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'Exploration of how 3D printing is influencing manufacturing businesses in Durban Kwazulu-Natal'

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I hereby declare that the Research Report submitted for the BCOM Honours in Management to The Independent Institute of Education is my own work and has not previously been submitted to another University or Higher Education Institution for degree purposes.

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Abstract

According to Valtas and Sun (2016), 3D printing, also known as additive manufacturing technology, has been labelled the next big thing and could be as popular as cell phones in the future. The purpose of this study is to explore how 3D printing is influencing manufacturing businesses in Durban KwaZulu-Natal (KZN). According to Valtas and sun (2016), this could give insight into how 3D printing may be disruptive as well as create opportunities and contribute to a competitive advantage for businesses that are looking to adopt the technology in the future. This study aims to not only highlight the opportunities that arise with 3D printing, but also the negative influences it has on businesses. There has not been much research conducted on how 3D printing has influenced businesses which is why this research is relevant and the aim of the study is to contribute to closing the gap in the literature. To collect data for the current study, the researcher made use of semi-structured interviews as the data collection method since this method offered a more flexible approach to the interview process (Ryan, Coughlan & Cronin 2009). Two interviews were concluded and findings demonstrate that the potentially disruptive technology of 3D printing has already started to diffuse into businesses in Durban which brings many benefits such as cost reduction and a few challenges which include not being able to manufacture on a large scale.

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1. Introduction

1.1. Contextualisation

According to Valtas and Sun (2016), 3D printing, also known as additive manufacturing technology, has been labelled the next big thing and could be as popular as cell phones in the future. 3D printing involves printing objects from a digital design into a physical 3D object (Valtas & Sun, 2016). The technology is being used around the globe in the manufacturing industry in sectors such as automotive, aviation, medical, as well as construction and the uses of the technology are increasing every day in various businesses (Mpofu, Mawere & Mukosera, 2014). The purpose of this study is to explore how 3D printing is influencing manufacturing businesses in Durban KwaZulu-Natal (KZN). The diffusion of 3D printing and its disruptive potential will be discussed as well as the business opportunities and challenges it brings to the manufacturing industry in Durban.

1.2. Rationale

3D printing is a new technology that is increasing in popularity with businesses in South Africa (SA) (Aghimien, Aigbavboa, Aghimien & Thwala, 2020). The researcher's aim is to explore the influence 3D printing has on manufacturing businesses in Durban that use 3D printing. According to Valtas and sun (2016), this could give insight into how 3D printing may be disruptive as well as create opportunities and contribute to a competitive advantage for businesses that are looking to adopt the technology in the future. This study aims to not only highlight the opportunities that arise with 3D printing, but also the negative influences it has on businesses such as taking away jobs from employees which could be a problem in SA. There has not been much research conducted on how 3D printing has influenced businesses which is why this research is relevant and the aim of the study is to contribute to closing the gap in the literature (Bai, Liu & Wang, 2017).

1.3. Problem Statement

3D printing is a technology that SA has adopted in the last ten years whereas countries like China and the United States (US) adopted the technology soon after it was

developed (Aghimien et al., 2020). This technology may have disruptive potential which may lead to new opportunities for manufacturing businesses but may also negatively influence them. As per Aghimien et al. (2020), there is a slow shift towards the use of 3D printing by businesses in Durban and SA is following suit from countries like China and the US which 3D printing plays a large part in. Even though it is a relatively new technology, 3D printing is increasing in popularity and has the potential to completely disrupt existing sectors in the manufacturing industry but is not yet at that point (Aghimien et al., 2020). A better understanding of the advantages and disadvantages of 3D printing needs further exploration.

1.4. Purpose Statement

Since the purpose of this exploratory study is to explore how 3D printing is influencing manufacturing businesses in Durban KwaZulu-Natal, the focus is on businesses and how they have been influenced by the implementation of 3D printing as part their business operations (Aghimien et al., 2020). The researcher aims to collect information from the business owners within the manufacturing industry in Durban to gain a clearer understanding of the influence the technology is having on businesses as well as the way 3D printing has changed how businesses operate (Aghimien et al., 2020). The study aims to identify the positives as well as the negatives it brings to the manufacturing businesses.

1.5. Research Question

How is 3D printing influencing manufacturing businesses in Durban KZN?

1.6. Research Objective

To understand how 3D printing is influencing the early adopters (manufacturing businesses) of the technology including the advantages and disadvantages that the technology brings to different parts of the business and their supply chains.

2. Literature Review

2.1. Conceptualisation

2.1.1. Disruptive Technology

As per Coccia (2017), when existing technology evolves or when older technology has been outdated, this is when technology is created and diffused into the world which could result in being disruptive. The technology can be regarded as disruptive when the technology that is created changes the way consumers, businesses or industries operate (Coccia, 2017). In the case of 3D printing, when the technology changes the way industries and businesses operate, it can be regarded a disruptive technology. This study will explore how the users of 3D printers (business owners) have noticed disruption in their businesses.

2.1.2. Business Opportunity

According to Shrestha (2015), business opportunity is the possibility to meet an unsatisfied need in a profitable manner. It is being able to deliver enhanced value by a unique and creative combination of resources to be able to satisfy a market or industry demand (Shrestha, 2015). 3D printing may create business opportunities for entrepreneurs and allow them to provide an enhanced value to customers and be able to meet an unsatisfied need in the market in a profitable manner (Shrestha, 2015).

2.1.3. Manufacturing Industry

As stated by Herman (2016), the manufacturing industry is made up of establishments that are involved in the mechanical, physical, or chemical transformation of materials, substances or components into new products which also includes establishments involved in the assembly of components and parts (Herman, 2016). 3D printing is a new method of manufacturing implemented in the manufacturing industry to produce products and components from materials (Ortt, 2017).

2.1.4. Supply Chain

According to Swink, Melnyk, Hartley, and Cooper (2017), a supply chain is a global network of businesses and suppliers which involves the production of goods and the distribution of these goods to the end user. The global network involves various procedures, people, businesses, information, and resources (Swink et al., 2017). 3D printing has an impact on the supply chains of businesses within the manufacturing industry (Rogers, Baricz & Pawar, 2016).

2.2. Theoretical Foundation

2.2.1. The Diffusion of Innovations Theory

The diffusion of innovations theory looks at why and how quickly new innovations diffuse into organisations and industries (Rogers, 1962 as cited by Rogers, 2003). The focus of the theory is based on diffusion which is made up of four main concepts. Diffusion is the process of how (1) an innovation is (2) communicated through various channels (3) over a period of time (4) in a social system (Rogers, 2003). According to Ortt (2017), 3D printing is a technology that is being diffused into businesses around the globe within the manufacturing industry. Since the aim of this study is to explore the influence 3D printing is having on the manufacturing businesses in Durban into which the technology is being diffused, the diffusion of innovations theory is relevant as it covers the diffusion process and relates to how 3D printing as a new technology is becoming more popular with manufacturing businesses over time in Durban (Rogers, 2003). The diffusion of innovations theory focuses on the four concepts mentioned below:

Innovation: The theory focuses on innovation as an concept which may support the researcher in exploring the thoughts and influences of 3D printing on manufacturing businesses and their owners and why they have decided to adopt the technology (Rogers, 2003).

