kind of open up the door for artists to make their work more sellable when using entry level FDM. Also not just to open the market to sell but also for artists to explore the cheaper side of printing.
(I): Okay right and do you think it will have an impact on any of the other industries?
(R): Yes and no. For someone like me that prefer the EOS technology SLS, I would rather maybe do it now on entry level FDM, because it is more affordable and I can do much more and experiment more. BUT I do not think it will create a big dent in the life

cycle of SLS because I for example didn't contribute so much in the first place. I think it would add to itself but not take away from the other processes.

16. Any last comments?

(I): Do you have any other comments you want to add when you look at the object in discussion to these kind of techniques.

(R): A yes I want to thank you because now I have the EOS and the FDM versions and now I can display the FDM one in my house and when it gets dusty I can clean it. With the EOS one you cant.

(I): That is a very good point

17. Any suggestions or recommendations you would like to add to the interview?

(I): Any suggestions or recommendations you would like to add to the interview? Any areas I didn't touch or that you needed to say?

(R): Not that I can think of now.

18. THANK YOU FOR YOU TIME AND VALUEBLE INPUT

(I): I would just like to thank you for taking the time and making your artwork available to me.

(R): I would just like to thank you for choosing me to use my artwork. It is an honour. Thank you so much and like I said now I have a pretty artefact I can use in my house

(I): It is a huge pleasure.

3.5 Respondent 5: JL

Transcript of interview with Jason Lang Interview: 2016-05-15 11-08-53

Legend for interview	
Questions	Are colored in RED
Important gist of the conversation	Highlighted in YELLOW
Background explanation (filler)	~~Strikethrough sentences~~
Interpretation of ideas or words	*(Italic and in brackets)*
Interviewers notes and comments	Track change comments on right side of doc

1. Introduction: Thank you once again for taking the time to partake…

~~Interviewee (I): Firstly Jason I would just like to thank you once again for taking part in this study. It is really a great honour to have you on board. I would like to assure you that the research will be published and will have a lasting effect on the industry. Not only will the results be in my dissertation but it will also feature in academic papers that will be published in the RPJ and RAPDASA conference proceedings.~~

~~Respondent (R): No problem. Okay~~

2. What is your background in 3D printing?

(I): What is your background in 3D printing?

(R): I got introduced to 3D printing towards the end of 1996 so this brings me into my 20th year of doing 3D printing. Been around pretty much from when the first Viper machine came into the country, at that stage the best resolution you could get was 1.2mm thick layers at the time and as you know NOW we are below 16microns and that was stereolithography based systems, it wasn't any poly-jet systems or powdering or sintering or anything like that on that side at that stage. I got introduced to it through winning cup competitions through the jewellery industry and with that then I got involved with the guys from MINTECH (The Metallurgy Institute of South Africa) and that is where I learned a lot about powered metallurgy which unravelled into sintering powder. That was to do primarily on your titanium metals and then obviously the jewellery industry got more involved the SOLISCAPE? Machines and the ROLAND CNC machining. Then I went overseas and worked on the Princess cruise-lines for almost 4 years and with that traveling around I got to deal with all the manufacturers on shore and all the distributors and this introduced me to the polijet systems, your vapouring, basically everything around the 3D printing industry. I did that for a number of years, that was based with everything to do with the female lifestyle, from jewellery to fashion accessories, to fashion apparel to cosmetics, porcelain, everything. It all boiled down to 3D printing to make a prototype for a mould. AND then fabrication thereafter and the finishing on that. On returning I got involved with a maxilla prosthodontist where we introduced polijet systems to make prosthetics and casting titanium inplants, customized titanium implants and then we got involved with the guys from Southern Implants and EOS to do laser sintering of titanium and Cobalt chrome. Then I got involved again with the guys from EOS to do gold sintering, they were still developing the machine at the time. That was around 2010. Then through the medical field and RAPDASA I got more involved in the research side with Terry Wohlers and Deon, so it has evolved drastically. I am now still very much involved in all sorts of sintering and during the time of me getting involved with the prosthodontist I went and spend quite a bit of time at Materialize in Belgium and got trained hand in hand with them and did a lot of research on their medical software and that would link back to 3D printing. The problem with (FLshort???) was the casting and the fabrication for moulding which me coming from the jewellery side knew backwards…uhmmm so getting skilled by them and doing research. At that stage they only had like 48 people working for them, now they are close to over a thousand eight hundred people worldwide. So getting trained in all their equipment, from the mammoth machines to all the stereotography, laser sintering, FDM machines, it is endless. And now im involved with the majority of all 3D printing

3. Which industry do you service in your opinion, with regards to 3D printing?

(I): uhm…so would you say you're more in design, architecture, which areas do you fall in?

(R): Where I currently stand right now is very much along the lines of the jewellery and fashion industry, also the medical and the composite industry because of new cold moulding and casting techniques using urethanes and polymers as well as your aramid materials that has led now into other areas.

(I): Now the specimen you send to me for reproduction, for which sector was that created?

(R): That was from the commercial manufacturing side, the trophy stems a little from the jewellery industry side and was used as a commercial product.

4. Do you have any prior knowledge of Post-production-finishing-techniques (PPFTs)?

(I): Do you have any prior knowledge of Post-production-finishing-techniques?
(R): I do…

5. If YES, please elaborate…

(I): If yes please elaborate.
(R): I've done a lot of commercial fabrication of acetone vapouring, your ethyl acetate vapouring, your cold composites as well as finishing like polymer oversprays, your priming and making materials conductive for electro plating. Electroforming so it's all prepping done to the surface. So yes that is my background as far as surface finishing goes.

6. If NO, explain to respondent so interview can be completed.

(I): We can obviously skip questions 6 as I am sure I do not need to explain anything about post-production finishing techniques to you?
(R): (*Respondent smiles*) sure…yeah.

7. Would you prefer to do (PPFTs) yourself or subcontract it out and why?

(I): Would you prefer to do (PPFTs) yourself or subcontract it out to another business and why?
(R) With the products that we develop, I would prefer to do that in-house, that way we have it controlled, all the different aspects like surface finish to how to control where it goes before it goes to moulding/tooling. If you don't have that aspect, you will definitely have a ripple effect throughout your production to the point that if you don't do it right your end product just turns into a massive disaster. What we then also did was I can understand why someone would want to outsource it because of the fumes, the control of acetone and ethyl acetate, chloroform or anything of that sort, but if you are doing it in a controlled environment, it is commercially acceptable and commercially compatible…then maybe it would be more viable for somebody to do it in-house. Outsourcing buts a lot of time on your production cycle, there are more room for errors because you have no control over that. If you give it to someone else they might not understand your business or product that well, they do not understand what needs to be done. The fields that I am in you have to be very accurate with that so I would rather do it in-house than outsource it.

8. What is your overall impression of the artefact that was reproduced?

(I): Now when you look at these specimens, what is your overall impression? It is a bit of an ambiguous question because I am trying to steer the conversation in a certain direction without steering/controlling your answer
(R): As far as the surface layering, that was controlled nicely, your calibrations are good, as far as the very fine detailing that's unfortunately not controlled over everyone else's side but the machine itself. For example the coke label on the shield has to do with the resolution (Figure1) of the machine and not the surface finishing afterwards.

Figure 23 Resolution detail

I understand why and where you did the split lines in order to print these, I also have notices how you have fused these two differently so what I've noticed there is some cracking on the parts. The parts themselves are printed very nicely though. If you worked on them a little more, they would be commercially acceptable for a once off object but if you had to do 50 of them you would have a problem with consistency. That might not make the job feasible.

(I): Now before we get into a bit more detail can you please look under specimen 1 for me, where it is marked (A) (Figure2).

Figure 24 Delamination (A)

(R): The delamination from the support material, where it was actually pulled apart yes?
(I): Yes, so what is your opinion in regards to that?
(R): That is something that happens on the UP MINI printer quite often and there could be a number of reasons such as the ambient temperature of the room, how quickly the plastic cools down, obviously the angle of the tray (*print orientation*), whether the fan was open or closed. You need to understand the part and accordingly do pre-setup.
(I): Can this be solved in post-production?
(R): Yeah we have done that before, by making an ABS paste (*ABS cement*), then you apply it, let it set and then skim it off. If the part will be spray painted you can use some body filler and then you won't even see it at all and it will be strong enough to hold together.
(I): Then on the same specimen there is an area demarcated as (B), (Figure3). What is your opinion about that finishing?

Figure 25 (B) Assembly area

(R): Well it definitely is better than the areas that have not been buffed. It is more uniform, but the problem with surface finishing using a rough sand paper, is that it does open these little pin holes. What we would normally do with that is, rough sandpaper it down and then acetone it without blowing away the sanding dust. So the sanding dust acts like a filler that goes into the little holes.

(I): Okay then we can move on to the area that is marked (C), (Figure4). That is just at the bottom of the ball (*sphere*). If you look at the area just above the C, focusing also on the joined area. What is your opinion about this section?

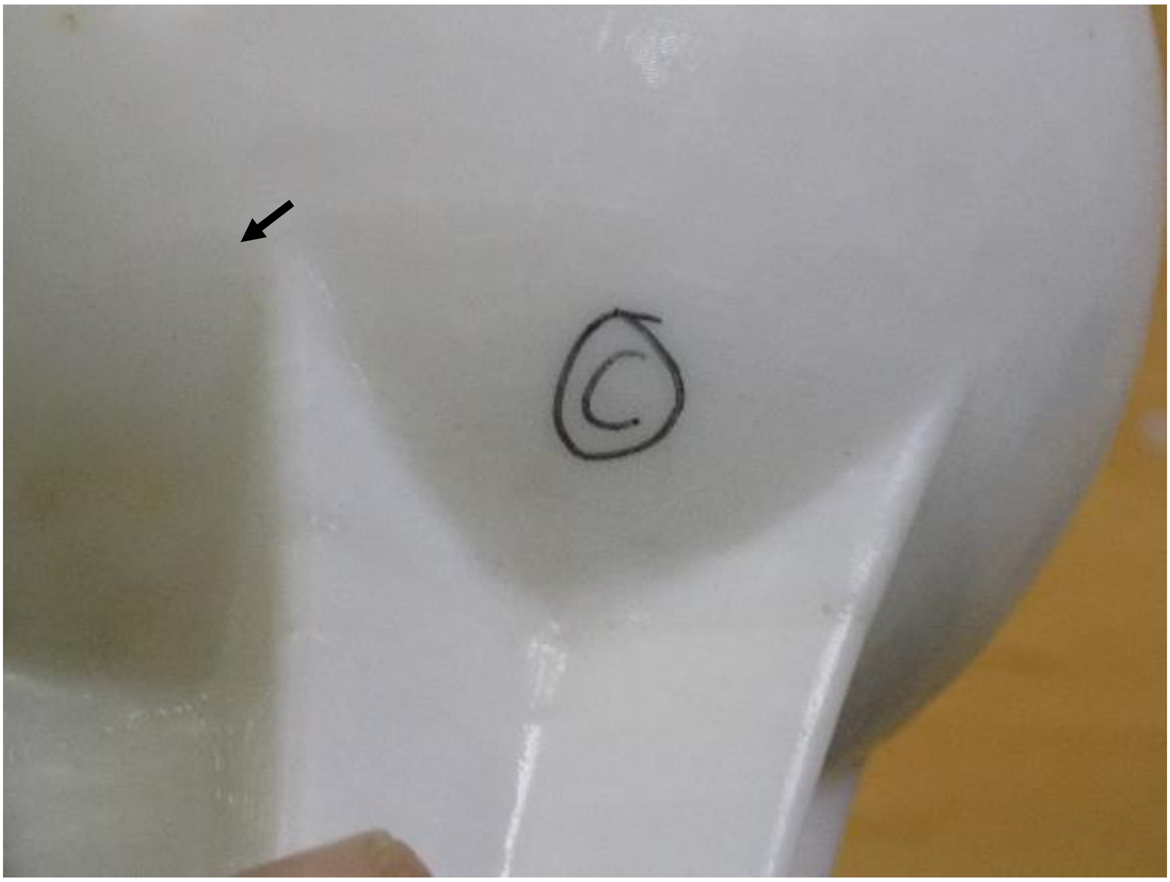


Figure 26 (C) Joined section

(R): I see you got a bit of moisture build up from acetoning, or polishing, it recesses as if it levelled itself, make a levelling. That is angulation from how the part was exposed to acetone (*orientation*). In order to avoid that you have to think through the process in pre-production.

(I): Okay then we can move on to where the coca cola sign is, marked as (D), (Figure5). I think you touched on this already when you said the loss of detail is because of the limitation of the extruders' size?

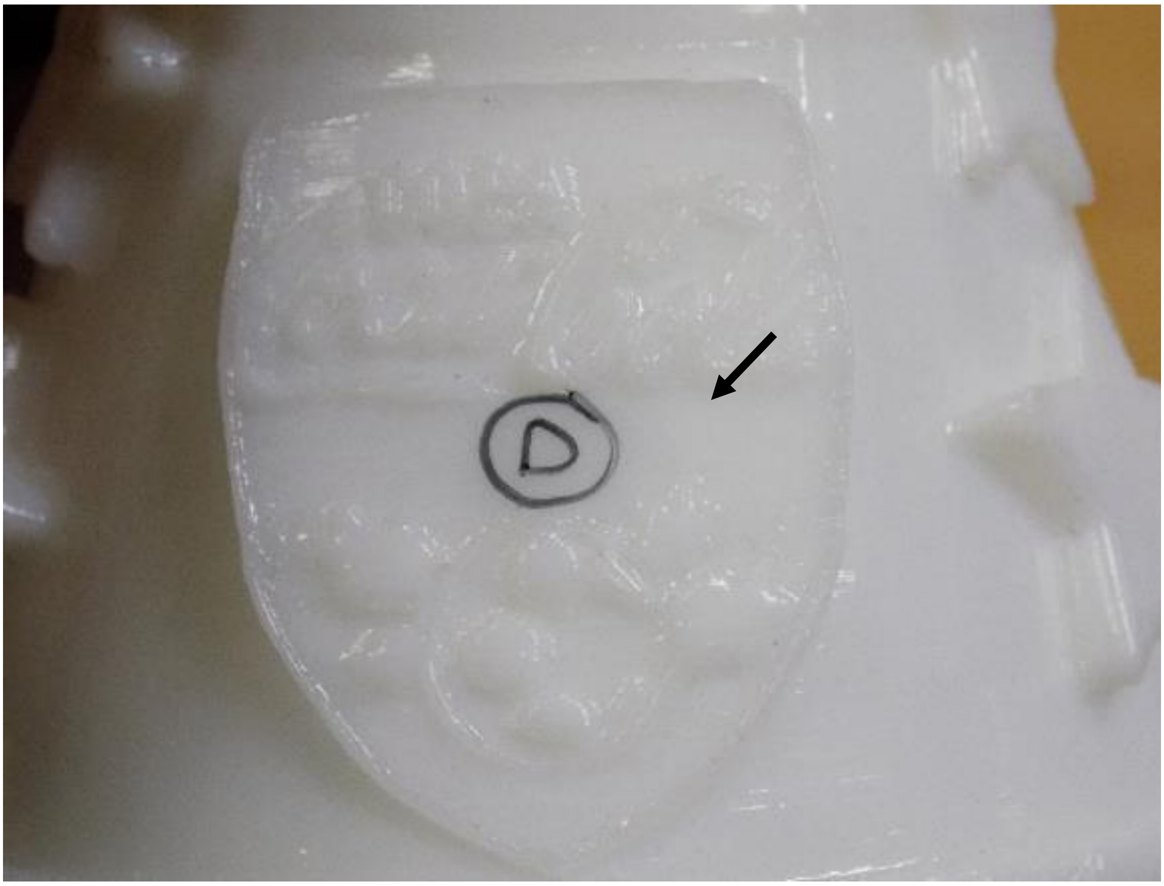


Figure 27 Shield detail loss

(R): Yes
(I): I can however from my side say that I did have partial loss, especially on the writing due to the acetone. Is there a way to better control that?
(R): yeah what we have actually done before on a model such as this is to remove the part (*shield)* from the print, print it on its own flat. When it is flat you have a more uniform surface as to when you print it upright and do it separately and then place the two parts together and fuse them by using acetone afterwards. That way nobody will know it is joined independently. The same thing would be done with the stars for example. They would be recessed and placed in afterwards.
(I): Now I would like to play devil's advocate and ask you. In the event that the part cannot be split into sections but can only be surface finished in post-production. Would these limitations steer you away or can this post-production finishing techniques be seen as viable?
(R): It would be viable.
(I): Okay so you say it is possible but you say preferably as a finisher you would rather go and plan it from the beginning, split the parts, make sure the print orientation is correct and then fuse the components together, instead of trying to print everything in one go?
(R): Correct, if you have to break it down into numbers…everybody has this emotional battle when it comes to a file being send, you got to get it done quickly, because rapid

prototyping is all about getting it done rapidly and people that want to work with these machines always want to leave it until the last minute

(I): Ok, there is one last one, when you look at the top here is an (E) (Figure6). You can now see the step layers as well as the little indentations that you usually get on a soccer ball where the seams are.

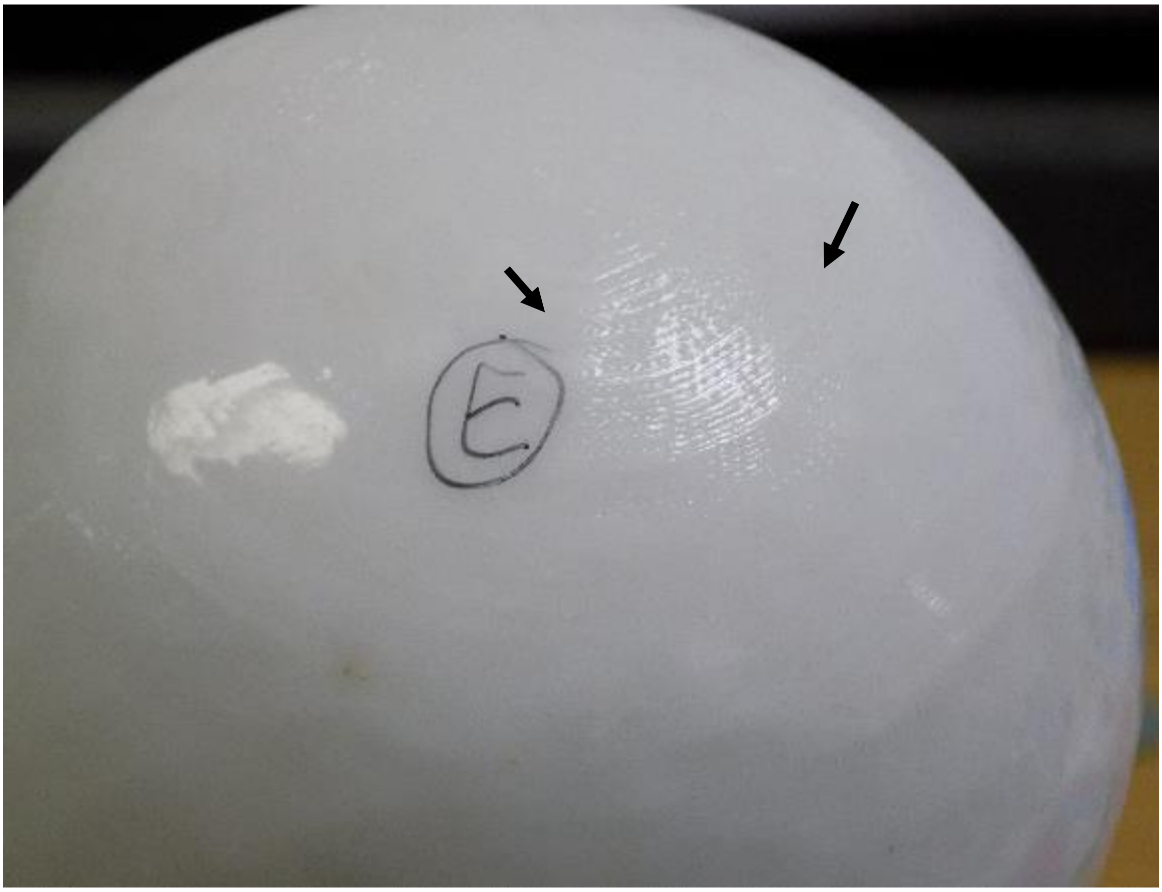


Figure 28 Step layers and indentations

With the vaporising, would you feel it equalized between the step layers but not taking away the seams from the ball itself too much? Or was it not successful?