Communication through various channels: The theory also focuses on the communication of the innovation which will allow the researcher to explore how business owners have heard of 3D printing and share information about 3D printing with other business owners in the manufacturing industry in Durban through channels such as mass media and interpersonal communication (Rogers, 2003).

Over a period of time: The theory can give insight into how the early adopters of the technology have experienced the use of 3D printing in South Africa where 3D printing is still growing in popularity in the manufacturing industry and if their experiences with 3D printing and the influence it has had on them has changed over time (Rogers, 2003).

Social system: The social system in the diffusion of innovations theory refers to the set of interrelated units involved in the same purpose. The theory may be referred to when identifying the social system as the business owners and their manufacturing businesses within in Durban into which 3D printing is being diffused (Rogers, 2003).

The diffusion of innovations theory states that relative advantage is the extent by which a certain group of users perceive an innovation as a preferred idea over the innovation it replaces (Rogers, 1995 as cited by Dibra, 2015). The larger the perceived relative advantage by a business, the quicker a business will adopt and diffuse the innovation within their operations. As per Aghimien et al. (2020), businesses in Durban who have adopted 3D printing as a preferred choice to other ways of manufacturing have diffused the technology in their business operations and have been influenced by the technology in different ways. The theory also focuses on complexity which is the degree to which an innovation is perceived as difficult to understand and make use of (Rogers, 1995 as cited by Dibra, 2015). The easier it is to understand an innovation, the quicker it will be adopted by businesses in their operations (Rogers, 1995 as cited by Dibra, 2015). With relative advantage and complexity being discussed above as two additional concepts in the diffusion of innovations theory, the theory suits the study as these two concepts relate to the influence 3D printing has had thus far on manufacturing businesses. The reason that complexity and relative advantage relate to the study is because business owners will look at the complexity of 3D printing and the relative advantage of the technology before adopting it into their business operations.

2.3. Review of Relevant Literature

2.3.1. 3D Printing as a Disruptive Technology

According to Attaran (2017), Henry Ford introduced the first moving assembly line in the 20th century which allowed for production of mass goods. Presently, 3D printing offers an alternative to this traditional method of manufacturing where goods can be produced in small to moderate quantities and allows for the customisation of goods (Attaran, 2017). The manufacturing lead times decrease, and products can be produced and introduced into the market quicker which satisfies customer demands more promptly (Attaran, 2017).

As discussed earlier, 3D printing has been labelled the next big thing and could be as popular as cell phones in the future (Valtas & Sun, 2016). As per Ramola, Yadav, and Jain (2019), technology allows people to do “more with less” and 3D printing is a technology that makes that possible. Since the development of 3D printing in 1984 and mainstreamed in the 2000s, it is growing in popularity and the positive influence it has had on businesses allows for 3D printing to have a significant place in the manufacturing industry and the ability to revolutionise the industry (Wong & Hernandez, 2012 as cited by Ramola et al., 2019). Gibson (2017) agrees with Wong and Hernandez (2012) that 3D printing can transform the manufacturing industry around the globe with the features and ease that it brings. Some researchers believe that 3D printing will completely transform existing industries while others believe that 3D printing will only be adopted in niche industries where customers demand specific products to be produced (Ortt, 2017). 3D printing has the potential to disrupt industries at large such as the manufacturing industry (Kothman & Faber, 2016 as cited by Ortt, 2017). Steenhuis and Pretorius (2016) as cited by Ortt (2017), agree with Kothman and Faber (2016) that 3D printing could potentially disrupt on a large scale. On the other hand, Meisel (2016) as cited by Ortt (2017), believes that 3D printing will only be adopted in niche industries such as manufacturing of parts in smaller environments. Oettmeier and Hofmann (2016) agree with Meisel (2016) that 3D printing is focused on smaller industries such as manufacturing in the hearing aid industry. One of the many reasons why 3D printing is a growing choice of technology in the manufacturing

industry is due to the layer-by-layer printing of products which produces less waste of materials than traditional manufacturing methods such as milling and moulding but also allows businesses to create new products in a quick and easy manner (Steenhuis & Pretorius, 2017 as cited by Ramola et al., 2019). Attaran (2017) states that 3D printing creates new business opportunities and gives possibilities to businesses striving to improve their manufacturing efficiency. There are many stages within the supply chain that are skipped due to 3D printing (Ramola et al., 2019). The technology could potentially minimise the requirement for logistics as the designs of objects needed to be printed by businesses can be transferred digitally. This results in a reduction of logistics costs and time taken to deliver products to customers as well as the environmental impact businesses contribute to annually.

Application areas of 3D printing within the manufacturing industry:

According to Attaran (2017), 3D printing is applied in several manufacturing sectors:

Automotive: The automotive industry was one of the first areas of application for 3D printing technology as businesses saw the benefit it brought in speeding up product development (Gibson, 2017). Companies like General Motors have been using 3D printing for over two decades to reduce time of production and overall costs (Fish, 2011 as cited by Attaran, 2017). Processes such as styling of vehicles and parts resulted in slowing the manufacturing process down which delayed product launches. This resulted in 3D printing becoming more popular amongst automotive manufacturers especially in part designs and is now seen as an essential tool in reducing lead times and allows for greater precision (Attaran, 2017). This highlights the disruptiveness of 3D printing as it has already started to change some of the ways that automotive manufacturers operate.

Healthcare and medical: According to Ramola et al. (2019), the healthcare and medical sector is among the sectors with the greatest transformative potential given the ability 3D printing has. 3D printing has been implemented in many businesses within the healthcare and medical industry due to the demand for patient specific designs (Gibson, 2017). Doctors and surgeons make use of 3D printing to customise objects such as implants, prosthetics, and even organs for patients. As stated by Gibson (2017), this has allowed for more speedy recoveries and slowly eliminates the

requirement for follow-up operations which reduces overall treatment costs for patients. The ability of 3D printing to print medical components in-house on demand has disrupted many businesses involved in the manufacturing and delivery of these medical products such as logistics companies delivering prosthetics (Oettmeier & Hofmann, 2016).

Construction: South Africa has a shortage of housing delivery which has been an ongoing issue for several years (Aghimien et al., 2020). The situation is so severe that the provision of adequate housing is the main priority in the National Development Plan of South Africa which the government aims to achieve before the year 2030. Aghimien et al. (2020) state that countries like China have adopted 3D printing in their construction sector to print houses but there seems to be no clear indication of the construction sector in South Africa adopting 3D printing. Aghimien et al. (2020) state that the technology could be a solution for poor housing delivery in SA. The construction industry could benefit from 3D printing as it would reduce construction time and labour costs (Attaran, 2017). It would also give the ability to print components for houses and transform the way houses are built in SA (Attaran, 2017). As stated by Aghimien et al. (2020), the technology provides a solution for quick and easy access to components, parts, tools, as well as building materials which would benefit the construction of housing in SA as there will be less delays in construction plans. This illustrates further potential for the disruptive nature of 3D printing in the construction sector as it has the potential to disrupt construction sectors and is slowly shifting to disrupt on a larger scale in the country.

Aviation: In the aviation sector, it is important to have designs with the focus being on reducing the weight or improving them to achieve high performance (Gibson, 2017). Even though saving costs is important in the manufacturing process of aviation components, savings in weight and improvements are just as vital which is why 3D printing is slowly being adopted in the aviation sector. As per Attaran (2017), 3D printing allows for components to be printed in remote locations which makes the use of 3D printing possible in places such as airports. Attaran (2017) adds onto the words of Gibson (2017) and states that reducing costs is important which is another reason why 3D printing is benefiting the aviation industry since delivery of components is no longer required which cuts the costs of component delivery. According to Gibson

(2017), Boeing and Airbus are both involved in 3D printing components for their aircraft which include cabin brackets and fuel nozzles.

It is evident that in all the sectors discussed above, many supply chain processes are skipped or not required due to 3D printing reducing the need for processes such as logistics and storage of products. The use of 3D printing in automotive manufacturing could modify the way vehicles look and operate in the future (Bargmann, 2013 as cited by Attaran, 2017). As per Gibson (2017), 3D printing allows hospitals to print medical parts on demand which skips the stages of delivering medical parts. South Africa is home to the largest 3D printer in the world and is involved in printing aviation components for airline companies like Boeing and Airbus operating in the country (Gibson, 2017). This yet again has disrupted some stages in the supply chain of these components in SA and allows for components to be printed on demand at airports when required. The construction sector in South Africa may have light at the end of the tunnel if 3D printing is diffused into the sector. The technology may be a solution for poverty-stricken areas where housing can be provided more adequately and at lower costs which could transform the way the construction sector operates in SA on a larger scale (Aghimien et al., 2020).

According to Ortt (2017), traditional manufacturing methods are costly and 3D printing is becoming much cheaper. Traditional methods of manufacturing involve many stages of production whereas 3D printing reduces stages of production which allows businesses within the manufacturing industry to focus on other areas of innovation making them more competitive (Ortt, 2017). It is clear that 3D printing is disrupting several sectors within the manufacturing industry which demands the need for new business models and sparks new business opportunities for entrepreneurs to explore with minimal capital (Holzmann, Breiteneker, Soomro & Schwarz, 2017).

3D printing is regarded as a disruptive technology that is currently being diffused into niche sectors but has the potential to become a large disruption in the future and substitute traditional methods of manufacturing (Rylands, 2016 as cited by Ortt, 2017). Ramola et al. (2019) echo the words of Rylands (2016) and believe that 3D printing is gaining acceptance and is starting to shift from being applied in niche sectors and disrupting on a larger scale within the manufacturing industry. Attaran (2017) adds to

this by stating that 3D printing provides a superior alternative to traditional methods and has the potential to disrupt and become the norm over the decade to come. It may be several years before 3D printing truly revolutionises sectors within the manufacturing industry significantly.

2.3.2. Advantages and Challenges of 3D Printing

Given the disruptive ability of 3D printing, the technology brings several advantages and challenges to the manufacturing industry as well as the supply chain of various manufacturing businesses.

According to Niaki and Nonino (2017), the cost of 3D printers is regarded as a challenge for manufacturers wanting to adopt the technology as industrial printers may be costly and unaffordable for many businesses. Even though the costs of 3D printers and materials used in the printing process have reduced in the last few years, the costs of the printers and materials are still regarded as high (Niaki & Nonino, 2017). The high cost of maintenance is also a challenge for manufacturers. The reason for these high costs is a result of the uncertainties of 3D printing as well as the minimal number of printer and material suppliers which gives suppliers more negotiating power over manufacturers (Niaki & Nonino, 2017). Nevertheless, 3D printers reduce capital costs for manufacturers as they will not have to invest heavily in factory machinery and equipment (Niaki & Nonino, 2017).

In the process of 3D printing, pieces such as car parts and aeroplane components of any geometry and no matter how complex can be manufactured in one procedure unlike traditional methods of manufacturing which requires several procedures to complete the production of a component (Dwivedi, Srivastava, and Srivastava, 2017). A single 3D printer has the ability to print various different designs which only requires different digital files to be able to print objects thus making 3D printing a technology with a high degree of versatility (Bai et al., 2017). This is yet another reason why 3D printing is in demand in sectors which require smaller quantities of customised products such as the medical and healthcare sector discussed earlier. Often in traditional methods of manufacturing, parts are shipped from all over the globe for manufacturers to use in their process to complete a product (Dwivedi et al., 2017). 3D printing allows for damaged or lost components to be printed by manufacturers without

waiting for components to be sourced from suppliers around the globe (Dwivedi et al., 2017). The challenge manufacturers face with this is that the spare components that are printed may be printed from a different material than the original component which reduces the consistency in products (Dwivedi et al., 2017). Even though 3D printing offers an easier and more efficient approach to manufacturing, the speed of manufacturing and the low output rate compared to traditional manufacturing methods are lower which serves as a challenge for manufacturers producing on a larger scale (Baumers, 2016 as cited by Dwivedi et al., 2017).

According to Ortt (2017), the internet initially disregarded distance as an issue when moving information from one part of the globe to the next and now 3D printing is solving this issue in the material world. Digital files consisting of 3D designs can be transferred via the internet to manufacturers who make use of 3D printers in their business operations and are able to print objects in 3D (Ortt, 2017). 3D printing offers several advantages to manufacturing businesses such as the reduction or complete elimination of physical inventory due to on-demand printing as well as longer product lifespans (Niaki & Nonino, 2017). As per Oettmeier and Hofmann (2016), 3D printing makes it possible for manufacturers to continue operating with smaller amounts of stock as they can manufacture according to demand. Oettmeier and Hofmann (2016) echo the words of Niaki and Nonino (2017) and state that 3D printing reduces the stockpile of inventory and eliminates the need for predicting future sales. However, manufacturers would still need to stock materials needed to produce products and components. This may result in lower consumer prices as manufacturing on demand reduces the need for storage and packaging costs as well as logistics costs and allows manufactures to be more sustainable (Oettmeier & Hofmann, 2016). Rogers et al. (2016), agree with Oettmeier and Hofmann (2016) that 3D printing reduces logistics costs as the decentralisation of manufacturing by businesses allows them to manufacture inhouse without the need for sourcing parts at additional costs. Online platforms offer 3D printing services to manufacturers and can be marketplaces for designs and sourcing materials (Rayna, 2015 as cited by Rogers et al., 2016). However, as 3D printing matures in certain sectors such as the aviation sector, businesses may face constraints and certification requirements set by governments

that may hinder agreements between manufacturers and service providers of the technology.