(R): This job was tricky from the word go, because the seams weren't designed deep enough, so there was already an error there. It does boil down to orientation and setup. With this kind of contouring you will lose detail through polishing so it goes back to understanding your design and how the machine will play out. You have to think ahead for the machine not the machine for you. You have to roll it out in categories so you plan each phase ahead. The other area you have to take into consideration is the direction/orientation of the step layers, because… is it structurally sound? Its always a back and forth game.

8.1. STEP LAYERING:

(I): Okay so I am going to step back and ask you when you look at the step layers. Would you say they are very prominent?

(R): The step layers on the products are commercially acceptable, I would say but the surface finishing was not completed to the standard of high-end commercial production in the industry at the moment. But at the end of the day I understand where it is at and what you intended to do. If for example the client wanted to only pay for a cheap end trophy then this is successful. If the client wanted a high-end mirror finish for example electro plating, yeah…it won't work.

(I): Now when you look at it like that, do you think it would have been more successful with more surface finishing?

(R): Yes, for a once off piece, yes. For a production of let's say 50 units… (*Respondent shakes head NO*). For a time factor it would just be too high compared to producing it any other way.

8.2. ASSEMBLY TECHNIQUES:

(I): Then your overall feel about the assembly techniques, in other words using the acetone ABS glue/cement to fuse those parts together. Do you think it is successful?

(R): I think it definitely is successful, maybe just need some more post-processing with body fillers. You can hide a lot of marks other than that you can get away with it.

8.3. SURFACE TEXTURE:

(I): …

(R): Read above for answer!

8.4. AESTHETIC VALUE OUTPUT:

(I): Is it a visual pleasing object, you have already answered this when you referred to the difference between high-end and mid to end-level production. It is pleasing and aesthetic as a once off object but not as a commercial viable batch produced (*50 sample etc*) group of objects

(R): Yes

(I): Okay when can go over to specimen 2 now. When you look at the area marked as (A) (Figure7), what is your opinion about that?

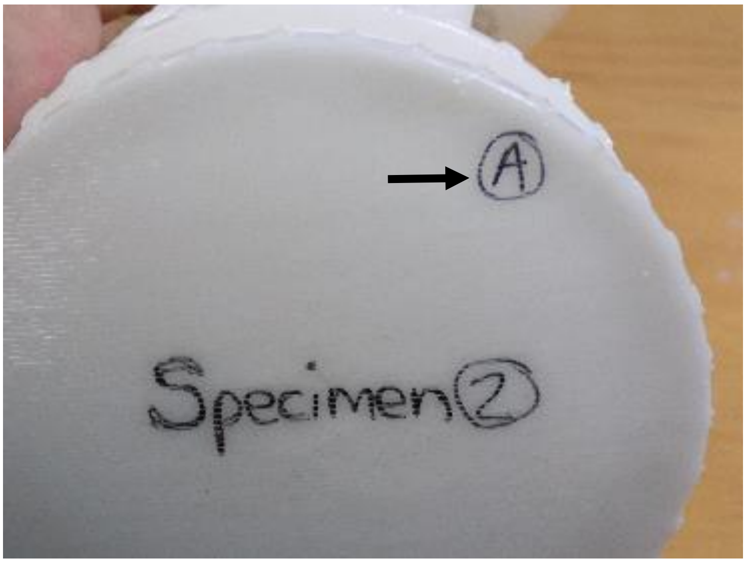


Figure 29 Specimen2 bottom

(R): Firstly the doming section which is part of the machine settings, you have to monitor that you do not get warping. Setting the height of the nozzle tip sometimes help to minimize this effect. The closer the tip is the more PULL BACK you will get.
(I): There are actually different schools of thought in regards to this. Another school argues that printing/ depositing layers further apart will weaken the strength of the part and cause more warping to take place due to shrinkage caused by the cooling between the tray and the deposited plastic. What is your take on that?
(R): Look I can understand, at the end of the day this is not a structural part for example for the automotive industry. For a trophy you will get away with it because you are going to do so much post-processing on it BUT when you are doing stuff for the automotive industry you need structural strength, you will need to place your part in such a way so that your loadbearing is more. So you have to ask yourself where you are going with this, what is the purpose of the object, is it for structural support, is it for aesthetic value, you need to decide from that perspective. As far as delamination goes, it can be controlled by post-processing.
(I): Okay we can move on to the section marked as (B) (Figure 8). It is again the little joined area. When you look at this one now and compare it to specimen 1's section (B), what is your opinion?
(R): It is different, there is more of an actual step layer between the sections where the two parts meet. This one clearly has not been post-processed with sand paper. This only has been fused.

Figure 30 Unfinished surface texture section

(I): Fantastic, then we can move on the section marked (C) (Figure9) which is just at the bottom of the ball (*sphere*)…
(R): Still getting the same type of setting there but compared to the (C) on specimen 1, the first specimen is obviously better. The second one has more warping too, but both you can get away with it on the low-end (*entry-level*).

Figure 31 Assembly borders

(I): Now if you focus on the area just to the right of the section marked as (C), you will see slight burn marks (Figure9). Is that something that should be of concern? Or can you also get away with it in post-production?
(R): Where it comes from is when the nozzle is not cleaned after the previous build. There is oxide on the brass as well as some of the plastic that has broken down. Superficially it won't make a difference but having a lot in between layers can cause delamination. Further aesthetically it is not appealing especially on a white item, but you can get away with it by doing an overspray on it, however if it's an automotive or structural part then it WILL pose as a problem.
(I): so you think this kind of burn scarring has an impact on the structural integrity of the part?
(R): It definitely does. I have worked with products where we used acetone fume over such areas and it is almost like it trapped an air bubble in the plastic and it actually

expanded. Then you get this tiny little pit hole section around it and from a strength perspective we have notice it tends to crack in those areas.

(I): Okay so acetone weakens such areas because the structural integrity has broken down due to the plastic polymer being broken down and secondly acetone is not a great idea to reconstitute the molecules because as you said it causes vapour entrapment.

(R): Yes that is correct, yeah, so the way we got around it is to drill out or grind out that area and then you re-melt plastic filament into that area and fuse it. So not acetone but by melting the plastic by a soldering drill.

(I): Okay then on specimen 2 there is an area marked (D) (Figure10) as you will see by one of the stars. It is just above the little shield that says Coca-cola. What is your take on that seam?

Figure 32 Seam running through star

(R): You can see because of the bottom warp that the seam left a gap that needs to be filled up, the only way to do that obviously would be to solder it closed and then buff it down or cement paste it or just hand finish and use acetone. From an aesthetics point of view you might get away with it but not from a structural viewpoint.

(I): Okay then we can move on to the section that is marked (E) (Figure11), I think it is on the ball at the top where you can see the cracking.

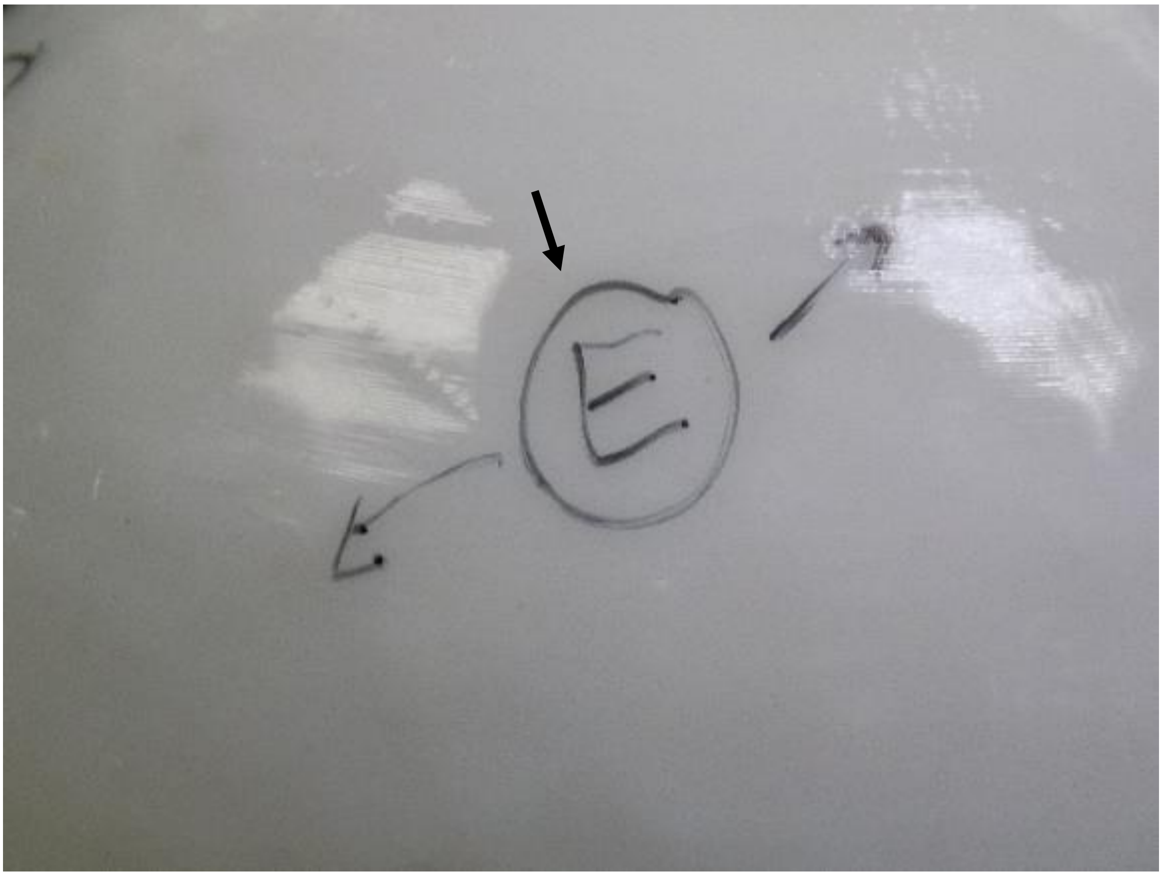


Figure 33 Surface cracks

(R): Tell me did you get this cracking before or after you applied the acetone?
(I): I would first like to hear what you think happened?
(R): I think you got this post vaporing, I don't think you got it from the printing itself, it's more a fine crack as it was cooling down. It is definitely due to atmospheric cooling.
(I): I short this one was not a hot vapour but a cold vapour but there was some slight delamination between the step layers where the arrows are indicating which caused slight vapour entrapment, not a lot though. But when I moved it from one environment to another with a different ambient temperature it was large enough to cause the cracks.
(R): Nobody takes into account how intense atmospheric temperature can be on a printed part. It does not matter whether its pre or post print, it is detrimental.
(I): Another respondent's specimen cracked so bad that I had to use a body filler to close the gaps.
(R): We usually use a fast setting CYANOACRYLATE because when you sand and buff it down it keeps its consistency with the acetone finish. Acetone does nothing to epoxy

9. Which part would you consider most successful?

(I): In short if you take the two specimens that you have in front of you…if you have to look at them, which areas would you consider most successful at this stage?

(R): I would say specimen 1, the reason being that there is more uniformity in the surface finishing. There is obviously no cracking and the percentage of this specimen becoming more commercial viable is higher. Specimen 2 just needs a bit more hand work that is al

10. Has these finishing techniques improved or made worse the quality of the artefact?

(I): Now would you say in your opinion that these techniques, the acetone finishing and ABS cement glue has improved or made worse the quality of the product?

(R): It has improved.

11. Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM?

(I): Do you think these techniques in your opinion be seen as a viable option to compete with high end FDM or other AM processes?

(R): if you look at the machines side by side they don't compare with each other (*example: Uprints from Stratasys*) BUT if you were able to put what we call soft-skilling or soft-skills onto the part, meaning more your labour content, training people to do it so you go to portfolios of a course that needs to be followed, then it can definitely compete. There is no doubt about it that your low-end printers can get to a point of getting to do what your high-end printers does. It's just a time frame thing, you have to spend more time manually than computerised. So basically you can but somebody that's very skilled on a UP MINI printers and slap somebody hands down on an Uprinter and doesn't know how to finish a part off. BUT can you compete on time for manufacturing when everyone has the same skill set? You would probably fall short by 10 to 15% for the low-end production. Otherwise competing where the commercial market sits, what the general public would look for, they are almost on par.

12. Do you feel the tech is successful or does the technical ability of the artist/ designer play a role?

(I): Do you feel the tech is successful or does the technical ability of the artist/ designer play a role? Well you just answered that question above for me.

(R): Yes without a doubt, it's not push button easy, there is a lot more skill set that comes with it. That is where the guys that are selling machines are not supplying, they come and show you how to set the machine up and run it great but they don't know how to finish parts off half the time. It is not what they do. They sell machines, not finished products. That is where the shortfall is. The artisan will eventually come back into play.

13. Are there areas where these techniques can be improved?

(I): I would say… I am asking the question, taking into consideration the two specimens in front of you as well as in general. Are there areas with these techniques of vaporizing and ABS cement glue, where we can improve step layering, assembly techniques, surface texture and aesthetical value?

(R): So uhm right across the board?

13.1. STEP LAYERING:

(I): …

(R): It would help you a bit when you look at your orientation

13.2. ASSEMBLY TECHNIQUE:

(I): ….
(R): Such an answer in general is part specific, some parts are more subject to you using some form of cement or glue but when it comes to these specific specimens over here, when I am looking at the assembly techniques over here I would say the acetone ABS cement would work better for you as you get a proper seal and finish. You can compress the cement to get bubbles out that will strengthen the glue to about 75 to 80% of its original cross polymer link strength.

13.3. SURFACE FINISH:

(I): …
(R): Finishing you are pretty much on par, it's just implementation and processing of how you do it, maybe teaching on how to do it.

13.4. AESTHETIC VALUE OUTPUT:

(I): …
(R): …

14. Do you have any other suggestions of techniques that can be beneficial for PPFTS?

(I): Do you have any other suggestions of techniques that can be beneficial to these kind of finishing techniques?
(R): Look uhm, you don't have much of another option besides acetone at this point that is commercially available or can work really well. It boils down to your skill set.

15. What do you think will the future hold for PPFTS in the AM industry as well as other industries?

(I): What do you think will the future hold for PPFTS in the AM industry as well as other industries? Do you think there is a future?
(R): It will definitely grow, everything that we deal with in regardless what happens in the industry, it boils down to your perceived perception and surface finish of everything and whether it fits in with the requirements of the commercial sector. Now from what I can already see establishing is that printers are beginning to run smoother and smoother surfaces. BUT at the same time a skill set is growing more and more because even though it is getting finer there is a lot more work to be done in order to make the quality even finer. The higher the technology goes of the printing the higher the request of skill set will go. So there will be some form of course needed eventually so they can run in parallel.
(I): Do you think these acetone techniques will lessen the gap between your high-end and low-end production eventually?
(R): Definitely yes because it will get to a point where even the high-end machines cannot develop any further without some or other form of post-processing.

16. Any last comments?

(I): Are there any last comments? Anything that you want to add in regards to these post-processing finishing techniques?
(R): Uhm…no, not really hey.

17. Any suggestions or recommendations you would like to add to the interview?

(I): Do you have any suggestions or recommendations?

(R): Uhm you know I think if there is a way to do a finite element analysis. So you take these specimens and scan them against your original CAD file and then see what the deviation is and then see how structural deformities can be compared to it.

~~18. THANK YOU FOR YOU TIME AND VALUEBLE INPUT~~

~~(I): Thank you very much for partaking in the study~~

~~(R): Sure you are welcome. I hope it helps.~~

3.6 Respondent 6: MJvV

Transcript of interview with Michaella Janse van Vuuren Interview: 2016-05-26 10-08-13

Legend for interview	
Questions	Are colored in RED
Important gist of the conversation	Highlighted in YELLOW
Background explanation (filler)	~~Strikethrough sentences~~
Interpretation of ideas or words	*(Italic and in brackets)*
Interviewers notes and comments	Track change comments on right side of doc

~~1. Introduction: Thank you once again for taking the time to partake…~~

~~Interviewee (I): Dr Janse van Vuuren I would just like o really thank you for taking part in this study. It is a great opportunity to work with you and I would just like to say that this will have a very meaningful contribution to this study, not only on the South African field but also abroad. Welcome~~

~~Respondent (R): Thank you.~~

2. What is your background in 3D printing?

(I): I would like to ask you, can you briefly explain to us what is your background in 3D printing?

(R): Uhm… I started in 3D printing in 2006/7 when I did a post-doctorate in medical implant design at the Central University of Technology (CUT) in Bloemfontein. A year or so after that I started my own company NOMILI which specialises in end product 3D printing. It is basically design for 3D printing, so I have worked with many processes like selective laser sintering (*SLS*), the colour prints like the Connex3 from Stratasys, the Zcorp colour powder systems…so I do have experience with selling end products and 3D printed items. I work more in the end product realm rather than the prototyping world.

3. Which industry do you service in your opinion, with regards to 3D printing?

(I): In your opinion which industry do you service the most in regards to 3D printing?

(R): At the moment I would say no industry...hahaha joking... I am working in the fine art and design industry. Or I have been, because of the prototype price you can do free expression and artistic creative works, trying to push the boundaries of the medium, there are not so many market yet because of the price it is very expensive. So you have to enter the very high art and design market to sell creative works, if it was cheaper it would have been in bigger markets that I would have exposed my work. I am not selling my files, because I spend too much time on them so the value ratio is too high. I don't work for other companies, I generate them for myself. In other words as an artist, designer and engineer I produce for myself not for other people because it takes too long.

4. Do you have any prior knowledge of Post-production-finishing-techniques (PPFTs)?

(I): Okay then we can move on to the next question. Do you have any knowledge of Post-production-finishing-techniques?

(R): No, I usually design everything so that it comes in a box and it is finished. I have actually not worked with the more lower cost systems because I didn't want to do any post-production finishing.

5. If YES, please elaborate…

(I): Okay, so the question I want to ask is you have knowledge of Post-production finishing techniques but you choose not to use them?

(R): Yes, exactly.

(I): Okay can you elaborate a little bit…?

(R): I don't have that much experience in the low cost ones but I know that you can take acetone and apply it to make step layering less visible. To get a smoother finish you can use sanding apply chemicals to melt the plastic to give smoother layers and chemicals that will remove support structures.

6. If NO, explain to respondent so interview can be completed.

(I): ~~Okay then we can skip the next question as I do not have to explain what these techniques are.~~

~~(R): Sure.~~

7. Would you prefer to do (PPFTs) yourself or subcontract it out and why?

(I): Would you prefer to do (PPFTs) yourself or subcontract it out to somebody else. So I want to ask hypothetically if you were to use entry-level/ low-level 3D printing production would you prefer from your artistic perspective to do this finishing yourself or subcontract it out to somebody else?

(R): I would prefer to give it to somebody else if I already know exactly what I want and what it looks like. If there is something that needs more of a creative eye, I would do one and then get someone else to duplicate it. I don't like doing things over and over. The other reason is I have children so I do not have a lot of space or time. So for me personally… outsource.

8. What is your overall impression of the artefact that was reproduced?

(I): okay then we can move over to the specimens that I send to you. As you can see that they are demarcated at the bottom with the letters specimen (A) and (B). So I would just like you to look at both of these specimens and tell me what is your overall impression of the artefacts reproduced?

(R): I know a little bit about the low cost printing and what they usually look like and I do not like it at all, BUT these specimens are much better. The smooth finish and I can see that this is obviously very complex geometry so the fact that you were actually able to print that is amazing. I can see that it is possible to do that. I can see that some areas are easier to smooth out than others for example from the legs. I can see the inside of the spring has problems with the limitation of how to get the support out. Internal geometries but we know that. But I can see that with the post-processing if you knew what the limitations are you can bring it closer towards high-end specimens. So if you have a little knowledge of how you can adapt your design I think that you can make things that can add to the industry to create a little more of an upmarket look.

(I): Okay, can we assume then that it might be a viable option to narrow the gap between your low-cost entry level and your high-end more expensive additive manufacturing processes.

(R): I definitely think so, if you have the right design that would accommodate for the limitations. I think the splicing of the file into segments worked very well. It does definitely open up the field, giving more possibilities and also I'm not sure but the cost would differ and that is something that definitely interest me.

8.1. STEP LAYERING:

(I): When you compare the two specimens in front of you, what is your opinion about the step layering? In your experience to the normal step layer deposits you get on the UP MINI printers, would you say these finishing techniques improved or made worse the step layers?

(R): Like I have said, I don't have much experience with them but I have looked at them… I would say previously I would have though pretty hard of how I could rather incorporate these layers into the design so that it is rather pretty with the layers but I see its pretty fine detail that was picked up compared to the things that I have seen.

8.2. ASSEMBLY TECHNIQUES:

(I): I ~~am going to ask the same question here in regards to the assembly techniques. What I did here was to take the support and raft material and break it down with acetone to form ABS cement glue. I then used that to fuse the different sections together. Now when you look at these sections would you say that they are fused together successfully?~~

(R): I would say… because it is hard to find them (*visually*)… *laughs*… it is successful.

(I): Okay let's say, if you look on the belly of the buck that says specimen A (Figure1), you will see there is one big area that has been fused together.

(R): Yes, A seems to be nicer than B, not sure if that was your intension?

~~(I): Great that's perfect. I used two techniques on the two specimens. The one is a brush on technique and the other one is a cold vapour technique.~~

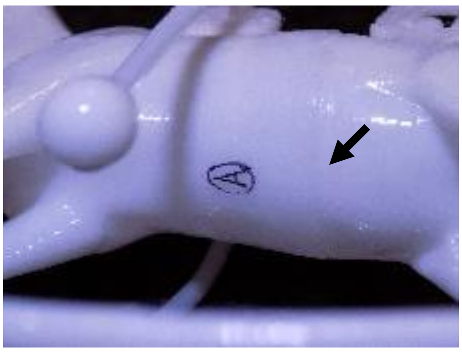


Figure 34 Specimen A Seam line

8.3. SURFACE TEXTURE:

(I): The same thing applies now for surface texture. Do you think the surface texture has improved or been made worse by these techniques?
(R): Yes of course. Definitely

8.4. AESTHETIC VALUE OUTPUT:

(I): In your opinion, the aesthetic value output from an artistic and design perspective, would you say it improved the artefacts or made it worse.
~~(R): So now you want me to compare it to what it usually is (*SLS- selective laser sintered*). AND compare it to what it should be compared to entry level?~~
~~(I): Correct.~~
(R): It's a little bit hard to compare it to them because the entire artefact has not been finished, because for the high-end designer market everything needs to be perfect. The art market however is different in that it will accept the artists' technique and background story if it is interesting. In the art market the artefact and the story are together, but in the design market it has to be perfect. Also for the design world the material used is important and not so much in the art world. In the design world it is important that the object exudes perfection and always the difficult one is high-end value. So for now SLS wins for me because it is perfect and also because it is 100% reproducible. If the design was a little bit different…because this is a complex design which is obviously why you chose it…but for example if the design was a little different, maybe adding a weight so that the artefact feels heavier…people tend to increase value with weight. Because of the functionality of the gear parts I am leaning towards the high-end.

9. Which part would you consider most successful?

(I): Okay to get back to the questions, when you look at the two specimens, which areas in your opinion do you consider the most successful?
(R): I would say on specimen A the legs (Figure2), the front legs. You can't see the lines anymore.

Figure 35 Specimen (A) legs

(I): By specimen (A) you will see that the neck was fused and on (B) that the spring was left intact with the support material still present. Now on specimen (A) (Figure3) you will see little cracks right above where the seam was fused. What is your opinion in regards to these cracks?

Figure 36 Cracks above seam line

(R): I think if that was for the high-end design world it would not be acceptable, because it has to be perfect, but if it was created just as a prototype then it would not matter so much.

(I): Okay so we can summarize that from an artistic perspective, depending on the narrative it could be incorporated into the artefact to add to the aesthetic value but from a design and engineering perspective it definitely is not acceptable?

(R): It is not acceptable unless you can say that it really is so cheap that it is worthwhile but it will never be a successful end product. Design…no, engineering… maybe if it's a prototype and art… yes because anything flies.

(I): If you look at specimen (A) with the front legs and head facing you will see there are slight burn marks on the chest area (Figure4) where the nozzle was dirty and the burned plastic deposited on the surface. What is your opinion about that?

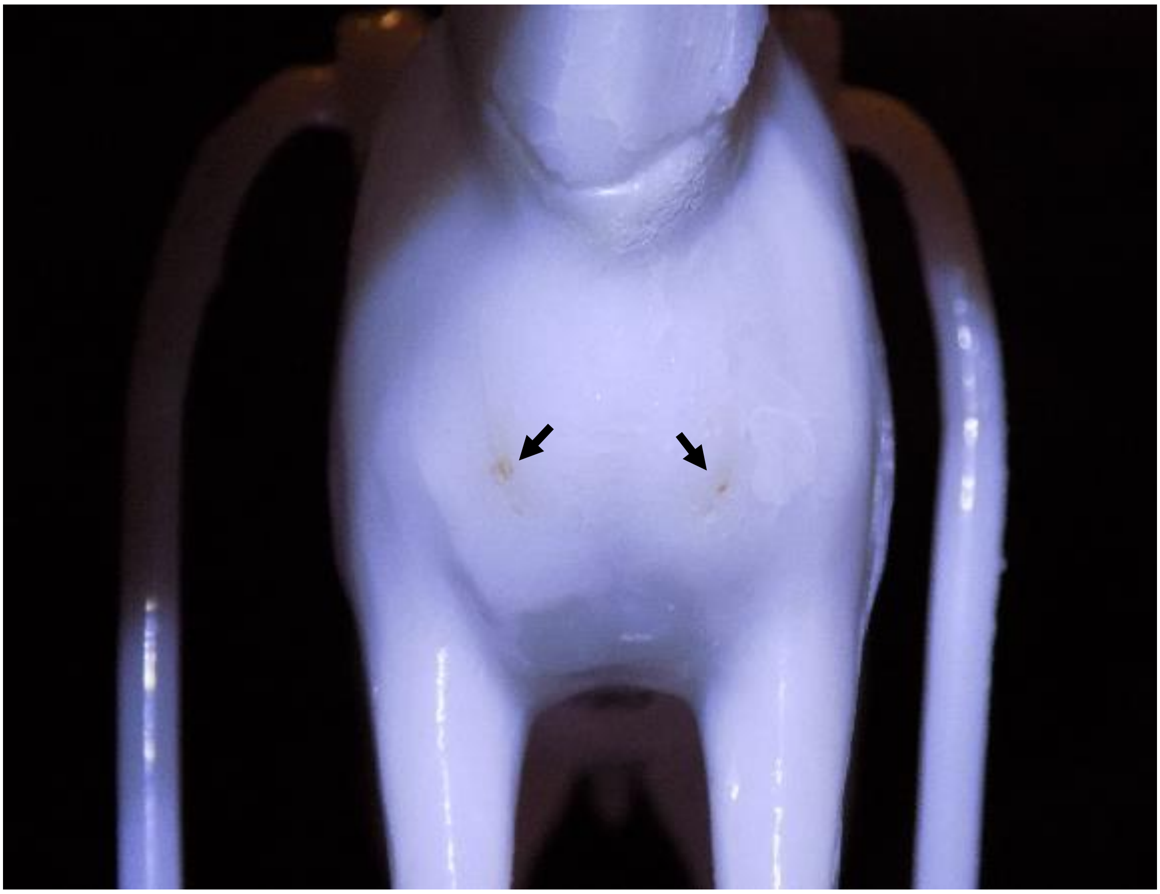
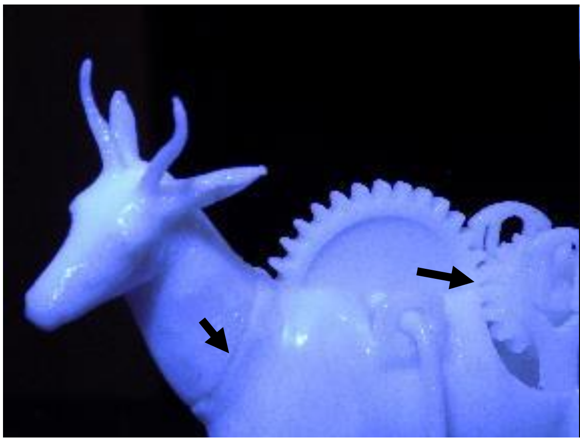


Figure 37 Specimen (A) Burn scars

(R): Again the same thing, if it was an artwork I would take my paint and add a little squiggle around it and it would be fine. If it is for design, no! And if it is a prototype for illustration in engineering then it probably would not matter.

(I): Now if you look at the two specimens' necks and you have to adapt it for this specific entry level market, which of the two would you prefer? To keep the spring section in (Figure5and 6) or to fuse it as it is in specimen A?

(R): I would take the spring out, for one I always work around the technology in other words focus on bringing out the best of the technology. I mean if you think of the Connex colour printer there are so many things you cannot do with it, it is actually a disaster in so many ways…so rather focus on what its strengths are. I would never design a spring on the inside of a FDM grown part, because it will make it harder to remove the support structure. I will always consult the printing technician and get advice about the machines limitations, then I will go home and design around that, rather than have to design and hope for the best.



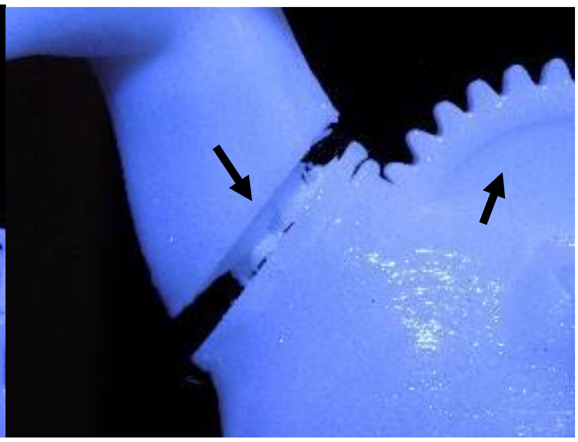


Figure 38 Fused neck Specimen A

Figure 39 Spring separated neck

(I): Okay then you have already discussed with the gears in specimen (A) (Figure 5 and 6 above) that they work if you wiggle them but they are not working smoothly, so you still prefer the high-end processes.

(R): It has done well, I assume you used a different assembly technique where the gears are printed separately and was then put together. I think it is a bit unfair to judge it because it was designed for the SLS process but I can move it so it probably just be a little design alteration.

(I): So basically with design alteration you can utilize these post-production finishing techniques more successfully?

(R): Yes, if you work hand in hand with the person that knows the machine.

(I): Okay thank you, now if you look at the front facing you again and you look at the bottom towards the feet on specimen (A) (Figure7), you will see where they were fused together. What is your opinion about this?

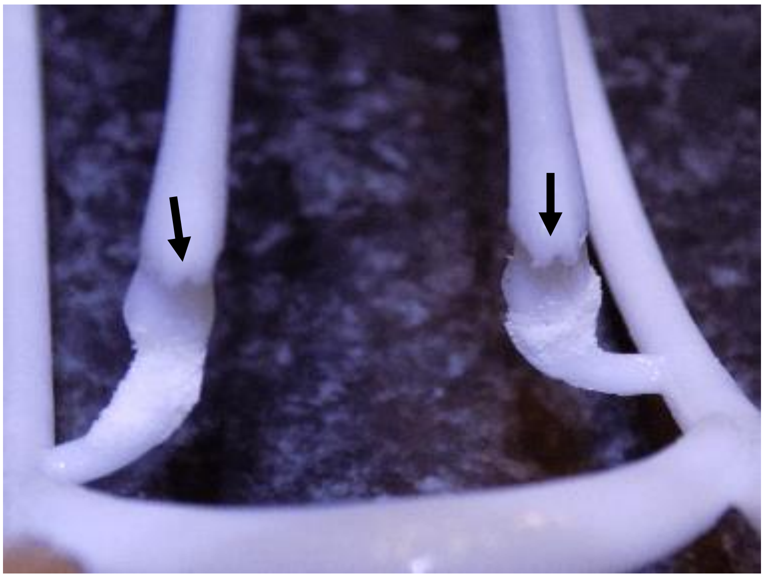
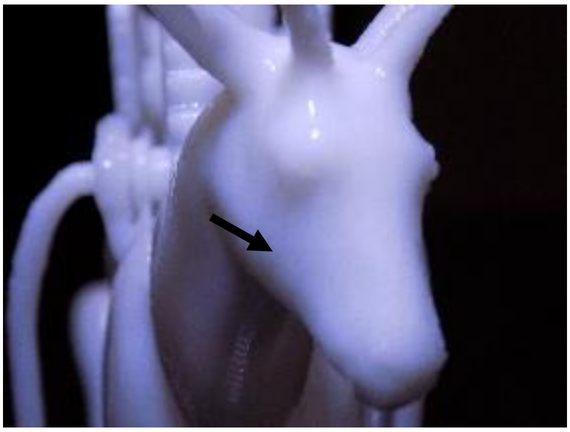


Figure 40 Fusing section of feet

(R): If I look at the front legs and compare it to the original it's not the fused section that bothers me but the difference in texture. If it was smooth all the way through it would not bother me. I does not bother me aesthetically if it was smoothed out.
(I): If you have to compare the two heads with each other, specifically the two right cheeks (Figures8 and 9) which one do you prefer?
(R): I would prefer the smoother of the two, so that is specimen (B) (Figure9), because it makes it less obvious that it was 3D printed. However, if it was incorporated in the design for a specific reason it could work.
(I): When you compare this to the original artefact that was produced on the SLS (EOS machine), do you feel there is a loss of detail and does that bother you.
(R): I have an older model that was printed on the Formiga, not the one that David printed on and I can clearly see the same step layer lines as in specimen (A), so it does not make much of a difference.



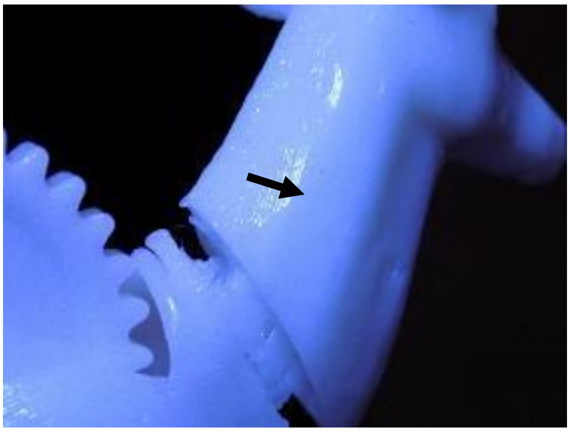


Figure 41 Specimen (A) Step layers on cheek Figure 9 Specimen (B) Step layers less prominent

I will send you a photograph so you can compare the two with each other. (Figure10)[3]
(I): Thank you very much.

[3] Photograph courtesy of the Dr Michaella Janse van Vuuren

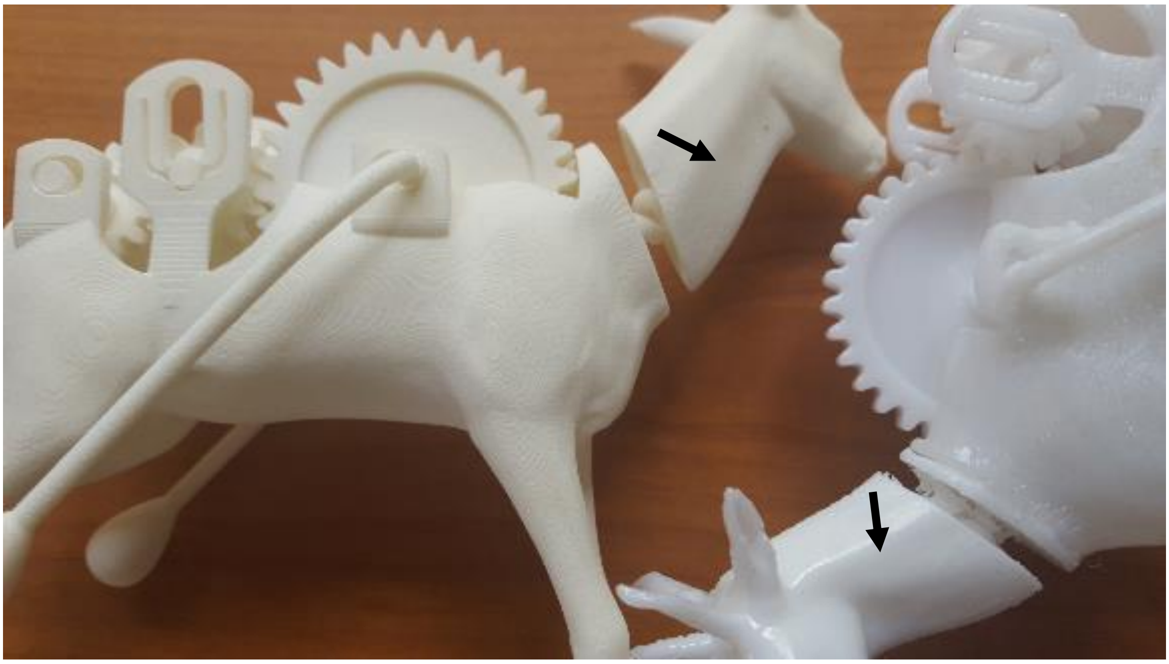


Figure 10 Print comparison between Formiga and UP MINI

(I): Just to finish off the question, when you look at the eye sections of the two specimens, do you think there is a lot of detail loss or not?

(R): Uhm…not really, maybe a little bit but not that much, you can see it in the horns but it wouldn't be a problem.

10. Has these finishing techniques improved or made worse the quality of the artefact?

(I): Okay thank you, we can move on to the next question. In your opinion do you think these techniques improved or made worse the quality of the artefact?

(R): I would definitely say that it improved it from the raw entry-level ABS printed artefact.

(I): Okay and if you had to compare it to the high-end artefacts?

(R): I would say it is something different, but I can see it being used as an end product in a certain market depending on how far the finishing is pushed.

11. Can these techniques in your opinion be seen as a viable option to compete with high end FDM/AM?

(I): Okay great. Do you think these techniques are a viable option to compete with high-end FDM and other additive manufacturing, if the technology can develop further?

(R): Again, it always will depend on what you are trying to do, so if you have a design that is very friendly to your machine method and if it is nicely smoothed out, I think why not. At the end of the day it is about what it looks and feels like that counts, it does not matter how much it cost and it must be strong. It definitely has potential, you know those little fish I made, and I think it would look beautiful (Figure11)[4].

[4] Image courtesy of the artist from http://www.nomili.co.za/wp-content/uploads/2011/09/bottomleft2.jpg

Figure 11 Fishtales sculpture

12. Do you feel the tech is successful or does the technical ability of the artist/ designer play a role?

(I): Do you feel the technical ability of the finisher plays a role. In other words do you think the skill of the finisher will have an influence on the outcome of artefacts?

(R): I think the skill of the finisher will have a huge influence but you will probably be able to say better how much skill is needed. See I haven't done it but I can imagine it takes a lot of skill.

(I): Okay so I want to ask you if you have to weigh up the following scenarios which would you prefer? Would you rather spend less money and have to spend hours to finish the artefact or spend a lot of money and have it consumer ready immediately?

(R): Should I have had the space to have these machines and place to apply these techniques I would definitely do it myself. I would prefer low-cost.

13. Are there areas where these techniques can be improved?

(I): Okay we can move on to the next section. Are there areas where these techniques can be improved? So now we going to subdivide it into the different areas.

(R)…*No reply*

13.1. STEP LAYERING:

(I): So let us start with the step layers. When you look at the two specimens in front of you are there any areas where you feel the step layer reduction could have been improved or made more prominent?

(R): okay firstly I want to ask. The wheels, where they printed in different orientations?

(I): Yes that is correct.

(R): The one is smoothed out really nicely, the one on specimen (B), I think it could be interesting if you moulded these.