As per Aghimien et al. (2020), third world countries like South Africa struggle from inequality and have high poverty and unemployment rates. Even though 3D printing brings about several advantages, it may also have a negative impact. Businesses within the manufacturing industry in third world countries are slowly adopting 3D printing within their business operations and is causing labour to be replaced by 3D printers (Aghimien et al., 2020). Due to 3D printing being an emerging technology, there is still a gap in the manufacturing industry's workforce as workers lack knowledge of the technology and do not hold the skills to operate such a technology. However, Dwivedi et al. (2017) highlight the positive in the situation stated by Aghimien et al. (2020) and believe that people should continue to have a positive outlook on the situation because even though some jobs may be lost, more will be created in other ways. 3D printing will not completely replace the workforce but will rather be used as a tool to enhance the manufacturing process (Dwivedi et al., 2017). Workers need to become knowledgeable of 3D printing and improve their skills in the process but the challenge for manufacturers is finding suitable candidates to operate the 3D printers (Dwivedi et al., 2017). Many workers are not comfortable with learning about a new technology such as 3D printing after being involved in traditional methods of manufacturing for several years. This makes workers resistant to change which may be a challenge for manufacturing businesses in South Africa to resolve (Mellor, 2014 as cited by Dwivedi et al., 2017).

2.3.3. Critical Assessment

After reviewing the literature above, it can be seen that the literature demonstrates that 3D printing is an ever-growing technology which is disrupting several manufacturing businesses and their supply chains. The technology is currently being diffused and adopted on a small scale by businesses around the globe to be used in manufacturing several components and products. The use of 3D printing is growing by the day and there is an evident shift of the technology from small scale use to becoming a large part of the manufacturing industry around the globe. Even though 3D printing has disrupted many stages in the supply chain of various sectors, at the

same time it has created business opportunities for entrepreneurs. There is not much evidence to suggest that South Africa is adopting 3D printing on a large scale in the manufacturing industry but rather on a small scale, however, taking the above literature into consideration, we can assume that 3D printing will influence manufacturing businesses in Durban in a similar way. The technology could bring advantages to the manufacturing industry but also pose similar challenges. If manufacturing businesses in Durban adopt 3D printing on a large scale, there could be potential for a brighter future in the South African manufacturing industry.

3. Research Design and Methodology

3.1. Research Design

3.1.1. Research Paradigm

The study at hand followed an interpretivist paradigm as the study was based around the influence a phenomenon has on participants as well as their perceptions and emotions of the phenomenon (Thanh & Thanh, 2015). Having adopted interpretivism as a paradigm, it allowed the researcher to see the world from the participants' perspective and gain insight into how they were influenced by certain phenomena. Since 3D printing is a relatively new phenomenon, 3D printing and the influence it has had on businesses in Durban within the manufacturing industry had not been researched thoroughly (Aghimien et al., 2020). Therefore, the interpretivist paradigm suited this study as it allowed the researcher to gain insight into how manufacturing businesses in Durban have been influenced by 3D printing as a new phenomenon. As per Thanh and Thanh (2015), a researcher who follows an interpretivist paradigm, interprets, and familiarises themselves with the emotions and perceptions of the participants being studied to be able to understand the data gathered from the participants. Thus, interpretivism suited this study as the data collected from the businesses owners in Durban that use 3D printing in their business operations, required the researcher to interpret and familiarise themselves with the emotions, perceptions, as well as the influence 3D printing has had on the business owners. When following an interpretivist paradigm, it is common for the researcher to realise the reality of a phenomenon through the eyes of the participants by understanding their experiences with a phenomenon and the influence it has had on them (Thanh & Thanh, 2015). This was possible through qualitative data collection methods such as in-depth interviews as there was a connection between interpretivism and qualitative methodology. This allowed the researcher to gather information from participants. According to Groenewald (2004), interpretivism is based on the subjective reality of people and highlights that people are unique individuals who have their own perceptions on reality as they experience and are influenced by phenomena in

different ways. Business owners who make use of 3D printing in their operations have their own thoughts and views of the technology and have been influenced by it in different ways either negatively or positively. Therefore, an interpretivist paradigm suited this study as it encompassed the different perceptions of 3D printing of business owners in Durban.

3.1.2. Conceptual Approach

This study followed a qualitative approach. As stated by Thanh and Thanh (2015), a study that follows an interpretivist paradigm typically also follows a qualitative approach. The aim of the researcher who follows a qualitative study is to explore participants in terms of their behaviours, trends, perceptions, as well as their experiences to harness the participants' interpretations of reality. Thanh and Thanh (2015) state that this is done by researching participants in depth by using qualitative methods, such as in-depth interviews mentioned above, to understand how a phenomenon has influenced them. A qualitative approach suited this study as the aim of the study was to explore the businesses in Durban and gain an in-depth understanding of the influences 3D printing has had on businesses and how business owners have perceived the technology (Thanh & Thanh, 2015). By using qualitative methods allowed the researcher to gain insight into the reality of participants by having displayed a form of empathy towards participants to relate to the meaning they gave to reality. This resulted in the researcher harnessing information from business owners around how 3D printing has influenced them and their businesses.

3.1.3. Exploratory Research

The researcher conducted an exploratory study as part of the research. Davis (2018) states that exploratory research is conducted due to gaps of knowledge in specific areas. Since the world is evolving each year with regards to aspects such as technology, new gaps emerge, and exploratory research can be conducted to explore these gaps. Stebbins (2001) states that exploratory research often relies on qualitative methods such as in-depth interviews and informal discussions to collect data about unknown areas. The aim for the researcher when conducting exploratory research was to seek an understanding of the unknown area which potentially laid the

groundwork for future research. Exploratory research was not intended to provide conclusive evidence but rather assisted the researcher to gain a better understanding (Stebbins, 2001). Since 3D printing is a new technology that had not yet been researched thoroughly, exploratory research was best suited for this study. It allowed the researcher to explore the unknown area of 3D printing and the influence it has had on business owners. In-depth interviews were used to collect data from the business owners.

3.1.4. Inductive Approach

Qualitative studies typically follow an inductive approach also known as the “bottom up” approach. An inductive approach moves from specific observations to broader theories (Strauss & Corbin, 1998 as cited by Thomas, 2003). Data can be used to derive concepts and themes through the researchers’ interpretation of the data collected. The researcher will identify the area they aim to study and will let the theory that forms the foundation of the study emerge from the data that the researcher collects (Strauss & Corbin, 1998 as cited by Thomas, 2003). An inductive approach was followed by the researcher as the study at hand was qualitative and exploratory. The inductive approach assisted the researcher in answering the research question since 3D printing was a new phenomenon that was explored. Concepts and themes were derived from the researchers’ interpretations of the data collected from business owners in Durban where the researcher identified relationships between the findings and the *Diffusion of innovations theory* (Rogers, 2003).