13.2. ASSEMBLY TECHNIQUE:

(I): Then we can move on to the next section, assembly techniques, are there any areas where you think it can improve?

(R): I think the bottom part of the belly on specimen (B) needs more work, (A) is smoother

13.3. SURFACE FINISH:

(I): When you look at the cracks on the right shoulder of specimen (B), behind the leg (Figure12) does that bother you?

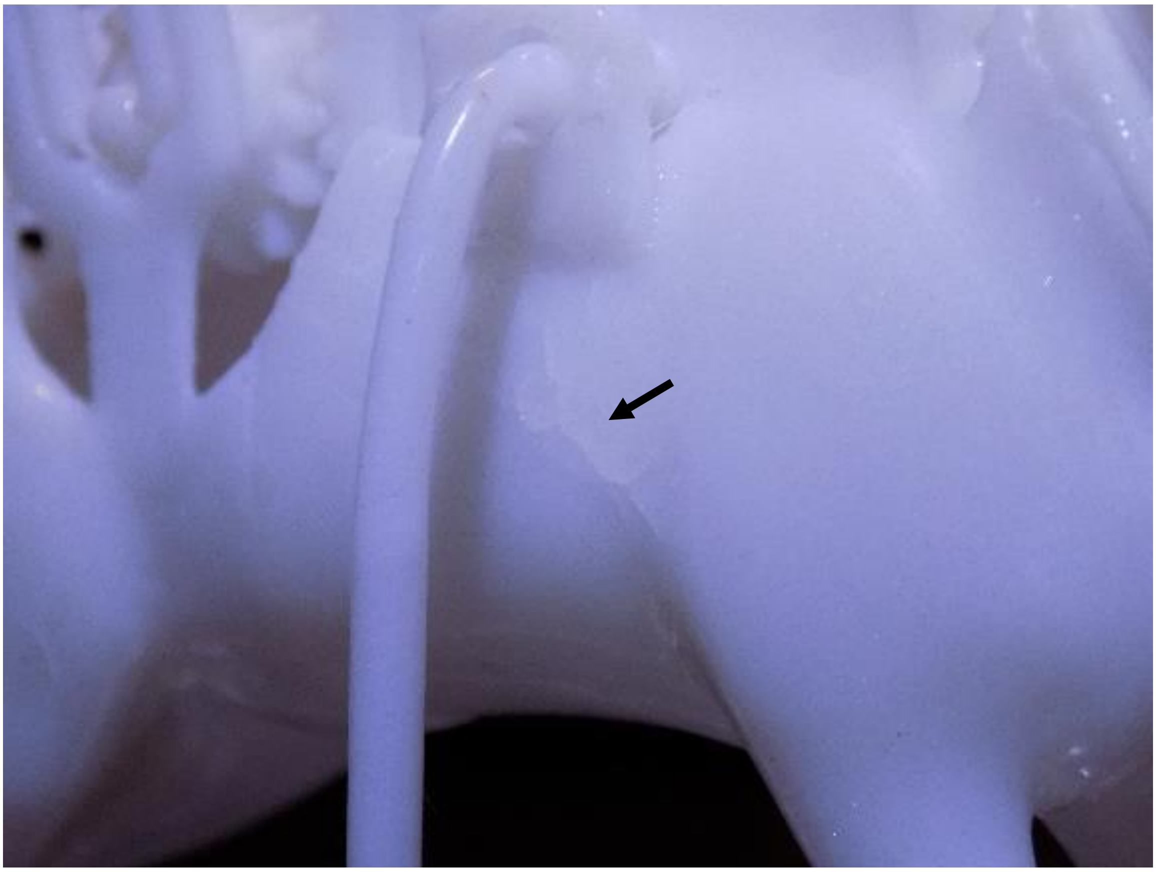


Figure 12 Surface cracking

(R): yes it does not really bother, it does not interfere with the shape, and you know the geometry but on specimen (A) it looks like the neck is broken

13.4. AESTHETIC VALUE OUTPUT:

(I): Okay then for the last one are there any areas where the techniques can be improved in regards the aesthetic output.

(R): Okay on specimen (B) on the left side is not as smooth/ as finished. Obviously on specimen (A) the head, the step layering could be smoothed more that would improve the aesthetic value. Where the step layers are more prominent it looks like a mistake. I reads like an unfinished artefact.

14. Do you have any other suggestions of techniques that can be beneficial for PPFTS?

(I): Okay we are almost done, can you think of any other techniques that could be beneficial for post-production finishing techniques?

(R): Perhaps it would be interesting to see the areas that you didn't finish if you could apply a white glaze paint to make it more consistent.

15. What do you think will the future hold for PPFTS in the AM industry as well as other industries?

(I): What do you think will the future hold for PPFTS in the AM industries as well as other industries including art etc?

(R): okay I will start with art, very often when I have exhibited 3D printed art I always keep them white, the reason being I don't want to take it further. I can see in art how this can help for it to become an armature from where you will add paint, braiding, your electronics or whatever else you see fit, so I can see it becoming a starting point. This definitely can help incorporate different people to start using the technology, I think the future of 3D printing is going to become a lot more interactive but people don't really use their hands now anymore, this might help them to get back to using their hands and not just sit in front of the computer or Ipad.

(I): Fantastic, what do you think the future will hold for other additive manufacturing industries when it gets to these techniques?

(R): I think in the small business industry the finishing will play a big role, also industries that will specialise in finishing will benefit from this. In mass manufacturing maybe not so much. Additive manufacturing is for making custom things so it makes sense that this would be incorporated.

16. Any last comments?

(I): Do you have last comments you want to add?

(R): I think it would be interesting to see objects that you have completely finished off to get a complete look of the aesthetic feel of the object because at the moment your eye gets distracted by the unfinished areas.

17. Any suggestions or recommendations you would like to add to the interview?

(I):…

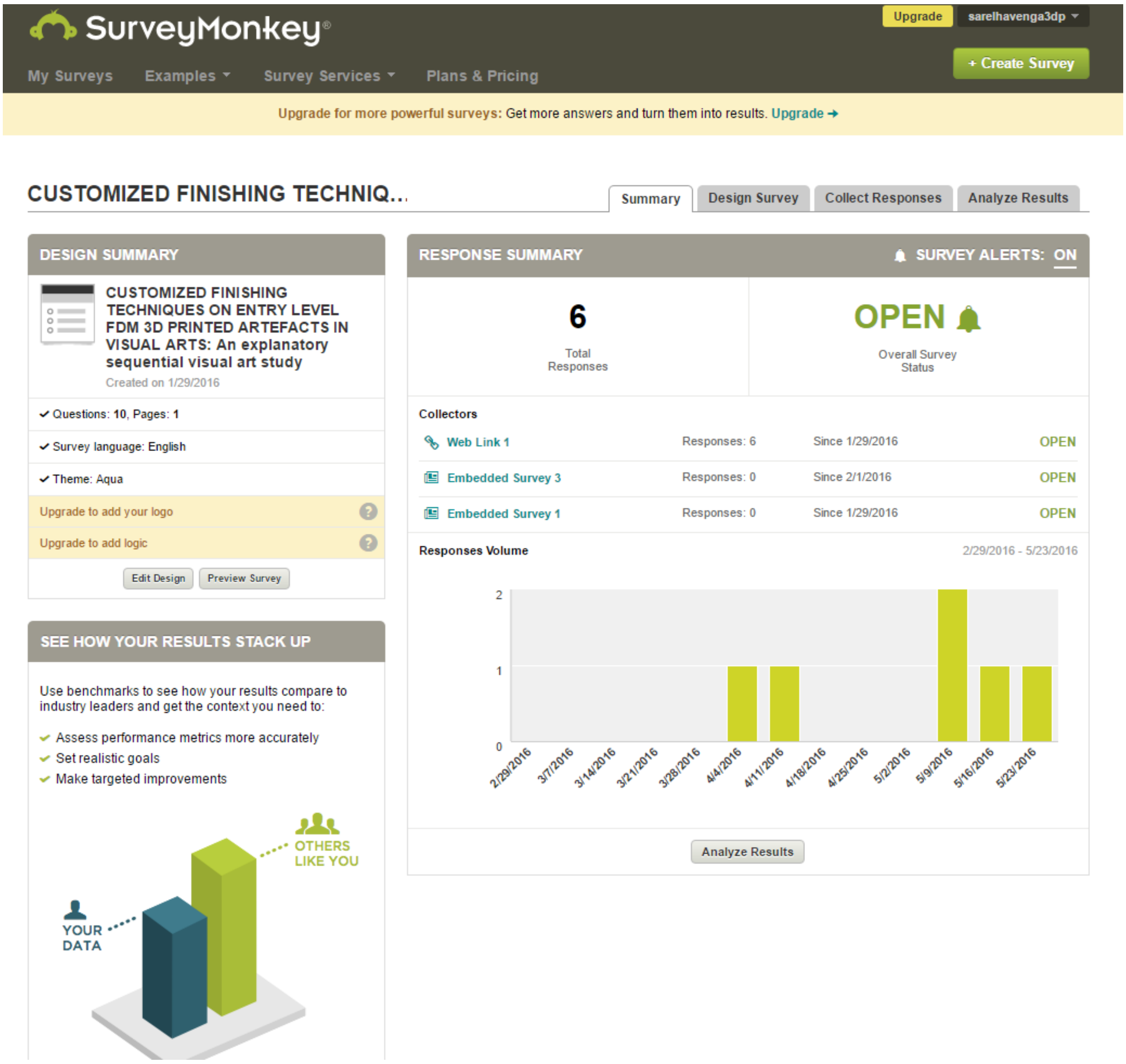
(R):…

18. THANK YOU FOR YOU TIME AND VALUEBLE INPUT

(I): Thank you so much. This concludes the interview

(R): Sure.

Appendix 4: Online survey:



4.1 Individual responses:

4.1.1 Respondent 1: PvdW

RESPONDENTS: 6 of 6

Export All | Share All

Question Summaries | Data Trends | Individual Responses

Respondent #1

#1 **COMPLETE**

Edit | Delete | Export

Collector: Web Link 1 (Web Link)
Started: Sunday, April 10, 2016 5:41:19 PM
Last Modified: Sunday, April 10, 2016 5:45:44 PM
Time Spent: 00:04:25
IP Address: 165.255.166.151

PAGE 1

Q1: Do you know what Post-production finishing techniques (PPFT's) are?

YES

Q2: Have you used Post-production finishing techniques (PPFT's) before in entry-level 3D printing (EL3DP)?

YES

Q3: How important is Post-production finishing techniques (PPFT's) for Entry-level 3D printing?

(no label)	Very important

Q4: What is the rate of success for Post-production finishing techniques (PPFT's) on Entry-level 3D printing (EL3DP)?

(no label)	Moderately successful

Q5: Would the use of Post-production finishing techniques for Entry-level 3D printing establish a niche market that can compete with High-end Additive Manufacturing in the future?

Other (please specify)	For display purposes perhaps

Q6: Is the use of Acetone cement glue as an adhesion method successful?

YES

Q7: Can the production of your artefact be seen as successful when split into multiple components to fit on the UP Mini 3D printer?

NO

Other (please specify)	Only for display,not as a usable product

Q8: Do you think the structural integrity (strength) of the artefact is compromised by splitting and acetone-cementing it together?

Other (please specify)	dependsonthe structure,where the split is made and the integrity of the print and acetone cement

Q9: Has the Acetone surface finishing techniques improved the aesthetic quality (visual appearance value) of the artefact?

Other (please specify)	If yiu want a glossy surface yes, but there is loss of detail

Q10: Do you consider the use of Post-production finishing techniques as a competitive alternative to High-end Additive manufacturing?

(no label)	Good chance of competing
Other (please specify)	For display yes, but there is detailloss

4.1.2 Respondent 2: LTD

RESPONDENTS: 6 of 6 Export All Share All

Question Summaries | Data Trends | Individual Responses

Respondent #2

#2 **COMPLETE** Edit Delete Export

Collector: Web Link 1 (Web Link)
Started: Monday, April 11, 2016 11:05:53 AM
Last Modified: Monday, April 11, 2016 11:08:21 AM
Time Spent: 00:02:28
IP Address: 86.158.210.104

PAGE 1

Q1: **Do you know what Post-production finishing techniques (PPFT's) are?**

YES

Q2: **Have you used Post-production finishing techniques (PPFT's) before in entry-level 3D printing (EL3DP)?**

YES

Q3: **How important is Post-production finishing techniques (PPFT's) for Entry-level 3D printing?**

(no label)	Moderately important

Q4: **What is the rate of success for Post-production finishing techniques (PPFT's) on Entry-level 3D printing (EL3DP)?**

(no label)	Moderately successful

Q5: **Would the use of Post-production finishing techniques for Entry-level 3D printing establish a niche market that can compete with High-end Additive Manufacturing in the future?**

YES

Q6: **Is the use of Acetone cement glue as an adhesion method successful?**

Other (please specify)	seems to depend on size

Q7: **Can the production of your artefact be seen as successful when split into multiple components to fit on the UP Mini 3D printer?**

YES

Q8: **Do you think the structural integrity (strength) of the artefact is compromised by splitting and acetone-cementing it together?**

YES

Q9: **Has the Acetone surface finishing techniques improved the aesthetic quality (visual appearance value) of the artefact?**

YES

Q10: **Do you consider the use of Post-production finishing techniques as a competitive alternative to High-end Additive manufacturing?**

(no label)	Moderate chance of competing

4.1.3 Respondent 3: WvdH

RESPONDENTS: 6 of 6 Export All Share All

Question Summaries | Data Trends | Individual Responses

Respondent #3

#3 COMPLETE

Collector: Web Link 1 (Web Link)
Started: Saturday, May 14, 2016 2:15:23 PM
Last Modified: Saturday, May 14, 2016 2:24:48 PM
Time Spent: 00:09:25
IP Address: 41.145.239.116

Edit Delete Export

PAGE 1

Q1: **Do you know what Post-production finishing techniques (PPFT's) are?**

YES

Q2: **Have you used Post-production finishing techniques (PPFT's) before in entry-level 3D printing (EL3DP)?**

YES

Q3: **How important is Post-production finishing techniques (PPFT's) for Entry-level 3D printing?**

(no label)	Important

Q4: **What is the rate of success for Post-production finishing techniques (PPFT's) on Entry-level 3D printing (EL3DP)?**

(no label)	Moderately successful

Q5: **Would the use of Post-production finishing techniques for Entry-level 3D printing establish a niche market that can compete with High-end Additive Manufacturing in the future?**

YES

Q6: **Is the use of Acetone cement glue as an adhesion method successful?**

YES

Q7: **Can the production of your artefact be seen as successful when split into multiple components to fit on the UP Mini 3D printer?**

Other (please specify)	If a successful surface finish is applied to eliminate seams.

Q8: Do you think the structural integrity (strength) of the artefact is compromised by splitting and acetone-cementing it together?

Respondent skipped this question

Q9: **Has the Acetone surface finishing techniques improved the aesthetic quality (visual appearance value) of the artefact?**

YES

Q10: **Do you consider the use of Post-production finishing techniques as a competitive alternative to High-end Additive manufacturing?**

(no label)	Good chance of competing

Question 7 is answered as a "YES"

Question 8 was skipped by accident when the respondent double clicked on the answer. His/her answer was "NO" after telephonic confirmation was applied.

4.1.4 Respondent 4: JB

RESPONDENTS: 6 of 6 Export All Share All

Question Summaries | Data Trends | Individual Responses

Respondent #4

#4 **COMPLETE** Edit Delete Export

Collector: Web Link 1 (Web Link)
Started: Saturday, May 14, 2016 4:15:38 PM
Last Modified: Saturday, May 14, 2016 4:57:34 PM
Time Spent: 00:41:55
IP Address: 169.0.239.44

PAGE 1

Q1: Do you know what Post-production finishing techniques (PPFT's) are?

YES

Q2: Have you used Post-production finishing techniques (PPFT's) before in entry-level 3D printing (EL3DP)?

NO

Q3: How important is Post-production finishing techniques (PPFT's) for Entry-level 3D printing?

(no label)	Important

Q4: What is the rate of success for Post-production finishing techniques (PPFT's) on Entry-level 3D printing (EL3DP)?

(no label)	Successful

Q5: Would the use of Post-production finishing techniques for Entry-level 3D printing establish a niche market that can compete with High-end Additive Manufacturing in the future?

YES

Q6: Is the use of Acetone cement glue as an adhesion method successful?

YES

Q7: Can the production of your artefact be seen as successful when split into multiple components to fit on the UP Mini 3D printer?

YES

Q8: Do you think the structural integrity (strength) of the artefact is compromised by splitting and acetone-cementing it together?

NO

Q9: Has the Acetone surface finishing techniques improved the aesthetic quality (visual appearance value) of the artefact?

YES

Q10: Do you consider the use of Post-production finishing techniques as a competitive alternative to High-end Additive manufacturing?

(no label)	Good chance of competing
Other (please specify)	On the aesthetic side, definitely. But maybe not so much when it comes to more functional parts like gears, parts that need to fit into or onto other parts, parts in or around other parts (also depending in the size, intricacy and precision of these types of parts. If they are larger, fdm may work)

4.1.5 Respondent 5: JL

RESPONDENTS: 6 of 6 Export All Share All

Question Summaries | Data Trends | Individual Responses

Respondent #5

#5 COMPLETE Edit Delete Export

Collector: Web Link 1 (Web Link)
Started: Monday, May 16, 2016 10:39:30 AM
Last Modified: Monday, May 16, 2016 10:41:53 AM
Time Spent: 00:02:22
IP Address: 41.160.36.186

PAGE 1

Q1: **Do you know what Post-production finishing techniques (PPFT's) are?**

YES

Q2: **Have you used Post-production finishing techniques (PPFT's) before in entry-level 3D printing (EL3DP)?**

YES

Q3: **How important is Post-production finishing techniques (PPFT's) for Entry-level 3D printing?**

(no label)	Very important

Q4: **What is the rate of success for Post-production finishing techniques (PPFT's) on Entry-level 3D printing (EL3DP)?**

(no label)	Successful

Q5: **Would the use of Post-production finishing techniques for Entry-level 3D printing establish a niche market that can compete with High-end Additive Manufacturing in the future?**

YES

Q6: **Is the use of Acetone cement glue as an adhesion method successful?**

YES

Q7: **Can the production of your artefact be seen as successful when split into multiple components to fit on the UP Mini 3D printer?**

YES

Q7: **Can the production of your artefact be seen as successful when split into multiple components to fit on the UP Mini 3D printer?**

YES

Other (please specify)	Layout it important and in some cases it is part specific

Q8: **Do you think the structural integrity (strength) of the artefact is compromised by splitting and acetone-cementing it together?**

YES

Q9: **Has the Acetone surface finishing techniques improved the aesthetic quality (visual appearance value) of the artefact?**

YES

Q10: **Do you consider the use of Post-production finishing techniques as a competitive alternative to High-end Additive manufacturing?**

(no label)	Good chance of competing

4.1.6 Respondent 6: MJvV

RESPONDENTS: 6 of 6 Export All Share All

Question Summaries | Data Trends | Individual Responses

Respondent #6

#6

COMPLETE

Collector: Web Link 1 (Web Link)
Started: Thursday, May 26, 2016 12:21:51 PM
Last Modified: Thursday, May 26, 2016 1:53:49 PM
Time Spent: 01:31:58
IP Address: 41.223.24.151

Edit Delete Export

PAGE 1

Q1: **Do you know what Post-production finishing techniques (PPFT's) are?**

YES

Q2: **Have you used Post-production finishing techniques (PPFT's) before in entry-level 3D printing (EL3DP)?**

NO

Q3: **How important is Post-production finishing techniques (PPFT's) for Entry-level 3D printing?**

(no label)	Very important

Q4: **What is the rate of success for Post-production finishing techniques (PPFT's) on Entry-level 3D printing (EL3DP)?**

(no label)	Very successful

Q5: **Would the use of Post-production finishing techniques for Entry-level 3D printing establish a niche market that can compete with High-end Additive Manufacturing in the future?**

YES

Q6: **Is the use of Acetone cement glue as an adhesion method successful?**

YES

Q7: **Can the production of your artefact be seen as successful when split into multiple components to fit on the UP Mini 3D printer?**

YES

Q8: **Do you think the structural integrity (strength) of the artefact is compromised by splitting and acetone-cementing it together?**

NO

Q9: **Has the Acetone surface finishing techniques improved the aesthetic quality (visual appearance value) of the artefact?**

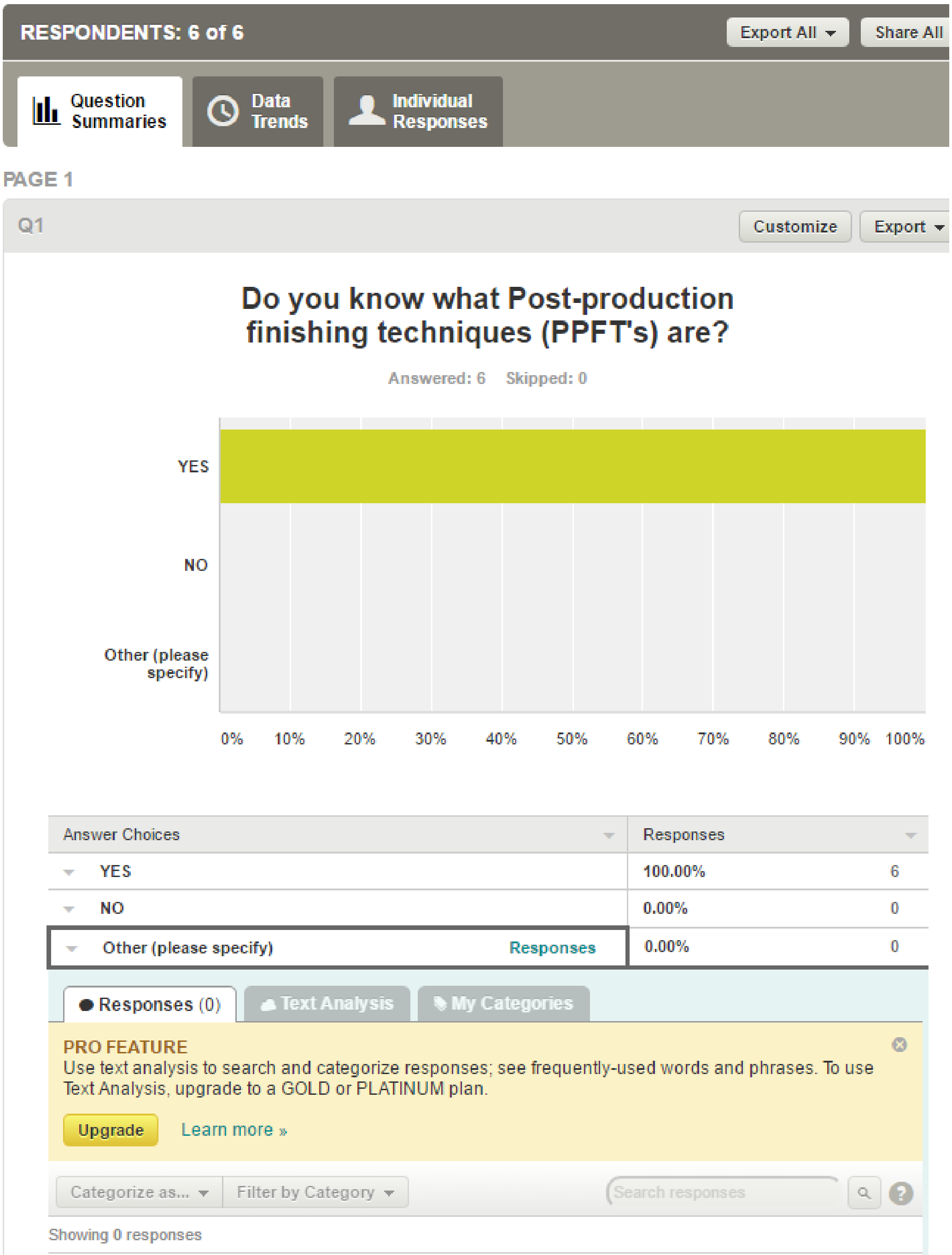
YES

Q10: **Do you consider the use of Post-production finishing techniques as a competitive alternative to High-end Additive manufacturing?**

(no label)	Good chance of competing
Other (please specify)	It depends on the context and the geometry of the object. If these are suitable then it certainly competes.

4.2 Summary of individual questions:

4.2.1 Question 1: Do you know what PPFTs are?



It can be deduced that all respondents had a clear understanding of what PPFTs are and therefore marginalize the population group to industry specific experts.

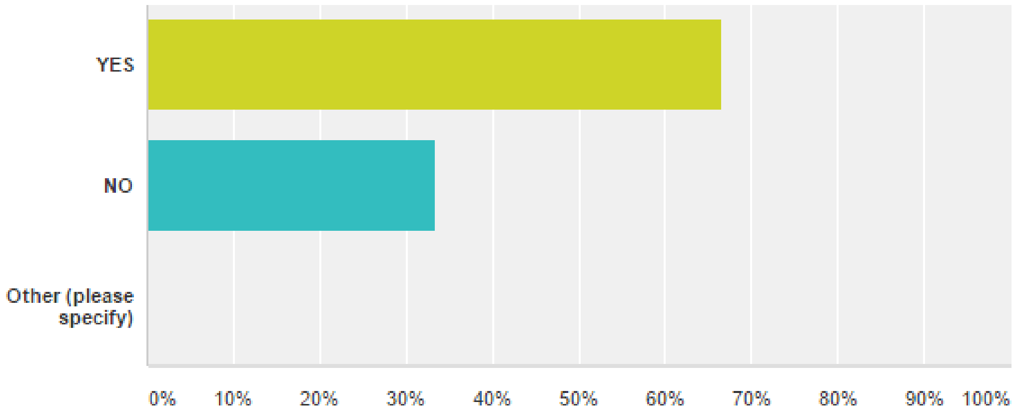
It was necessary to marginalize the group for the specified outcomes. We are not trying to establish whether a random sample carries knowledge about PPFTs but whether industry specific experts have knowledge on the topic of post-production finishing techniques. The fields are industrial, engineering, design and fine art. All of the respondents knew what PPFTs are.

4.2.2 Question2: Have you used PPFTs?

Q2 Customize Export

Have you used Post-production finishing techniques (PPFT's) before in entry-level 3D printing (EL3DP)?

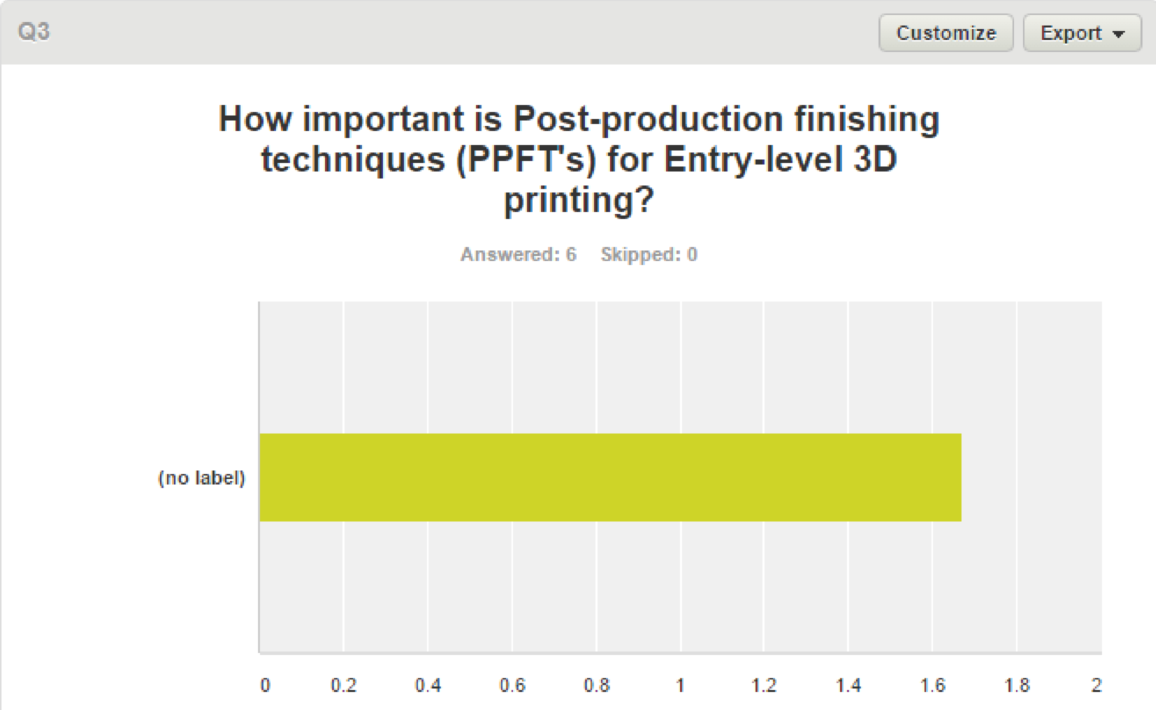
Answered: 6 Skipped: 0



Answer Choices		Responses	
YES		66.67%	4
NO		33.33%	2
Other (please specify)	Responses	0.00%	0
Total Respondents: 6			

Although all the respondents are experts in their respective fields, only 66.67% have used PPFTs on entry-level FDM 3D printed artefacts. Some of the reasons are that their exposure to these finishing techniques were limited.

4.2.3 Question 3: Importance of PPFTs?



	Very important	Important	Moderately important	Little important	Not important	Total	Weighted Average
(no label)	50.00% 3	33.33% 2	16.67% 1	0.00% 0	0.00% 0	6	1.67

Half of the respondents felt that PPFTs are very important for entry-level 3D printing. A third of the respondents felt it was important and only one sixth of the respondents felt it was moderately important.

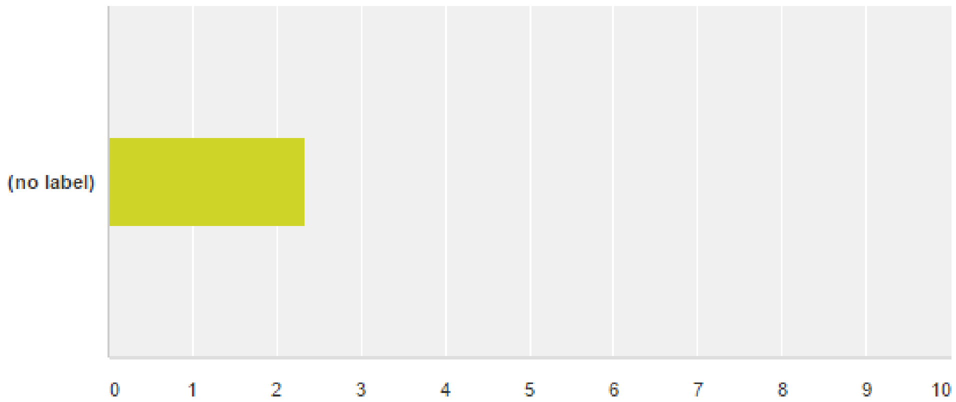
This indicated clearly that the respondents are all of the opinion that PPFTs are important to finish off entry-level 3D printed artefacts.

4.2.4 Question 4: Rate of success?

Q4 Customize Export

What is the rate of success for Post-production finishing techniques (PPFT's) on Entry-level 3D printing (EL3DP)?

Answered: 6 Skipped: 0

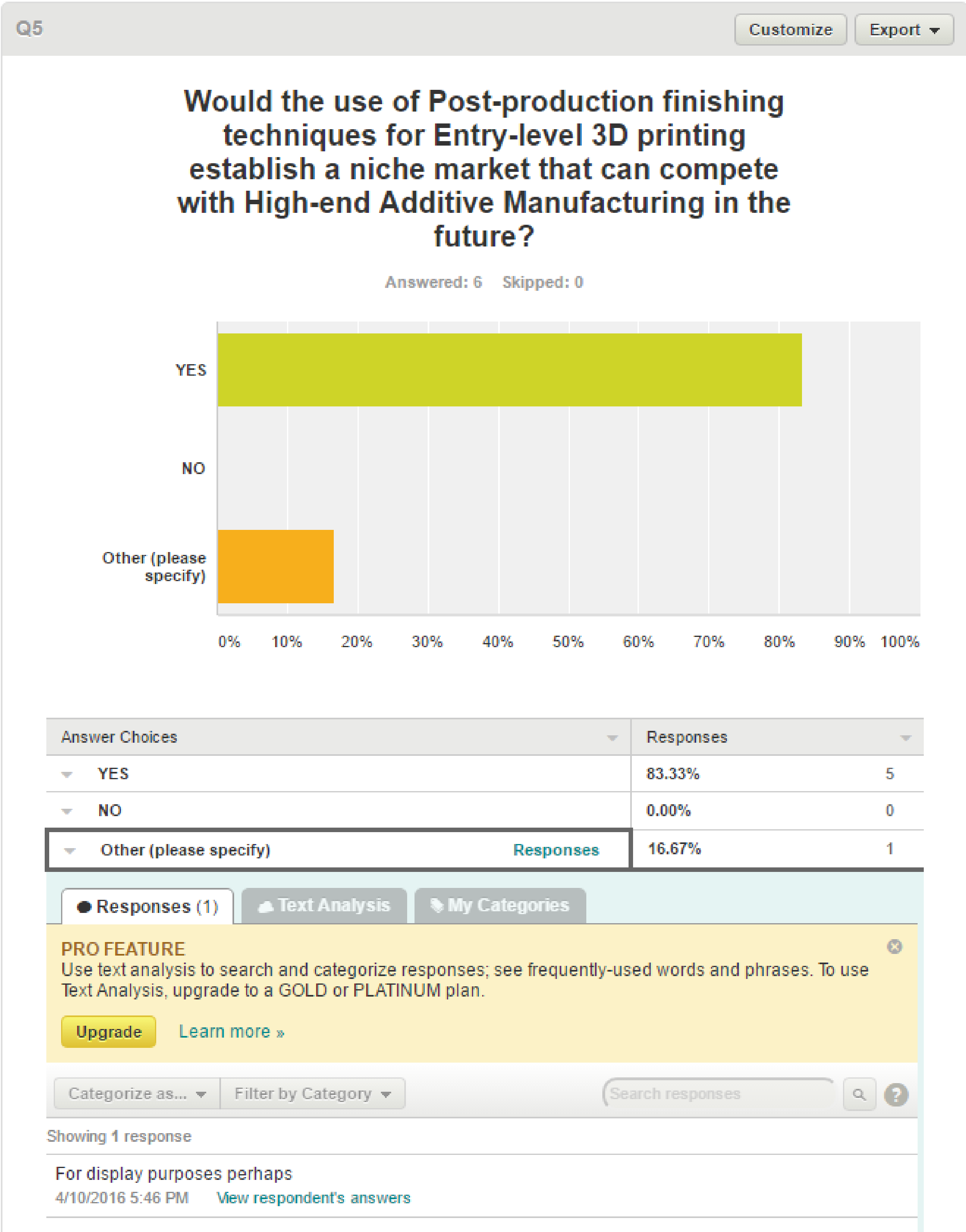


	Very successful	Successful	Moderately successful	Little success	Not successful at all	Total	Weighted Average
(no label)	16.67% 1	33.33% 2	50.00% 3	0.00% 0	0.00% 0	6	2.33

Half of the respondents felt that PPFTs are moderately successful on Entry-level FDM artefacts. One third felt is a successful process while only one-sixth of the respondents felt it is very successful.

Even though there are a variety of responses, all of them are in the success range showing that all respondents across their respective fields of expertise felt that PPFTs are a successful post-production finishing method.

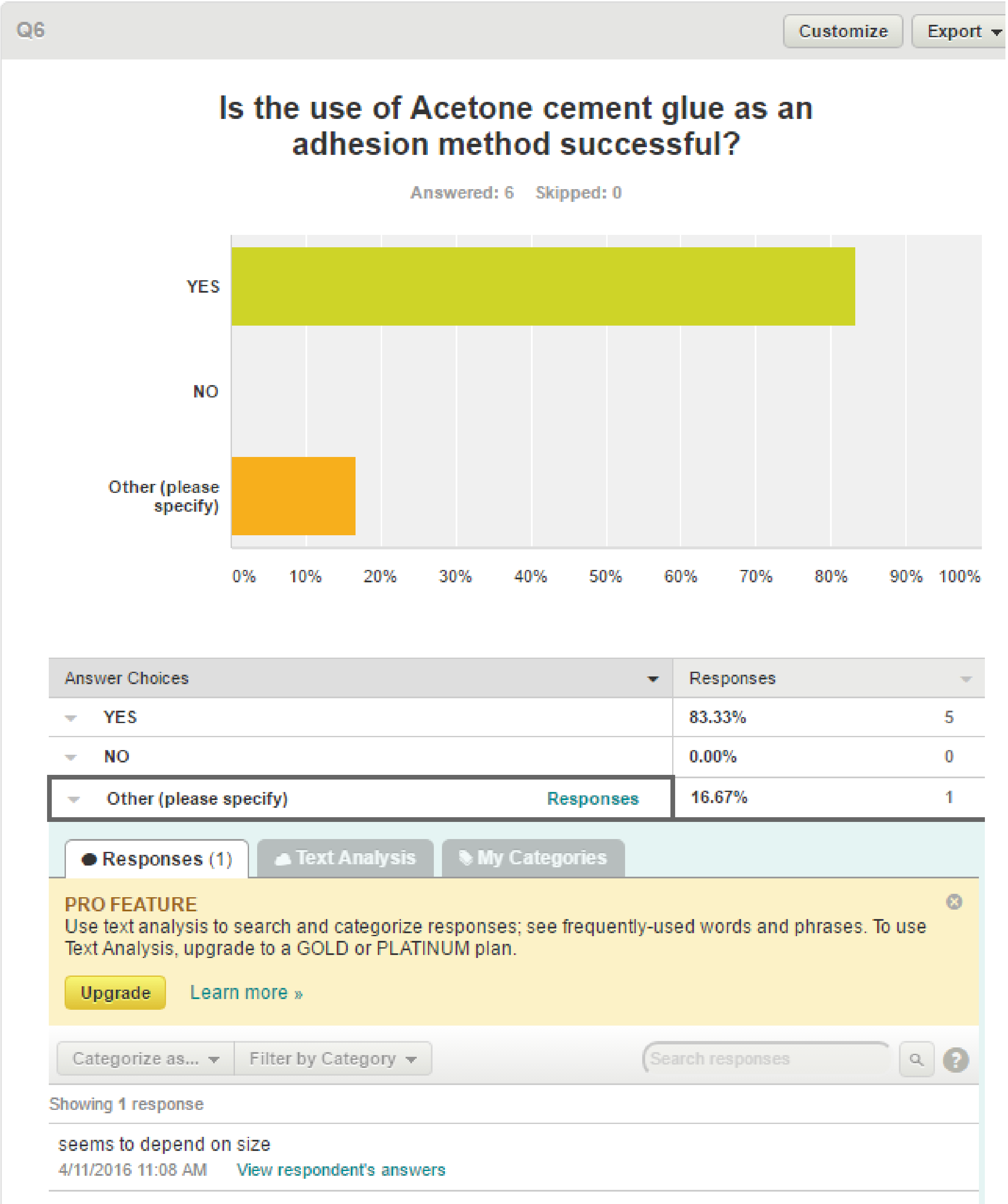
4.2.5 Question 5: Establish niche market?



Over 83% of the respondents feel that PPFTs can support the establishment of a niche market that would narrow the gap between High-end and entry-level additive manufacturing. 16% of the respondents felt that this can only apply if the artefacts are for display purpose value.