3.1.5. Phenomenology

As per Van Manen (2007), phenomenology seeks to understand the outside world as it is interpreted by and through human consciousness. Phenomenology involves the researcher attempting to gain insight into the experience of other humans and the essence of the phenomenon which can be done using in-depth interviews. In phenomenology, to study humans sufficiently, a simple experiment would not be accurate as human beings are unique and are influenced by things differently (Van Manen, 2007). For the researcher to understand a phenomenon effectively, an in-depth understanding of the participants was required during the research process.

According to Bai et al. (2017), 3D printing is a new phenomenon that is being diffused into the world. The researcher aimed to broaden his understanding of 3D printing by identifying patterns in the data collected in the interviews of the business owners who have been influenced by 3D printing. The researcher was able to gain a rich and detailed description of the human experience of 3D printing as a phenomenon that has influenced manufacturing businesses in Durban.

3.1.6. Ontological Position of Interpretivism

In the ontological position of interpretivism, people are believed to experience reality in unique ways rather than in the same way (Nieuwenhuis, 2020). There are multiple realities that are products of mental constructions. Reality is something that depends on each individual's set of experiences, beliefs and understanding (Nieuwenhuis, 2020). The researcher intentionally directed his focus to describe the subjective realities of the participants being studied by adopting an exploratory study. To achieve a deeper understanding of the participants' realities, the researcher separated his biasness and judgement to collect data effectively from the business owners in Durban who have been influenced by 3D printing. This is where in-depth interviews were used by the researcher as a qualitative collection tool to achieve a better understanding of the phenomenon of 3D printing.

3.2. Research Plan/Research Methods

3.2.1. Unit of Analysis

The unit of analysis is the subject that one will analyse in the research study (Pascoe, 2018). This includes the "what" and "who" of the study. For the purpose of this study, the unit of analysis was the individual business owners who make use of 3D printing in their manufacturing businesses in Durban.

3.2.2. Population

Target Population

The target population refers to everyone that falls within the population parameters which refer to the nature, size, and common characteristics that the target population share (Pascoe, 2018). The target population for this study consisted of business owners who currently use 3D printing in their businesses. The business owners who formed part of the target population shared common characteristics which included that all the business owners and their manufacturing businesses were located in Durban KZN. The business owners that formed part of the target population needed to make use of 3D printing in their business operations.

Accessible Population

The accessible population refers to the portion of the population that the researcher can include in their study (Asiamah, Mensah & Oteng-Abayie, 2017). In this study, the accessible population included business owners in Durban KwaZulu-Natal who made use of 3D printing that the researcher could gain access to. The researcher was able to access the business owners who formed part of the target population and included them in the study for the researcher to gain insight into the influences 3D printing has had on them and their businesses.

3.2.3. Sample

Sample Size

The researcher used a sample size of two participants ($n=2$) to be interviewed as part of the research study as it was not feasible for the researcher to include all business owners who formed part of the population in the research study. The participants included two business owners although initially, the sample size included three participants, but the researcher was faced with time constraints and only managed to include two out of the three participants in the research study. Even though the sample size of two participants was small, the sample size and the information gathered from the two participants was sufficient for the research study since the study was qualitative in nature (Bryman, 2012). The reason for this being that research was an

in-depth exploration of the experiences of a small number of participants rather than data from a large sample of participants (Bryman, 2012).

3.2.4. Sampling Method

The researcher made use of a non-probability sampling method for this study since randomisation was not important in selecting the sample from the population (Etikan, Musa & Alkassim, 2016). Non-probability sampling is used when all members of the population do not have an equal chance of being selected to be part of the sample which means that some members have more of a chance of being selected than others (Bryman, 2012). The researcher selected non-probability sampling as it was difficult to identify and gain access to the entire population (Etikan et al., 2016). For this reason, convenience sampling was used to select the subjects from the accessible population to be studied and is also typically used in exploratory research studies such as these (Etikan et al., 2016). Convenience sampling is affordable, simple, and the subjects are often readily available. The relative cost and time required to carry out a convenience sample are small compared to probability sampling techniques (Etikan et al., 2016). This is why it was a better option for the researcher to adopt convenience sampling since the researcher had limited resources available and it enabled the researcher to select the sample size in a quick and affordable manner (Etikan et al., 2016). The researcher knew business owners in Durban KZN that use 3D printing as part of their business operations. The researcher was able to gain access to them easily and in a quick and inexpensive way. The negative side of non-probability sampling is that the findings cannot be generalised to the broader population. However, for the nature of this qualitative study it was suitable for the small scale, exploratory nature of the study as the intention of the researcher was not to generalise to the wider population.

The researcher used the following recruitment method:

The researcher managed to contact the business owners via WhatsApp messenger and inquired if they would be willing to participate in the research study. The researcher gave a brief explanation of what the research study would involve and what was expected of the business owners. Contact between the researcher and the

business owners continued further via WhatsApp messenger and electronic mail. Both participants agreed to be involved in the research study and interviews were scheduled for both participants thereafter.

3.2.5. Data Collection Method

As stated by Ryan et al. (2009), semi-structured interviews are used in qualitative studies as data collection methods to harness information from participants to gain insight into their interpretations of and experiences with a phenomenon. To collect data for the current study, the researcher made use of semi-structured interviews as the data collection method since this method offered a more flexible approach to the interview process (Ryan et al., 2009). Semi-structured interviews allow the researcher to be flexible in asking further questions after listening to responses from participants (Bryman, 2012). Semi-structured interviews suited the study at hand since they are usually conducted when researchers follow an interpretivist paradigm (Ryan et al., 2009).

After receiving consent letters from both participants who agreed to be involved in the research study, interviews were conducted which were approximately thirty minutes each. The researcher did not follow a structured interview process where a set interview schedule was followed. The researcher rather allowed participants to elaborate on the questions asked which is seen as an advantage of semi-structured interviews (Ryan et al., 2009). This allowed the researcher to gain a more in-depth understanding of the experiences of participants. Ryan et al. (2009) state that semi-structured interviews are typically organised face to face which lets the researcher examine body language and facial expressions which may allow the researcher to explore hidden meanings of participants and interpret their feelings more accurately during the interview process. Due to Covid-19, both the interviews scheduled by the researcher had to be conducted over live Zoom video calls as social distancing was still a government requirement at the time that the interviews were conducted. One of the interviews were rescheduled twice due to load shedding where the researcher further managed to agree an interview time that suited both him and the business owner. The researcher conducted both interviews from home whilst both business owners were located at their 3D printing businesses in Durban. The interviews took

place on different days of the week and not simultaneously. The researcher was able to examine body language and facial expressions through the Zoom video calls and he gained rich and descriptive data from the semi-structured interviews which he used as part of the research study. The aim of the interviews was to collect adequate information from the business owners to help answer the research question of how 3D printing has influenced them thus far. The researcher was successful in harnessing adequate information from the business owners which was further analysed by the researcher which will be discussed further.

The open-ended questions available in **Appendix B** were asked to both business owners in the semi-structured interviews. The structure and order of the questions varied throughout both interviews as some of the planned questions were answered by participants when they elaborated on other questions asked by the researcher. The researcher gave both participants pseudonyms to hide their identity.

3.2.6. Data Analysis Method

The data analysis method used was qualitative content analysis (Hsieh & Shannon, 2005). The aim for the researcher when following a qualitative content analysis approach is for the analysis to provide greater knowledge and understanding about the phenomenon under study (Hsieh & Shannon, 2005). Qualitative content analysis is typically used by researchers in interpretivist studies which is why qualitative content analysis best suited the study as the researcher was following an interpretivist paradigm with a qualitative approach (Hsieh & Shannon, 2005). After the data collection (Semi-structured interviews) had been completed, the Zoom recorded interviews were transcribed verbatim (Hsieh & Shannon, 2005). Qualitative content analysis was used to analyse the interviews with the use of coding where the codes were further categorised into themes. Qualitative content analysis is typically used in qualitative studies as a research method to analyse text data (Hsieh & Shannon, 2005). The text data collected by the researcher can be in a verbal, print, or electronic form which is gathered from data collection methods such as semi-structured interviews with open-ended questions (Kondracki & Wellman, 2002 as cited by Hsieh & Shannon, 2005). In this study, since the semi-structured interviews were conducted over live Zoom video calls, the data collected was in verbal form and thereafter

transcribed into text form electronically.

According to Strauss and Corbin (1990), themes are the classification of more discrete concepts. This classification is discovered when concepts are compared against each other and appear to relate to a similar phenomenon (Strauss & Corbin, 1990). The concepts are grouped together under a higher order concept called a theme (Strauss & Corbin, 1990). In most instances, themes emerge from observed data such as texts, images, and sounds. Even with a certain amount of open-ended questions, nobody can predict all the themes that will emerge before analysing the data (Dey, 1993). The act of discovering themes is what grounded theorists call “open coding” and what classic content analysts call qualitative content analysis (Berelson, 1952). The data transcribed by the researcher was further coded where the researcher gave meaning to certain words and phrases from the data of the participants where he created categories next to the quotes of the participants (open coding). To identify themes, researchers can look for repetition where topics occur and reoccur in the data (Bogdan & Taylor 1975). The “constant comparison method” involves searching for similarities and differences by making comparisons in the data retrieved (Glaser & Strauss, 1967). The researcher was able to look for several similarities and differences as well as repetition in the data where categories were then created. Finally, the categories were further grouped into three main themes. The researcher was able to identify the themes and patterns that emerged from the text data which gave meaning to the phenomenon of 3D printing (Hsieh & Shannon, 2005).

Qualitative content analysis is an inductive approach where the researcher works inductively to allow the themes to emerge from the data (Hsieh & Shannon, 2005). The researchers’ choice of using qualitative content analysis to analyse the data linked well with the study and allowed him to identify the themes and patterns that were embedded in the data. Qualitative content analysis was used to analyse the data collected from business owners in Durban to identify themes and patterns around how they have experienced 3D printing as a new phenomenon and how they were influenced by it. The themes that emerged from the interviews after the transcribing and coding process were: Keeping up with the times, Cost reduction, and Simplifying manufacturing processes.

4. Findings and Interpretation of Findings

4.1. Participants

Participant A (Tom) is a business owner based in Durban KZN who owns a 3D printing business that specialises in manufacturing automotive parts. He has been working in the automotive sector for fifteen years. Tom initially serviced automobiles with parts sourced from other organisations and then made the decision to incorporate 3D printing in his business. Tom implemented 3D printing within his business operations in 2016 and has been making use of 3D printing for 4 to 5 years.

Participant B (Jerry) is a business owner based in Durban KZN who owns a 3D printing business that manufactures medical products customised to patient specifications. He has been working in the medical sector for eight years. Jerry initially made use of older moulding equipment and machinery to manufacture medical objects for patients. Jerry implemented 3D printing within his business operations in 2018 and has made use of 3D printing for 2 to 3 years.

4.2. Themes

Three themes emerged from the research, namely: Keeping up with the times, Cost reduction, and Simplifying manufacturing processes.

4.2.1. Keeping Up with The Times

Both Tom and Jerry highlighted that they implemented 3D printing in their businesses to keep up with the times meaning that they did not want to be left behind and become obsolete in the manufacturing industry.

Tom said that he realised that many automotive businesses were implementing 3D printing as a new way to manufacture parts for vehicles and thought it would be wise to invest in purchasing 3D printers to do the same. The following quote from Tom illustrates this:

“I initially heard from a friend of mine, who also has an automotive business in Durban, that 3D printing is quite big in the automotive sector in countries like

the United States". I decided to read up about 3D printing and check if any businesses in SA make use of the technology to manufacture vehicle parts as well. I was amazed to find that there were already automotive businesses in SA that were 3D printing spare parts for vehicles, although they were manufacturing specialised parts for their customers. I then spoke to my friend about investing in 3D printers to use for manufacturing parts and components for my business as well as for his so we can keep up with the times of manufacturing."

Jerry had a similar situation to Tom where he heard through his medical community that 3D printing started growing in the health and medical sector in SA. The following quote from Jerry illustrates this:

"I'm part of several South African WhatsApp and Facebook groups where we talk about all things medical. We keep up to date with the latest news in the industry and share reports and interesting articles with each other. I was aware that businesses were 3D printing medical parts in other countries, but I assumed that SA was slightly behind in that regard. It was on a WhatsApp group chat where I first heard about 3D printing in SA when one of the community members shared an article about businesses in SA using 3D printing to print things like prosthetics. A few months down the line there were several businesses around SA that had incorporated 3D printing and I thought that I would sacrifice some of my own capital and invest in 3D printers to stay relevant in the industry. I also saw it as a new business opportunity as not many businesses were 3D printing medical parts as they did not think much of it. This was when I decided to implement 3D printers in my business to manufacture medical parts for my customers. 3D printing has become more popular in the medical sector in SA and more of us are investing in the technology which has become the new way forward."

The responses of Tom and Jerry concur with previous research highlighted in the literature review that 3D printing will only be adopted in niche industries where customers demand specific products to be produced (Meisel, 2016 as cited by Ortt, 2017). Both Tom and Jerry are involved in manufacturing products that are customised which could be considered as part of the niche industries highlighted above. Ortt

(2017) states that 3D printing will only be adopted in niche industries such as manufacturing of parts in smaller environments. We can see from the words of Tom that SA has adopted 3D printing on a smaller scale in the automotive industry where some businesses are manufacturing specialised parts for their customers rather than mass producing automotive parts.