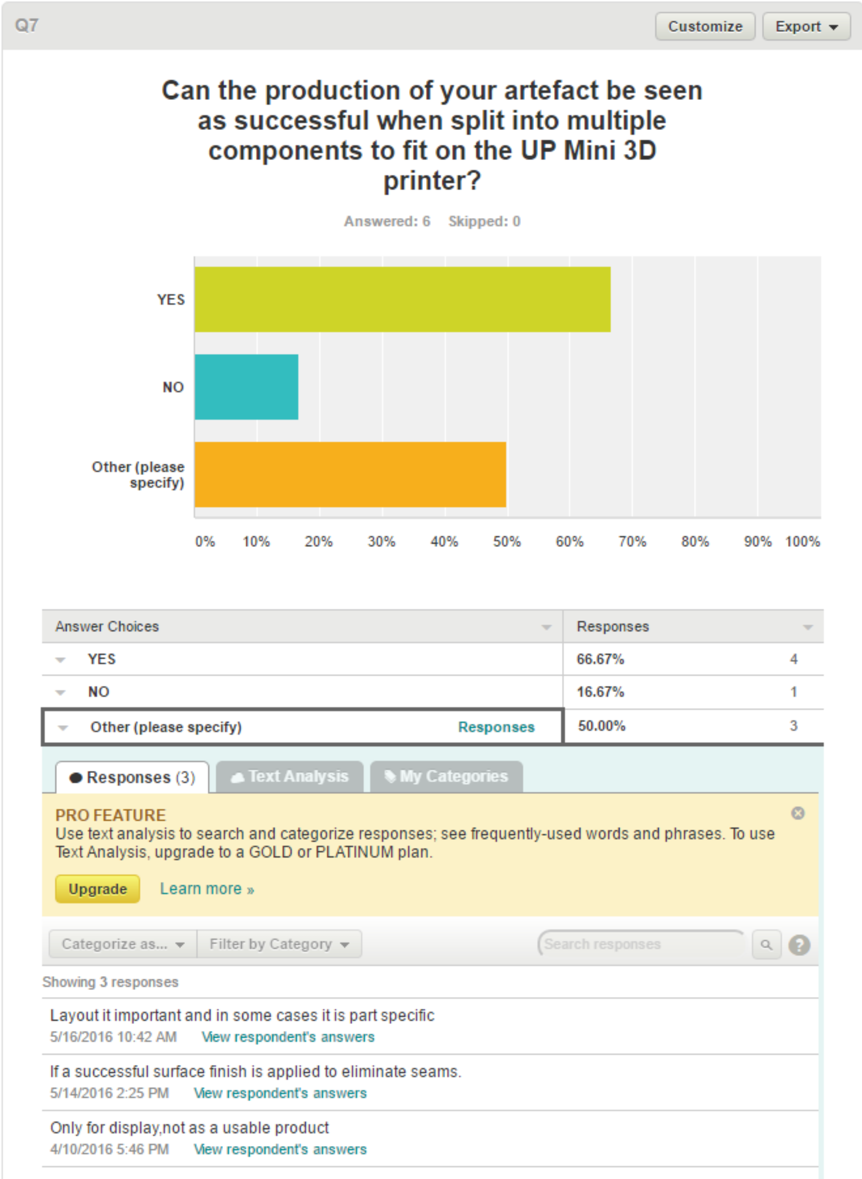
Overall all respondents therefore felt that PPFTs will assist in narrowing the gap between Entry-level and High-end FDM 3D printing.

4.2.6 Question 6: Acetone glue success?



Over 83% of the respondents felt that acetone cement glue can be used successfully on entry-level FDM artefacts. However 16% of the respondents felt that they are indecisive about the cements success rate and responded that it seems to depend on the size of the affected artefact surface areas that need to be assembled.

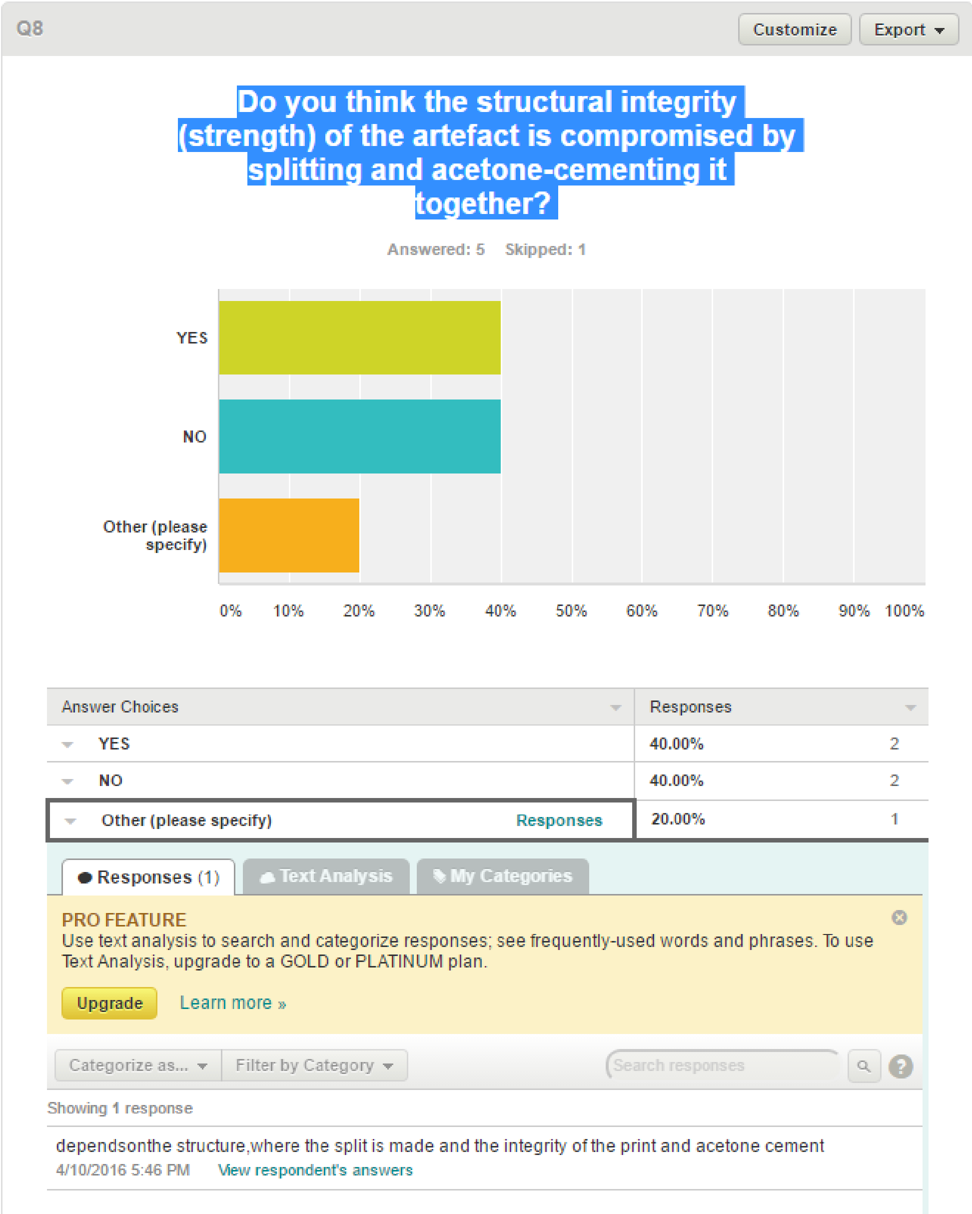
4.2.7 Question 7: Split successful?



Over 66% of the respondent felt that splitting the artefact into components to accommodate the UP MINI build size limitation was successful. Only 16% of the respondents felt that it is not a viable option.

Opinions included that the layout of the parts (cuts) are important and is part-specific. They also responded that successful surface finishing should be applied to hide any seams from fusing the components together. One of the comments stated that the artefact can only be used for a display example when using this “splitting” of the artefact and it cannot be seen as a usable product.

4.2.8 Question 8: Do you think the structural integrity (strength) of the artefact is compromised by splitting and acetone-cementing it together?



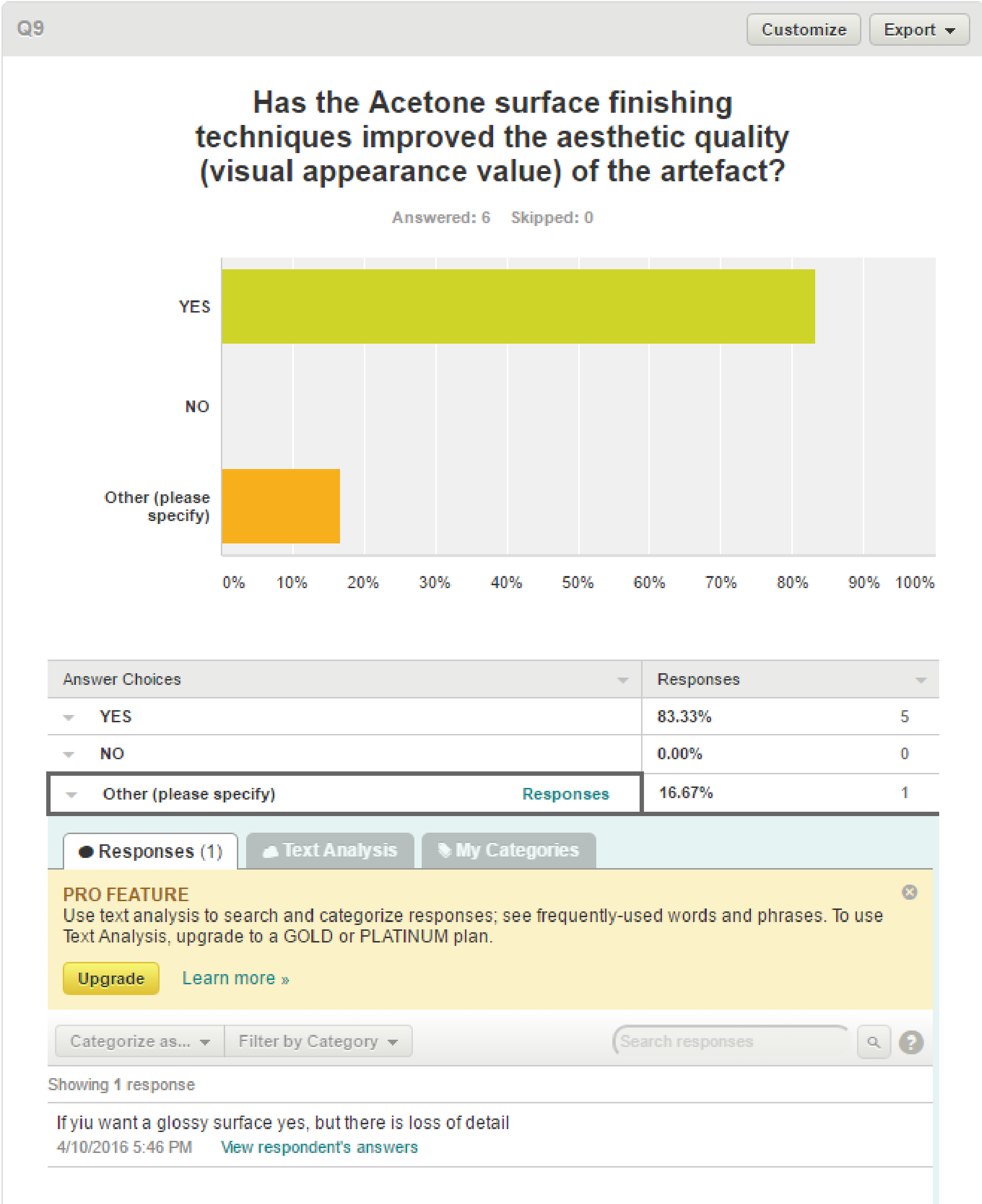
PLEASE NOTE: Respondent 4 by accident omitted question 8 by double clicking their answer, therefore the researcher are adapting the above graphical representation to reflect the complete submission. The respondents answer was NO, and are verifiable via the post interview email correspondence.

Fifty present of the respondents thought that the structural integrity of the artefact is not compromised by acetone gluing/ ABS cementing the components together after production.

Thirty three present of the respondents however did feel that the structural integrity is compromised, making the artefact more frail when seen as a functional part.

A response was made stating that it depends on the structure (*of the artefact*) and where it was split.

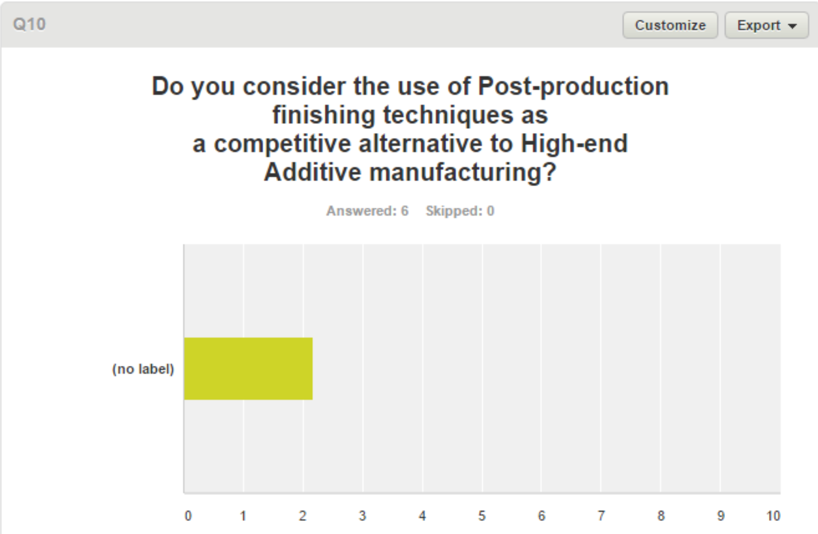
4.2.9 Question 9: Has the Acetone surface finishing techniques improved the aesthetic quality (visual appearance value) of the artefact?



All the respondents (100%) are of the opinion that acetone surface finishing improves the aesthetic value of the reproduced ELFDM artefacts. It can therefore be conclusively be assumed that the artefacts are visually more appealing after surface finishing was done with acetone.

However it should be noted that one of the respondents commented that it is only successful if a glossy finish is required and loss of detail may occur in the event of overexposure to acetone.

4.2.10 Question 10: Do you consider the use of Post-production finishing techniques as a competitive alternative to High-end Additive manufacturing?



	Yes, it will compete with other Additive manufacturing platforms	Good chance of competing	Moderate chance of competing	Little success of competing	No chance of competing	Total	Weighted Average
(no label)	0.00% 0	83.33% 5	16.67% 1	0.00% 0	0.00% 0	6	2.17

Comments (3)

Responses (3) | Text Analysis | My Categories

PRO FEATURE
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Showing 3 responses

It depends on the context and the geometry of the object. If these are suitable then it certainly competes.
5/26/2016 1:54 PM View respondent's answers

On the aesthetic side, definitely. But maybe not so much when it comes to more functional parts like gears, parts that need to fit into or onto other parts, parts in or around other parts (also depending in the size, intricacy and precision of these types of parts. If they are larger, fdm may work)
5/14/2016 4:58 PM View respondent's answers

For display yes, but there is detailloss
4/10/2016 5:46 PM View respondent's answers

Note to researcher

All respondents agreed that there is a moderate to good chance of acetone finishing competing with High-end AM as an alternative method. More than eighty present of the respondents replied with a good chance rather than moderate.

Some comments suggested that it depends on the context and geometry of the artefact. Another suggests that it competes from an aesthetic viewpoint rather than from a functional side, they also felt that the size of the object, intricacy and precision of the artefacts plays a role, meaning the larger the artefact the more likely the technique will succeed.

Lastly it was suggested that it is only successful from a visual display viewpoint as there is detail loss with the application of acetone.

Appendix 5: Respondent personal information:

5.1 Respondent 1: PvdW

Philip van der Walt is a Product Artist specializing in Design & Digital Sculpting for Additive Manufacturing (3D Printing)

Philip is founder & managing partner of BunnyCorp, a partner of VR3.glass and a director at the newly founded non-profit Phoenix Foundation for Advanced Medical Research.

He has a Degree in Graphic Design, Lectured Jewellery Design, and Design & CAD at 5 Universities across SA. He has published 4 books on Rhino CAD software, is a frequent speaker at international conferences and frequently collaborates with local and international artists & designers, one of which was a project called divine intervention with Dr. Lionel T. Dean from future factories, a pair of shoes was digitally sculpted, 3D printed, plated and exhibited in New York in 2014. His projects include Jewellery Design & Manufacturing, Medical Design, Industrial Design/Product Development, Concept Development, and Digital Sculpting for small and big public sculptures, High-End Fashion Design & Accessories, Footwear Design, Aerospace projects, Defense Projects, Furniture, Toys, Prosthetics for People & Animal and lately Virtual Reality products & display art.

About the artefact:

The artefact is a collaboration between Philip and Dr. Lionel T. Dean from future factories. The title of the project was DIVINE INTERVENTION and consist of a pair of shoes that was digitally sculpted, 3D printed, plated and exhibited in New York in 2014. The artefacts were designed specifically for the SLS technology and reproduced on ELFDM.

Figure 42 Images courtesy of the artist from http://bunnycorp.co.za/3d-printing/

Central University of Technology, Free State

Non-Disclosure Agreement*

This Non-Disclosure Agreement (the "Agreement") is accepted into effect from the moment of both signatories dated below by and between Sarel Havenga (the researcher, ID: 7806135036088),

and Philip van der Walt (the respondent).

IN MUTUAL AGREEMENT AND DISCLOSURE OF CONFIDENTIAL INFORMATION (HEREIN REFERRED TO AS THE CAD STL FILE AND/ OR ARTEFACT), THE PARTIES AGREE AS FOLLOWS:

1. 1. DEFINITION OF CONFIDENTIAL INFORMATION.

A) "Confidential information" means any non-public (non-open sourced) CAD generated file that the disclosing party "respondent" designates as being confidential to the receiving party "researcher" or which might be treated as confidential by the receiving party. Confidential information includes, without limitation, any information in tangible or intangible form, any software or products, marketing or promotion thereof.

Disclosing party includes any affiliates of said party and receiving party includes any affiliates, meaning any person, partnership, joint venture, corporation or enterprise that directly or indirectly control, are controlled by or are under control of mentioned parties.

Where the receiving party (researcher) uses confidential information to develop finishing techniques for any person, partnership, joint venture, corporation, other enterprise or customer, it shall take precaution to ensure this information is a not disclosed to unmentioned third party, unless specific written permission is obtained from the respondent in advance.

B) Confidential information shall not include any information that:

i. Become publicly available during or after the research has been completed, accept for the purpose of academic publication where the respondent has been acknowledged with his/ her permission.

ii. Became known to the receiving party (researcher) from a source other than the disclosing party that may stand in breach of the obligation of confidentiality owned by the disclosing party (respondent).

iii. That is independently developed or modified by the receiving party (researcher) without prior consent of the disclosing party (respondent).

1.2. OBLIGATIONS REGARDING CONFIDENTIAL INFORMATION

A) The receiving party (researcher) shall:

i. not disclosing any confidential information of the disclosing party (respondent) to any third parties without prior written consent.

ii. Take necessary precaution to protect disclosing party (respondent) confidential information and behave ethical.

*Non-disclosure agreement adapted from open source format at:
http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

iii. Notify the undersigned disclosing party (respondent) immediately upon discovery of any unauthorised use or breach of this agreement by receiving party (researcher) or its employers and consultants.

iv. At disclosure party's (respondent) request, return all original, copied, reproduced or surface finished artefacts, as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

B) The disclosing party shall;

i. Refrain from disclosing, reproducing, summarizing and/ or distribute confidential information regarding the research without the written consent of the receiving party (researcher).

ii. Refrain from publishing any findings under this academic research study before the completion and/ or publication of the said resulting findings.

1.3. RIGHTS AND REMEDIES

A) The receiving party (researcher) and its employers and consultants will cooperate with the disclosing party (respondent) in every reasonable way to assist in regaining possession of confidential information and further unauthorised use in the event of a breach.

B) The receiving party (researcher) shall at the request of the disclosing party (respondent), return all original, copied, reproduced and/ or surface finished artefacts as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

C) The parties agree that monetary damages may not be a sufficient remedy for unauthorized disclosure of confidential information unless stipulated and agreed upon by both parties involved or deemed proper by a court of competent jurisdiction.

1. 4. MISCELLANEOUS

A) All confidential information shall remain the property of the disclosing party (respondent). The disclosing party (respondent) reserves the ability to protect its rights under any patent, copyright, trademark or trade secret agreement.