Attaran (2017) states that 3D printing creates new business opportunities and gives possibilities to businesses striving to improve their manufacturing efficiency. We can see from the response of Jerry that he identified the business opportunity of investing in 3D printers to stay relevant in the industry where he could manufacture medical parts for his customers.

The findings contribute towards the theoretical framework of the 'diffusions of innovations' theory which is the process of how (1) an innovation is (2) communicated through various channels (3) over a period of time (4) in a social system (Rogers, 2003).

The first concept that the theory focuses on is the 'innovation' (Rogers, 2003). Both Tom and Jerry adopted 3D printing in their businesses to keep up with the times. This following quotes of Tom and Jerry illustrate this:

Tom: *"I then spoke to my friend about investing in 3D printers".*

Jerry: *"I thought that I would sacrifice some of my business's capital and invest in 3D printers".*

The second concept of the 'diffusions of innovations' theory is the 'communication through various channels' which focuses on how the innovation is communicated through various channels. In the context of this study, it refers to how business owners have heard of 3D printing and share information about 3D printing with other business owners in Durban through channels such as mass media and interpersonal communication (Rogers, 2003). Both Tom and Jerry heard about 3D printing in different ways and communicated through different channels. Tom was made aware of 3D printing through a friend of his who also has a business in the automotive sector which is seen as interpersonal communication:

“I initially heard from a friend of mine, who also has an automotive business in Durban, that 3D printing is quite big in the automotive sector in countries like the United States”.

Jerry on the other hand was made aware of 3D printing through his online medical WhatsApp group where his community shared information about 3D printing in SA:

“It was on a WhatsApp group chat where I first heard about 3D printing in SA”.

The theme of keeping up with the times also links to the concept of ‘over a period of time’ which refers to how the innovation is communicated over time (Rogers, 2003). It can be seen from Jerry’s quote that 3D printing is growing and being communicated about in SA where it is increasing in popularity over a period of time:

“3D printing has become more popular in the medical sector in SA and more of us are investing in the technology”.

The final element of the ‘diffusions of innovations’ theory which the theme of keeping up with the times links to is the ‘social system’. The element of ‘social system’ refers to the set of interrelated units involved in the same purpose. In the context of this study, the social system is the manufacturing businesses in Durban into which 3D printing is being diffused (Rogers, 2003). Both Tom and Jerry own businesses that are part of the social system that 3D printing is currently being diffused into and both have the same purpose of adopting 3D printing to manufacture items and keep up with the times. The following quotes of Tom and Jerry illustrate this:

Tom: *“Investing in 3D printers to use for manufacturing parts and components for my business as well as for his so we can keep up with the times of manufacturing.”*

Jerry: *“I decided to implement 3D printers in my business to manufacture medical parts for my customers”.*

We can see that both participants were made aware about 3D printing through different communication channels in their social system. Tom was made aware of the technology through a friend whilst Jerry was made aware through a WhatsApp group. There seems to be an indication that 3D printing has diffused to a greater degree than what was expected and is slowly being adopted by both business owners.

4.2.2. Cost Reduction

The second theme of the research study is “Cost reduction”. Both Tom and Jerry raised the point of 3D printing resulting in cost reduction. The cost reduction being that 3D printing provides many cost reductions compared to conventional ways of manufacturing items.

Jerry raised the point of how 3D printing has helped him and his business save money with regards to logistics and capital costs. The following quote from Jerry illustrates this:

“The one thing I can say about how 3D printing has changed my business is the money I have saved in making medical parts for my customers. What I mean by this is before I started using 3D printers to make parts and stuff, there were several delivery costs involved. Now that I have 3D printers, as long as I have the materials I need to make parts for my customers, I don’t have to worry as much about delivery costs and stuff like that because I’m not ordering as many components since I’m printing them myself now which I think is beneficial.”

Jerry’s response underpins the words of Oettmeier and Hofmann (2016), mentioned in the literature review, who believe that the ability of 3D printing to print medical components in-house on demand has disrupted many businesses involved in the manufacturing and delivery of medical products. It is evident that Jerry does not need to worry as much about delivery costs as he is manufacturing medical parts and components himself.

Jerry: “The one thing I must say about 3D printers is that they are very expensive. But I’ve realised that in the long run you actually save a lot because you don’t have to buy unnecessary machinery like prosthetic moulders or dryers and spend money on maintaining them since 3D printing eliminates those costs.”

Jerry underpins the words of Niaki and Nonino (2017) who state that 3D printers reduce capital costs for manufacturers as they will not have to invest heavily in machinery and equipment. Jerry has saved money as he does not need to purchase

larger machinery needed to manufacture medical products and allocate funds to pay for delivery costs, but he can rather print products in-house using his 3D printers.

Tom raised a similar point which was also in relation to reducing costs for his business. He focused more on the cost of storage rather than the logistics and capital costs which Jerry raised. The following quote from Tom illustrates this:

“Storing spares took up a lot of space in my warehouse and I mean we live in a country where crime is an issue which meant that I had to pay more to insure my business in case of theft. By making use of 3D printers I now print parts whenever I need to rather than storing parts in my warehouse which is less risky. I’ve managed to save a lot on storage and insurance costs since I started using 3D printing.”

Tom’s response further underpins the words of Oettmeier and Hofmann (2016) who state that manufacturing on demand reduces the need for storage and packaging costs. Tom has been able to save on storage costs since he is manufacturing on demand and when required rather than storing many of his products like he did before he implemented 3D printing in his business. Saving on insurance costs was not found in the literature and requires further research.

Both business owners have saved costs in various aspects including delivery, storage, machinery, as well as insurance costs. Having said this, the technology has disrupted many businesses involved in the delivery of components, production of machinery, as well as insurance.

4.2.3. Simplifying Manufacturing Processes

The third theme of the research study is “Simplifying manufacturing processes”. Both Tom and Jerry highlighted that 3D printing had made manufacturing processes simpler for them and their businesses. This meant that 3D printing changed the way their businesses operate.

Tom highlighted that 3D printing has eliminated several steps and procedures in the manufacturing process in his automotive business. The following quote from Tom illustrates this:

“I’ve been using various manufacturing processes in my business depending on what parts I’m making. I still use things like sandblasters and welders to this day because I don’t use my 3D printers for everything, but it definitely makes the process much simpler. If I want something made, I simply program the digital design I want into the printer and the part can be made within a few hours rather than ordering or making the part from scratch which requires way more time and effort. Although I’m not able to produce parts at a high volume, it’s still beneficial because I own a small business that manufactures small volumes specific to customers”.