B) The parties agree to comply with all international and national laws that apply to:

i. Confidential information (CAD file in the form of and .stl file).

ii. Any product, process or service that is the direct product of the confidential information and restrictions issued by the South African government and/ or other Governments.

C) The receiving party (researcher) shall be free to use for academic purpose the residuals resulting from access to or working with the confidential information of the disclosure party (respondent). Residual meaning information in tangible form, including ideas, concepts or technologies contained herein.

PtW SPH

*Non-disclosure agreement adapted from open source format at:
http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

D) This agreement does not grant the receiving party (researcher) a license to the disclosing party's (respondents) copyrights or patents nor to claim any monetary value for any artefacts reproduced or surface finished for this study.

E) This agreement stand for the entire agreement between all mentioned parties with respect to the subject matter contained herein. It may not be adapted with exception of written agreement that is dated and signed by all mentioned parties.

F) Both disclosing and receiving parties are entitled to employ legal assistance to enforce rights arising from a breach dispute and the prevailing party may request entitlement to recover reasonable legal fees incurred.

G) This agreement is a binding contract to benefit both receiving and disclosing parties from the moment of signing and dating.

H) Either party may reasonably terminate this agreement within 90 days from the first agreement date by written notice to the other party.

1. 5. SUGGESTIONS AND FEEDBACK

Both the Receiving Party (researcher) and the disclosing party (respondent) may during the time of this academic study and agreement provide suggestions, comments or feedback to the each other with respect to confidential information. Both parties agree that feedback is given entirely voluntarily.

In witness of this agreement the parties put into effect this contract:

Respondent (disclosing party)

Physical address:

18 Clarendon ave

Peacehaven

Vereeniging

By:

Name: Philip v/d Walt

Title: MR

Date: 20/01/2016

Researcher (receiving party)

Physical address:

I2P Laboratory, Science Park

Southern Gauteng, Sebokeng

Vaal University of Technology

By:

Name: Sarel Havenga

Title: MR

Date: 20/01/2016

SPH

*Non-disclosure agreement adapted from open source format at:
http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

5.2 Respondent 2: LTD

Figure 43 Lionel T. Dean (Image courtesy of the artist)

Product Artist Dr Lionel T Dean has been exploring the creative potential of digital design and manufacturing technologies for over a decade and is at the forefront of 3d printing in Art and Design. In 2002 he founded FutureFactories, a studio focused exclusively on 3D printing technologies and computational design methodologies which combine Computer Aided Design (CAD) with computer programming. These tools allow the creation of virtual meta-designs which have the ability to evolve and mutate over time and offer a potentially infinite stream of one-off solutions.

The FutureFactories project has proved a huge success yielding a string of iconic designs ranging from gallery pieces to retail products for well-known manufacturers. The significance of the work is perhaps illustrated by acquisitions by MoMA, The Museum for Modern Art in New York and DHUB, Design Museum Barcelona for their respective permanent collections. In 2008 the MoMA piece was included in a 'Highlights Collection' of the Museum's 250 most significant acquisitions since 1980.

Dean is heavily involved in academic design research and is Reader in Digital Arts at De Montfort University, UK.
About the artefact:

Divine Intervention was the result of 6 months of work between Dr. Lionel Dean in the UK and Philip van der Walt in South Africa, working over Skype and other social media they designed and sculpted a pair of Angel shoes that would be laser sintered and plated. They exhibited the shoes at the 3D Print Show in New York as part of their fashion section in February of 2014.

Figure 44 Images courtesy from the artists at: http://bunnycorp.co.za/future-factories/

Non-Disclosure Agreement*

This Non-Disclosure Agreement (the "Agreement") is accepted into effect from the moment of both signatories dated below by and between Sarel Havenga (the researcher, ID: 7806135036088),

and DR WONDER T. DEAN (the respondent).

IN MUTUAL AGREEMENT AND DISCLOSURE OF CONFIDENTIAL INFORMATION (HEREIN REFERRED TO AS THE CAD STL FILE AND/ OR ARTEFACT), THE PARTIES AGREE AS FOLLOWS:

1. 1. DEFINITION OF CONFIDENTIAL INFORMATION.

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Disclosing party includes any affiliates of said party and receiving party includes any affiliates, meaning any person, partnership, joint venture, corporation or enterprise that directly or indirectly control, are controlled by or are under control of mentioned parties.

Where the receiving party (researcher) uses confidential information to develop finishing techniques for any person, partnership, joint venture, corporation, other enterprise or customer, it shall take precaution to ensure this information is a not disclosed to unmentioned third party, unless specific written permission is obtained from the respondent in advance.

B) Confidential information shall not include any information that:

i. Become publicly available during or after the research has been completed, accept for the purpose of academic publication where the respondent has been acknowledged with his/ her permission.

ii. Became known to the receiving party (researcher) from a source other than the disclosing party that may stand in breach of the obligation of confidentiality owned by the disclosing party (respondent).

iii. That is independently developed or modified by the receiving party (researcher) without prior consent of the disclosing party (respondent).

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ii. Take necessary precaution to protect disclosing party (respondent) confidential information and behave ethical.

*Non-disclosure agreement adapted from open source format at:
http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

iii. Notify the undersigned disclosing party (respondent) immediately upon discovery of any unauthorised use or breach of this agreement by receiving party (researcher) or its employers and consultants.

iv. At disclosure party's (respondent) request, return all original, copied, reproduced or surface finished artefacts, as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

B) The disclosing party shall;

i. Refrain from disclosing, reproducing, summarizing and/ or distribute confidential information regarding the research without the written consent of the receiving party (researcher).

ii. Refrain from publishing any findings under this academic research study before the completion and/ or publication of the said resulting findings.

1.3. RIGHTS AND REMEDIES

A) The receiving party (researcher) and its employers and consultants will cooperate with the disclosing party (respondent) in every reasonable way to assist in regaining possession of confidential information and further unauthorised use in the event of a breach.

B) The receiving party (researcher) shall at the request of the disclosing party (respondent), return all original, copied, reproduced and/ or surface finished artefacts as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

C) The parties agree that monetary damages may not be a sufficient remedy for unauthorized disclosure of confidential information unless stipulated and agreed upon by both parties involved or deemed proper by a court of competent jurisdiction.

1. 4. MISCELLANEOUS

A) All confidential information shall remain the property of the disclosing party (respondent). The disclosing party (respondent) reserves the ability to protect its rights under any patent, copyright, trademark or trade secret agreement.

B) The parties agree to comply with all international and national laws that apply to:

i. Confidential information (CAD file in the form of and .stl file).

ii. Any product, process or service that is the direct product of the confidential information and restrictions issued by the South African government and/ or other Governments.

C) The receiving party (researcher) shall be free to use for academic purpose the residuals resulting from access to or working with the confidential information of the disclosure party (respondent). Residual meaning information in tangible form, including ideas, concepts or technologies contained herein.

D) This agreement does not grant the receiving party (researcher) a license to the disclosing party's (respondents) copyrights or patents nor to claim any monetary value for any artefacts reproduced or surface finished for this study.

E) This agreement stand for the entire agreement between all mentioned parties with respect to the subject matter contained herein. It may not be adapted with exception of written agreement that is dated and signed by all mentioned parties.

F) Both disclosing and receiving parties are entitled to employ legal assistance to enforce rights arising from a breach dispute and the prevailing party may request entitlement to recover reasonable legal fees incurred.

G) This agreement is a binding contract to benefit both receiving and disclosing parties from the moment of signing and dating.

H) Either party may reasonably terminate this agreement within 90 days from the first agreement date by written notice to the other party.

1. 5. SUGGESTIONS AND FEEDBACK

Both the Receiving Party (researcher) and the disclosing party (respondent) may during the time of this academic study and agreement provide suggestions, comments or feedback to the each other with respect to confidential information. Both parties agree that feedback is given entirely voluntarily.

In witness of this agreement the parties put into effect this contract:

Respondent (disclosing party)

Physical address:

52 RAUCEBY DRIVE

SOUTH RAUCEBY

LINCOLNSHIRE

NG34 8PT, UK

By:

Name: WONG T. DEAN

Title: DR

Date: 31/01/2016

Researcher (receiving party)

Physical address:

I2P Laboratory, Science Park

Southern Gauteng, Sebokeng

Vaal University of Technology

By:

Name: Sarel Havenga

Title: MR

Date: 20/01/2016

*Non-disclosure agreement adapted from open source format at: http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

5.3 Respondent 3: WvdH

At age 9 Mr Willie van der Heever took an interest in drawing and began attending art classes at Oliewenhuis Art Musuem. He continued with classes at Oliewenhuis until he finished matric. Along the way he sold several artworks and received a number of first and second place certificates at Bloemskou. After finishing high school he decided to study art as a profession at the Central University of Technology of the Free State. His interests shifted from drawing to sculpture and in his third year, he decided to study for his B. Tech in sculpture. 3D printing was part of his curriculum and really sparked his interest. He want to implement 3D printing in the art world in new and interesting ways that have not been seen before. His goal is to become a 3D character artist, and he will be using 3D printing as part of his workflow.

About the artefact:

Mr van der Heever wanted to experiment with a new free form sculpture and the resulting work was born from it.

Figure 45 Dinosaur Image courtesy of the artist

This Non-Disclosure Agreement (the "Agreement") is accepted into effect from the moment of both signatories dated below by and between Sarel Havenga (the researcher, ID: 7806135036088),

and Willie van der Heever (the respondent).

IN MUTUAL AGREEMENT AND DISCLOSURE OF CONFIDENTIAL INFORMATION (HEREIN REFERRED TO AS THE CAD STL FILE AND/ OR ARTEFACT), THE PARTIES AGREE AS FOLLOWS:

1. 1. DEFINITION OF CONFIDENTIAL INFORMATION.

A) "Confidential information" means any non-public (non-open sourced) CAD generated file that the disclosing party "respondent" designates as being confidential to the receiving party "researcher" or which might be treated as confidential by the receiving party. Confidential information includes, without limitation, any information in tangible or intangible form, any software or products, marketing or promotion thereof.

Disclosing party includes any affiliates of said party and receiving party includes any affiliates, meaning any person, partnership, joint venture, corporation or enterprise that directly or indirectly control, are controlled by or are under control of mentioned parties.

Where the receiving party (researcher) uses confidential information to develop finishing techniques for any person, partnership, joint venture, corporation, other enterprise or customer, it shall take precaution to ensure this information is a not disclosed to unmentioned third party, unless specific written permission is obtained from the respondent in advance.

B) Confidential information shall not include any information that:

i. Become publicly available during or after the research has been completed, accept for the purpose of academic publication where the respondent has been acknowledged with his/ her permission.

ii. Became known to the receiving party (researcher) from a source other than the disclosing party that may stand in breach of the obligation of confidentiality owned by the disclosing party (respondent).

iii. That is independently developed or modified by the receiving party (researcher) without prior consent of the disclosing party (respondent).

1.2. OBLIGATIONS REGARDING CONFIDENTIAL INFORMATION

A) The receiving party (researcher) shall:

i. not disclosing any confidential information of the disclosing party (respondent) to any third parties without prior written consent.

ii. Take necessary precaution to protect disclosing party (respondent) confidential information and behave ethical.

SPH

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D) This agreement does not grant the receivin[g party (res]earcher) a license to the disclosing party's (respondents) copyrights or patents nor to claim any monetary value for any artefacts reproduced or surface finished for this study.

E) This agreement stand for the entire agreement between all mentioned parties with respect to the subject matter contained herein. It may not be adapted with exception of written agreement that is dated and signed by all mentioned parties.

F) Both disclosing and receiving parties are entitled to employ legal assistance to enforce rights arising from a breach dispute and the prevailing party may request entitlement to recover reasonable legal fees incurred.

G) This agreement is a binding contract to benefit both receiving and disclosing parties from the moment of signing and dating.

H) Either party may reasonably terminate this agreement within 90 days from the first agreement date by written notice to the other party.

1. 5. SUGGESTIONS AND FEEDBACK

Both the Receiving Party (researcher) and the disclosing party (respondent) may during the time of this academic study and agreement provide suggestions, comments or feedback to the each other with respect to confidential information. Both parties agree that feedback is given entirely voluntarily.

In witness of this agreement the parties put into effect this contract:

Respondent (disclosing party)

Physical address:

21 Perskeblom road, Pellissier

Bloemfontein

9301

By: ______

Name: Willie van der Heever

Title: MR

Date: 22/01/2016

Researcher (receiving party)

Physical address:

I2P Laboratory, Science Park

Southern Gauteng, Sebokeng

Vaal University of Technology

By: ______

Name: Sarel Havenga

Title: MR

Date: 20/01/2016

SPH

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http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

5.4 Respondent 4: JB

Ms Jeané Bresler is a designer based in Gauteng. She holds a diploma in graphic design, however she has, for the last 8 years, focussed on the 3 dimensional aspects of design, and creative aspects of additive manufacturing.

She is experienced in Computer Aided Design (CAD), and has combined this experience with her understanding of the abilities of additive manufacturing technology to bring her digital creations into the physical realm. She has created many products and artworks using this technology, and was voted the overall winner of the RAPDASA 2015 3D design competition. Her work in this area of manufacturing continues to advance the integration of art and technology in South Africa.

About the artefact:

The artefact received an overall best designer award in the clock design category at the Rapid Product Development Association of South Africa (RAPDASA) conference held November 2015. This was the 16th annual international conference which took place in Pretoria. The conference aims at connecting researchers, designers, scientists and technical personnel worldwide. The association serves industry that allows 3D printing of objects directly from CAD designs.

Figure 46 Image courtesy of VUT news archive (RAPDASA 2015)

Ms Bresler entered a competition that aims to promote awareness of additive manufacturing (AM) and attempts to estimate the country's capability to design and engineer for AM. Participants could choose between a consumer product in the form of a clock or a 2-A design of an assistive device for a disabled patient. Bresler said: "I have a graphic design background. So this just goes to show that you do not have to be an engineer to design for this technology. You just need to learn how to use a CAD program and create a printable design."[5]

[5] Information adapted from: http://www.vut.ac.za/index.php/latest-news/1759-vut-student-wins-design-award

Non-Disclosure Agreement*

This Non-Disclosure Agreement (the "Agreement") is accepted into effect from the moment of both signatories dated below by and between Sarel Havenga (the researcher, ID: 7806135036088),

and Jeané Bresler, ID: 8505280034083 (the respondent).

IN MUTUAL AGREEMENT AND DISCLOSURE OF CONFIDENTIAL INFORMATION (HEREIN REFERRED TO AS THE CAD STL FILE AND/ OR ARTEFACT), THE PARTIES AGREE AS FOLLOWS:

1. 1. DEFINITION OF CONFIDENTIAL INFORMATION.

A) "Confidential information" means any non-public (non-open sourced) CAD generated file that the disclosing party "respondent" designates as being confidential to the receiving party "researcher" or which might be treated as confidential by the receiving party. Confidential information includes, without limitation, any information in tangible or intangible form, any software or products, marketing or promotion thereof.

Disclosing party includes any affiliates of said party and receiving party includes any affiliates, meaning any person, partnership, joint venture, corporation or enterprise that directly or indirectly control, are controlled by or are under control of mentioned parties.

Where the receiving party (researcher) uses confidential information to develop finishing techniques for any person, partnership, joint venture, corporation, other enterprise or customer, it shall take precaution to ensure this information is a not disclosed to unmentioned third party, unless specific written permission is obtained from the respondent in advance.

B) Confidential information shall not include any information that:

i. Become publicly available during or after the research has been completed, accept for the purpose of academic publication where the respondent has been acknowledged with his/ her permission.

ii. Became known to the receiving party (researcher) from a source other than the disclosing party that may stand in breach of the obligation of confidentiality owned by the disclosing party (respondent).

iii. That is independently developed or modified by the receiving party (researcher) without prior consent of the disclosing party (respondent).

1.2. OBLIGATIONS REGARDING CONFIDENTIAL INFORMATION

A) The receiving party (researcher) shall:

i. not disclosing any confidential information of the disclosing party (respondent) to any third parties without prior written consent.

ii. Take necessary precaution to protect disclosing party (respondent) confidential information and behave ethical.

SPH B

*Non-disclosure agreement adapted from open source format at:
http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

iii. Notify the undersigned disclosing party (respondent) immediately upon discovery of any unauthorised use or breach of this agreement by receiving party (researcher) or its employers and consultants.

iv. At disclosure party's (respondent) request, return all original, copied, reproduced or surface finished artefacts, as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

B) The disclosing party shall;

i. Refrain from disclosing, reproducing, summarizing and/ or distribute confidential information regarding the research without the written consent of the receiving party (researcher).

ii. Refrain from publishing any findings under this academic research study before the completion and/ or publication of the said resulting findings.

1.3. RIGHTS AND REMEDIES

A) The receiving party (researcher) and its employers and consultants will cooperate with the disclosing party (respondent) in every reasonable way to assist in regaining possession of confidential information and further unauthorised use in the event of a breach.

B) The receiving party (researcher) shall at the request of the disclosing party (respondent), return all original, copied, reproduced and/ or surface finished artefacts as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

C) The parties agree that monetary damages may not be a sufficient remedy for unauthorized disclosure of confidential information unless stipulated and agreed upon by both parties involved or deemed proper by a court of competent jurisdiction.

1. 4. MISCELLANEOUS

A) All confidential information shall remain the property of the disclosing party (respondent). The disclosing party (respondent) reserves the ability to protect its rights under any patent, copyright, trademark or trade secret agreement.

B) The parties agree to comply with all international and national laws that apply to:

i. Confidential information (CAD file in the form of and .stl file).

ii. Any product, process or service that is the direct product of the confidential information and restrictions issued by the South African government and/ or other Governments.

C) The receiving party (researcher) shall be free to use for academic purpose the residuals resulting from access to or working with the confidential information of the disclosure party (respondent). Residual meaning information in tangible form, including ideas, concepts or technologies contained herein.

SPH

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D) This agreement does not grant the receiving party (researcher) a license to the disclosing party's (respondents) copyrights or patents nor to claim any monetary value for any artefacts reproduced or surface finished for this study.

E) This agreement stand for the entire agreement between all mentioned parties with respect to the subject matter contained herein. It may not be adapted with exception of written agreement that is dated and signed by all mentioned parties.

F) Both disclosing and receiving parties are entitled to employ legal assistance to enforce rights arising from a breach dispute and the prevailing party may request entitlement to recover reasonable legal fees incurred.

G) This agreement is a binding contract to benefit both receiving and disclosing parties from the moment of signing and dating.

H) Either party may reasonably terminate this agreement within 90 days from the first agreement date by written notice to the other party.

1. 5. SUGGESTIONS AND FEEDBACK

Both the Receiving Party (researcher) and the disclosing party (respondent) may during the time of this academic study and agreement provide suggestions, comments or feedback to the each other with respect to confidential information. Both parties agree that feedback is given entirely voluntarily.

In witness of this agreement the parties put into effect this contract:

Respondent (disclosing party)

Physical address:

7 Defoe Street

SW 1

Vanderbijlpark

By: ________

Name: Jeané Bresler

Title: Ms.

Date: 27-06-2016

Researcher (receiving party)

Physical address:

I2P Laboratory, Science Park

Southern Gauteng, Sebokeng

Vaal University of Technology

By: ________

Name: ____Sarel Havenga______

Title: _____MR_______________

Date: ___20/01/2016___________

SPH JB

*Non-disclosure agreement adapted from open source format at:
http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

5.5 Respondent 5: JL

Jason started his career in the early 1990's of which in a very short time excelled him to be finalist and winner of multiple manufacturer and designer awards both locally and internationally of which set the stage of further developments in the jewellery sector. After setting up a casting and manufacturing factory of which jewellery was supplied to retailers such as American Swiss, Sterns Jewellers, Browns jewellers and a number of other smaller independent organizations, Jason was approached by a major shipping line to facilitate the manufacture, sales and retailer control on board grand class passenger ships as well as that on shore. During this process Jason's background of 3D printing grew very quickly by becoming a concessionaire to Louis Vuitton and Mohet Hennessey dealing with a wide range of products besides jewellery alone.

Returning back to South Africa after being out at sea for 4 and half years and traveling and working in just over 67 countries worldwide the experienced he gained helped him pioneer further developments in the jewellery industry by taking 3D printing in the trade to a more end-user and commercially accepted consumer based item along with new developments in trade relations.

Since then Mr. Laing have expanded to the commercial post-production composite finishing of 3D printed artefacts which set him as one of the leading experts in this field ever since. During an unfortunate cycling accident Mr. Laing had to rethink his approach to life and used 3D printing to further his career in the medical field. It is in this field where he is currently advancing techniques for prosthetic surgery, occupational therapy for TBI (Traumatic Brain Injury) patients and even prosthesis for his own operations.

About the artefact:

The trophy was originally created as a prototype design for the multichoice soccer awards (Multichoice diski challenge awards). This was used during the national soccer championships and was made in plastic and then plated.

Figure 47 The final design. Image available from http://www.adfocusblackafricagroup.com/portfolio_page/supersport-trophy/

Non-Disclosure Agreement*

This Non-Disclosure Agreement (the "Agreement") is accepted into effect from the moment of both signatories dated below by and between Sarel Havenga (the researcher, ID: 7806135036088),

and Jason Laing (the respondent).

IN MUTUAL AGREEMENT AND DISCLOSURE OF CONFIDENTIAL INFORMATION (HEREIN REFERRED TO AS THE CAD STL FILE AND/ OR ARTEFACT), THE PARTIES AGREE AS FOLLOWS:

1. 1. DEFINITION OF CONFIDENTIAL INFORMATION.

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Disclosing party includes any affiliates of said party and receiving party includes any affiliates, meaning any person, partnership, joint venture, corporation or enterprise that directly or indirectly control, are controlled by or are under control of mentioned parties.

Where the receiving party (researcher) uses confidential information to develop finishing techniques for any person, partnership, joint venture, corporation, other enterprise or customer, it shall take precaution to ensure this information is a not disclosed to unmentioned third party, unless specific written permission is obtained from the respondent in advance.

B) Confidential information shall not include any information that:

i. Become publicly available during or after the research has been completed, accept for the purpose of academic publication where the respondent has been acknowledged with his/ her permission.

ii. Became known to the receiving party (researcher) from a source other than the disclosing party that may stand in breach of the obligation of confidentiality owned by the disclosing party (respondent).

iii. That is independently developed or modified by the receiving party (researcher) without prior consent of the disclosing party (respondent).

1.2. OBLIGATIONS REGARDING CONFIDENTIAL INFORMATION

A) The receiving party (researcher) shall:

i. not disclosing any confidential information of the disclosing party (respondent) to any third parties without prior written consent.

ii. Take necessary precaution to protect disclosing party (respondent) confidential information and behave ethical.

SPH

*Non-disclosure agreement adapted from open source format at:

III. Notify the undersigned disclosing party (respondent) immediately upon discovery of any unauthorised use or breach of this agreement by receiving party (researcher) or its employers and consultants.

iv. At disclosure party's (respondent) request, return all original, copied, reproduced or surface finished artefacts, as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

B) The disclosing party shall;

i. Refrain from disclosing, reproducing, summarizing and/ or distribute confidential information regarding the research without the written consent of the receiving party (researcher).

ii. Refrain from publishing any findings under this academic research study before the completion and/ or publication of the said resulting findings.

1.3. RIGHTS AND REMEDIES

A) The receiving party (researcher) and its employers and consultants will cooperate with the disclosing party (respondent) in every reasonable way to assist in regaining possession of confidential information and further unauthorised use in the event of a breach.

B) The receiving party (researcher) shall at the request of the disclosing party (respondent), return all original, copied, reproduced and/ or surface finished artefacts as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

C) The parties agree that monetary damages may not be a sufficient remedy for unauthorized disclosure of confidential information unless stipulated and agreed upon by both parties involved or deemed proper by a court of competent jurisdiction.

1. 4. MISCELLANEOUS

A) All confidential information shall remain the property of the disclosing party (respondent). The disclosing party (respondent) reserves the ability to protect its rights under any patent, copyright, trademark or trade secret agreement.

B) The parties agree to comply with all international and national laws that apply to:

i. Confidential information (CAD file in the form of and .stl file).

ii. Any product, process or service that is the direct product of the confidential information and restrictions issued by the South African government and/ or other Governments.

C) The receiving party (researcher) shall be free to use for academic purpose the residuals resulting from access to or working with the confidential information of the disclosure party (respondent). Residual meaning information in tangible form, including ideas, concepts or technologies contained herein.

SPM

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D) This agreement does not grant the receiving party (researcher) a license to the disclosing party's (respondents) copyrights or patents nor to claim any monetary value for any artefacts reproduced or surface finished for this study.

E) This agreement stand for the entire agreement between all mentioned parties with respect to the subject matter contained herein. It may not be adapted with exception of written agreement that is dated and signed by all mentioned parties.

F) Both disclosing and receiving parties are entitled to employ legal assistance to enforce rights arising from a breach dispute and the prevailing party may request entitlement to recover reasonable legal fees incurred.

G) This agreement is a binding contract to benefit both receiving and disclosing parties from the moment of signing and dating.

H) Either party may reasonably terminate this agreement within 90 days from the first agreement date by written notice to the other party.

1. 5. SUGGESTIONS AND FEEDBACK

Both the Receiving Party (researcher) and the disclosing party (respondent) may during the time of this academic study and agreement provide suggestions, comments or feedback to the each other with respect to confidential information. Both parties agree that feedback is given entirely voluntarily.

In witness of this agreement the parties put into effect this contract:

Respondent (disclosing party)

Physical address:

114 Hampton road

Glen Austin

Midrand.

By:

Name: Jason laing

Title: Mr.

Date: 28/12/2016

Researcher (receiving party)

Physical address:

I2P Laboratory, Science Park

Southern Gauteng, Sebokeng

Vaal University of Technology

By:

Name: Sarel Havenga

Title: MR

Date: 20/01/2016

SPH

5.6 Respondent 6: MJvV

Dr. Michaella Janse van Vuuren has excelled in multiple disciplines from her PhD in Electrical Engineering and postdoc in medical implant design to being an internationally renowned 3D print designer, artist and an innovator in education. She has been involved in 3D printing since 2006 when she did her Post doctorate in Custom Medical Implant design at the CUT.

In 2008 she founded Nomili an innovative multidisciplinary research, consulting and 3D printed product development studio. Her Chrysanthemum centrepiece was voted the Most Beautiful Object in South Africa at Design Indaba 2009. In 2012 she was the VISI emerging designer of the year and in 2014 she was named one of the City Press 100 world class South Africans. Her ground-breaking 3D Printed Garden of Eden fashion collection debuted on the 3D Printshow catwalk in New York in 2014.

The Horse Marionette, a fine art piece, was on exhibition for two years in the London Science museum, and is now part of the Museum's permanent collection. Michaella founded the Agents of the 3D revolution in 2013; through exhibitions and seminars the public is given access and education in cutting edge technology.

About the artefact:

Figure 48 Rocking Springbuck made with EOS SLS

The Rocking Springbuck was digitally designed using 3D CAD software. I love the challenge of creating something that is planned and then designed on computer and seeing if my idea printed out as envisioned. The Rocking Springbuck has rotating gears and they move as the buck rocks. All the parts of the buck have been placed in the same 3D file so no assembly is required, and the sculpture emerges from the 3D printer with all the moveable parts in place. The design is printed in Polyamide using a 3D printing process called selective laser sintering, this nylon material is well suited to creating movable parts with the texture and look of coral.[6]

[6] All media, artefacts, depictions and descriptions above are copyrighted (c) by Dr Michaella Janse van Vuuren. Information adapted from: http://nomili.co.za/ and http://nomili.co.za/?page_id=157

Non-Disclosure Agreement*

This Non-Disclosure Agreement (the "Agreement") is accepted into effect from the moment of both signatories dated below by and between Sarel Havenga (the researcher, ID: 7806135036088), and Dr. Michaella Janse van Vuuren ______ (the respondent).

IN MUTUAL AGREEMENT AND DISCLOSURE OF CONFIDENTIAL INFORMATION (HEREIN REFERRED TO AS THE CAD STL FILE AND/ OR ARTEFACT), THE PARTIES AGREE AS FOLLOWS:

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Disclosing party includes any affiliates of said party and receiving party includes any affiliates, meaning any person, partnership, joint venture, corporation or enterprise that directly or indirectly control, are controlled by or are under control of mentioned parties.

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ii. Take necessary precaution to protect disclosing party (respondent) confidential information and behave ethical.

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iii. Notify the undersigned disclosing party (respondent) immediately upon discovery of any unauthorised use or breach of this agreement by receiving party (researcher) or its employers and consultants.

iv. At disclosure party's (respondent) request, return all original, copied, reproduced or surface finished artefacts, as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

B) The disclosing party shall;

i. Refrain from disclosing, reproducing, summarizing and/ or distribute confidential information regarding the research without the written consent of the receiving party (researcher).

ii. Refrain from publishing any findings under this academic research study before the completion and/ or publication of the said resulting findings.

1.3. RIGHTS AND REMEDIES

A) The receiving party (researcher) and its employers and consultants will cooperate with the disclosing party (respondent) in every reasonable way to assist in regaining possession of confidential information and further unauthorised use in the event of a breach.

B) The receiving party (researcher) shall at the request of the disclosing party (respondent), return all original, copied, reproduced and/ or surface finished artefacts as well as all tangible parts and devices provided or certify destruction of the above mentioned same items.

C) The parties agree that monetary damages may not be a sufficient remedy for unauthorized disclosure of confidential information unless stipulated and agreed upon by both parties involved or deemed proper by a court of competent jurisdiction.

1. 4. MISCELLANEOUS

A) All confidential information shall remain the property of the disclosing party (respondent). The disclosing party (respondent) reserves the ability to protect its rights under any patent, copyright, trademark or trade secret agreement.

B) The parties agree to comply with all international and national laws that apply to:

i. Confidential information (CAD file in the form of and .stl file).

ii. Any product, process or service that is the direct product of the confidential information and restrictions issued by the South African government and/ or other Governments.

C) The receiving party (researcher) shall be free to use for academic purpose the residuals resulting from access to or working with the confidential information of the disclosure party (respondent). Residual meaning information in tangible form, including ideas, concepts or technologies contained herein.

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http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

D) This agreement does not grant the receiving party (researcher) a license to the disclosing party's (respondents) copyrights or patents nor to claim any monetary value for any artefacts reproduced or surface finished for this study.

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F) Both disclosing and receiving parties are entitled to employ legal assistance to enforce rights arising from a breach dispute and the prevailing party may request entitlement to recover reasonable legal fees incurred.

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H) Either party may reasonably terminate this agreement within 90 days from the first agreement date by written notice to the other party.

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Both the Receiving Party (researcher) and the disclosing party (respondent) may during the time of this academic study and agreement provide suggestions, comments or feedback to the each other with respect to confidential information. Both parties agree that feedback is given entirely voluntarily.

In witness of this agreement the parties put into effect this contract:

Respondent (disclosing party)

Physical address:

PLOT 21, Rhenosterfontein rd

Donkerhoek

Pretoria 0043

By:____________________

Name: Michaella Janse van Vuuren

Title: Dr.

Date: 20/01/2016

Researcher (receiving party)

Physical address:

I2P Laboratory, Science Park

Southern Gauteng, Sebokeng

Vaal University of Technology

By:____________________

Name: ____Sarel Havenga______

Title:_____MR______________

Date:___20/01/2016___________

*Non-disclosure agreement adapted from open source format at:
http://www.openaccess.co.za/BlackAndWhiteInc/Non-Disclosure%20Agreement.pdf

Appendix 6: Respondent correspondence and documentation:

Dear respondent
Thank you for taking the time to partake in this important research for the development of entry level 3D printing. This correspondence serves as a description for the research topic: (**Customized Finishing techniques on Entry level FDM 3D printed artefacts in visual arts: an explanatory sequential study**), done by Mr. Sarel Havenga, for the completion of MTech in Design at the Central University of Technology, Bloemfontein, South Africa.

People from around the world and from different sectors and industries are starting to make use of entry level fused deposition modelling (3D printing). However the quality of entry level production is still of a debatable standard leaving us with the question whether post-production surface finishing can be the answer to improve the quality of above mentioned artefacts. This study is in part centred on the respondents' expert and subjective opinions regarding specific post-production surface finishing techniques to attain a thorough holistic qualitative viewpoint.

An extensive pre-experimental pilot study was carried out which identified promising techniques for surface finishing. From there the researcher did a very in-depth quantitative data collection study to test the validity (success) of these techniques on ABS produced FDM artefacts. More information can be found on the cross-reference diagram page attached. This brings us then to you the respondent and how your participation will assist the research outcome:

What is expected?

- Respondents need to supply the researcher with a printable .stl CAD file that can be reproduced.
- The specifications for the file is that it MUST exceed the printing bed limitation of an UP MINI 3d Printer. Therefor the file must be larger than 120mm x 120mm x 120mm.
- This file must be split into at least two parts/sections that can be glued or attached in post-production to assist with proof of concept by the researcher.
- Thereafter the respondent will need to answer a short online closed-ended questionnaire on his or her artefact that was reproduced and surface finished. This will be based on image reproduced sampling online.
- Lastly the respondent will partake in an open-ended SKYPE interview that will be documented. The respondents will have the actual artefact with them for the duration of this interview to assist with their assessment of the surface finish techniques.

What are the outcomes?

The qualitative responses received will assist in completing the last phase of this research study to establish the success or failure of post-production finishing techniques. Furthermore it will assist with aesthetic interpretation from an artistic/designer perspective which will assimilate value outputs.

Non-disclosure agreement

All artefacts reproduced will stay the intellectual property of the respondent and will be destroyed after the completion of the study. If however the respondent chooses to keep the artefact it shall be handed over to him/her after proper documentation was done for research purposes.

Please find attached the cross-reference diagram as well as the Non-disclosure agreement.

Respondent Information and first contact session transcripts

Name	Date	Time	From	Title	Discipline	Email	First contact
Lionel Dean	03/01/ 2016	16:07 28min	UK – UH	Dr	Design	lionel@futurefactories.com	Verbal
Philip vd Walt	03/01/ 2016	16:35 12min	RSA – CUT	Mr	Design	bunnycorp@gmail.com	Verbal
Willie vd Heever	09/01/ 2016	18:19 14min	RSA – CUT	Mr	Fine arts/ Btech	wvanderheever7@gmail.co m	Telephonic
Jeane Bresler	09/01/ 2016	18:27 10min	RSA – VUT	Mrs	Mechanical	jeanebresler@gmail.com	Verbal
Jason Laing	11/01/ 2016	12:39 10min	RSA - COM	Mr	Mechanical	jason@hybrid3d.co.za	Social media Whatsapp
~~Jessica Taute~~	~~13/01/ 2016~~	~~21:09 6min~~	~~RSA UFS/ CUT~~	~~Mrs~~	~~Fine arts/ Btech~~		~~Social media Facebook~~
Michaella Janse van Vuuren	18/01/ 2016	09:45 5min	RSA ?	Dr	Fine arts/ Engineering	M Janse van Vuuren (C/o Charlotte : 0834140808) 267, 26th ave Villieria , Pretoria, 0186 Skype: michaella.janse.van.vuuren	Email correspond ence

UH: University of Huddersfield, UK

CUT: Central University of Technology, RSA

VUT: Vaal University of Technology, RSA

COM: Commercial/ Industrial 3D maker, RSA and International

UFS: University of the Free State, RSA

Appendix 7: Publications resulting from research/work

7.1 Pre-production/ experimental Pilot study (RAPDASA 2014)

PART FINISHING ON ENTRY LEVEL FDM MODELS

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ABSTRACT

The Idea 2 Product lab (I2P), which was implemented at the Vaal University of Technology, is a self-help laboratory with the objective of empowering students, staff and the community to develop their ideas into a physical product or prototype using entry level Fused Deposition Modeling (FDM) printers. Since the startup of the I2P lab in 2011, a need arose to determine different part finishing techniques on entry level models. The aspects that need to be addressed to improve the appearance of the entry level models are the visible layer step traces, color and bonding/binding/fusing different pieces together. Due to the print size restrictions on entry level FDM printers, multiple parts often need to be bonded-fused together in order to form an aesthetic or functional part. The aim of the study is to determine different surface finishing and bonding/binding/fusing techniques, which can be used on entry level FDM printed ABS models in order to improve their appearance, performance and quality.

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[3] The author is enrolled for a D. Tech (Engineering) degree in the Department of Electronic Engineering, Vaal University of Technology

7.2 Phase one: stage two quantitative data (RAPDASA 2015)

EFFECTIVENESS OF ACETONE POST-PRODUCTION FINISHING ON ENTRY LEVEL FDM PRINTED ABS ARTEFACTS.

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ABSTRACT

In the quest to improve post-production finishing techniques on entry level Fused Deposition Modelling printed artefacts, two main areas persistently stand out as limitations, namely the structural integrity of assembled artefacts after post-production treatment and the surface finish quality. After an extensive pre-experimental case study, acetone (propan-2-one/ dimethyl ketone) was identified as one of the most promising post-production finishing materials. This paper describe the effects that acetone post-production finishing has on the structural integrity and surface finishing of an entry level Fused Deposition Modelling Acrylonitrile Butadiene Styrene printed artefact.

OPSOMMING

In die soeke na verbeterde afwerkingstegnieke vir produkte wat met intreevlak gesmelte-gedeponeerde/neergelegde modelleringsmetode (GGM/GNM) geproduseer word, is twee konstante beperkingsfaktore geïdentifiseer. Strukturele integriteit van saamgestelde artefakte wat na afloop van produksie behandel word, asook die oppervlakafrondings-kwaliteit. Na 'n uitgebreide pre-eksperimentele gevallestudie was asetoon as 'n waarskynlike post-produksie chemiese-afrondingstof geïdentifiseer. Dié referaat beskryf die uitwerking wat post-produksie asetoonafronding op die strukturele integriteit en oppervlakafwerking van intreevlak gesmelte-gedeponeerde/neergelegde modellerings-metode (GGM/GNM) *Akrilonitriel Butadieen Styreen* (ABS) gegroeide artefakte het.

Keywords: Acetone, Acrylonitrile Butadiene Styrene, Artefacts, Fused Deposition Modelling, Post-production, Post-processing, Surface finish, tensile strength.

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7.3 Phase two: Qualitative data collection (RAPDASA 2016, iCAT 2016)

ACETONE POST-PRODUCTION FINISHING TECHNIQUES: INTEGRATING THE IMPACT OF IMPROVED METHODS TO ENHANCE THE ENTRY-LEVEL FDM INDUSTRY IN SOUTH AFRICA.

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[1] ABSTRACT

When considering the quality of Entry-Level Fused Deposition Modelling (ELFDM) specimens, it becomes evident that the development of improved finishing techniques can narrow the gap between low cost entry-level and high-end production methods. Narrowing this gap would allow the technology to become readily available to a larger spectrum of users who were previously excluded from using FDM, and thereby identify a potential niche market. This research paper is the accumulation of a two year study that has addressed the potential impact of acetone, as a post-production finishing material, on the quality of ELFDM models. The paper presents the results of several finishing investigations and discusses their impact on the creation of a larger market for ELFDM in the South African additive manufacturing industry. It also makes recommendations for future work in this area.

OPSOMMING

Wanneer die kwaliteit van intreevlak gesmelte-gedeponeerde/ neergelegde modellerings-metode (GGM/GNM) modelle in oorweging geneem word, word dit duidelik dat die ontwikkeling van verbeterde afrondings tegnieke, die gaping tussen intreevlak en gevorderde produksie metodes kan verminder. Sodoende sal die tegnologie beskikbaar gestel word aan ‘n grooter spektrum verbruikers wat voorheen uitgesluit was van GGM/GNM en identifiseer ‘n moontlike nismark. Hierdie referaat is die slotsom van ‘n twee jaar studie wat die moontlike impak van asetoon (as post-produksie afrondings middel) vertoon op die kwaliteit van GGM/GNM modelle. Die referaat verwys na verskei afrondings ondersoeke en bespreek die impak van die ontwikkeling van n gevorderde GGM/GNM mark in die Suid Afrikaanse toevoegings vervaardiging konteks. Dit maak ook aanbevelings vir toekomstige navorsing.

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