This links back to the words of Dwivedi et al. (2017) who state that in the process of 3D printing, pieces such as car parts of any geometry and no matter how complex can be manufactured in one procedure unlike traditional methods of manufacturing which requires several procedures to complete the production of a component. The speed of manufacturing and the output rate compared to traditional manufacturing methods are lower which serves as a challenge for manufacturers (Baumers, 2016 as cited by Dwivedi et al., 2017). Even though this is the case, Tom highlighted that he could complete a customer order in a few hours and did not mention that the speed of manufacturing and the output rate serves as a challenge to him since he is producing on a small scale. However, this may be a downside for larger organisations who manufacture on a larger scale which was highlighted by Dwivedi et al. (2017).

Jerry raised the point of how the 3D digital designs have simplified his manufacturing process. He mentioned how easy it is to work with digital designs and print customised products for his customers. The following quote from Jerry illustrates this:

“These days I’m able to use digital files specific to a customer’s requirements which I receive straight from hospitals and specialists. I’m able to simply enter these digital files in my 3D printers and can print things like prosthetic parts or casts for example within a couple of hours and I can even do that three at a time since I own three printers”.

The words of Jerry support the words of Bai et al. (2017) who state that a single 3D printer has the ability to print various different designs which only requires different digital files to be able to print different objects thus making 3D printing a technology

with a high degree of versatility. Digital files consisting of 3D designs can be transferred via the internet to manufacturers who make use of 3D printers in their businesses.

Jerry further stated that he uses online websites to source materials for the manufacturing process of his medical parts.

“I use online platforms like Takealot and the 3D Printing Store to source materials for printing. The only issue I have is that sometimes these stores don’t have stock of certain materials that I’m looking for which means I have to use other methods to make my medical parts or I simply just contact another 3D printing business to make it for me”.

Online platforms offer 3D printing services to manufacturers and can be marketplaces for designs and sourcing materials (Rayna, 2015 as cited by Rogers et al., 2016). The challenge that Jerry faced in not being able to source the correct materials was not found in the literature which requires further research.

The theme of simplifying manufacturing processes links back to ‘relative advantage’ which is one of the additional concepts of the ‘diffusions of innovations’ theory discussed in the literature review (Rogers, 1995 as cited by Dibra, 2015). The ‘diffusions of innovations’ theory states that relative advantage is the extent by which a certain group of users perceive an innovation as a preferred idea over the innovation it replaces (Rogers, 1995 as cited by Dibra, 2015). The larger the perceived relative advantage by a business, the quicker a business will adopt and diffuse the innovation within their businesses. We can see from the quotes of Tom and Jerry that both business owners prefer using 3D printing as a new method of manufacturing compared to other methods used, such as welding in the case of Tom:

“I still use things like sandblasters and welders to this day because I don’t use my 3D printers for everything, but it definitely makes the process much simpler”.

The reason for this being that it has simplified the process of manufacturing. 3D printing has been adopted quickly by both parties where Jerry has purchased three 3D printers thus far:

“I can even do that three at a time since I own three printers”.

4.3. Trustworthiness

It is important in qualitative studies that the research conducted is understood and considered legitimate by others including the participants (Nowell, Norris, White & Moules, 2017). Trustworthiness is a term used by researchers in qualitative research studies to convince the public that the findings from their study are worthy of attention. Trustworthiness can be broken down into four criteria including credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985 as cited by Nowell et al., 2017).

4.3.1. Credibility

When the research findings accurately represent the participants realities, the research is considered credible (Nowell et al., 2017). The researcher can implement various techniques to promote credibility in their research to show that they have accurately researched the phenomenon. Some of these techniques include adopting qualitative research methods that are well established such as semi-structured interviews and asking questions similar to studies based around the nature and topic (Lincoln & Guba, 1985 as cited by Nowell et al., 2017). Prolonged engagement between the researcher and participants can increase credibility as it allows the researcher to gain a better understanding of the participants due to longer periods spent with them which establishes trust in relationships between the two parties (Lincoln & Guba, 1985 as cited by Nowell et al., 2017). The researcher has adopted some of these techniques to increase the credibility of the findings. The researcher concluded semi-structured interviews with the business owners to gain insight into the influence 3D printing is having on their businesses which has enhanced the credibility of the study. The researcher was not able to spend prolonged periods with participants as time was limited for the study however credibility was still achieved.

4.3.2. Transferability

Transferability looks at the degree to which the findings of a study can be applied to other situations of a similar nature. Since qualitative studies focus on unique experiences and situations, it makes the generalisation of findings very difficult (Shenton, 2004). However, if other researchers or readers can relate their situations

to the findings of the study, the findings must then be applied with caution to their own positions (Shenton, 2004). Other researchers and readers of the study should identify the extent to which they want to transfer the findings of the study to other situations. This is possible if there is enough information of the phenomenon under study and a detailed description of the phenomenon has been provided. This will enhance the readers' understanding of the phenomenon which will allow them to transfer the findings of the study to other situations they wish to (Shenton, 2004). It is important for the researcher to identify the boundaries of the study to the readers as the boundaries need to be considered before the findings can be transferred to other situations (Cole and Gardner, 1979 as cited by Shenton, 2004). The number of participants that were part of the study and the data collection methods used in the study can be regarded as boundaries or additional information provided to the reader. The researcher provided the number of business owners that were part of the study as additional information to the reader who wishes to use the findings elsewhere. The researcher also provided the data collection method (semi-structured interviews) and by providing such information added to the transferability and therefore the trustworthiness of the study (Ryan et al., 2009).

4.3.3. Dependability

Dependability refers to how researchers follow the correct research process in a logical manner and how the process is clearly documented. When readers can identify the research process of a study, they can also identify the extent to which the research is dependable (Lincoln & Guba, 1985 as cited by Nowell et al., 2017). For researchers to establish dependability of their research, the research processes need to be reported in detail to allow other researchers and readers to repeat the work. As per Nowell et al. (2017), by reporting the research processes allows the reader to judge if the correct research methods and practices have been followed. Reports can include a description of the research design and implementation as well as detail on data gathering to increase the dependability of the research. The researcher followed a logical research process throughout the study. Details were given on data collection and analysis methods as well as the research design of the study which was clearly stipulated. The data collected from participants has contributed to the dependability of the study.

4.3.4. Confirmability

In qualitative research, confirmability is recognised when the other three criteria (credibility, transferability, and dependability) have all been achieved (Lincoln & Guba, 1985 as cited by Nowell et al., 2017). Confirmability is concerned with the degree to which the findings of the research study can be confirmed by other researchers. It is concerned with recognising that the interpretations and findings of the researcher are derived from the data gathered by the researcher (Shenton, 2004). Steps are required to be taken by researchers to make sure that the findings of the study are a result of the experiences of the participants rather than the researcher's liking. Researchers should include reasons for choosing certain theoretical frameworks and research methods in their studies for readers to understand how and why decisions were made by the researcher (Koch, 1994 as cited by Nowell et al., 2017). The researcher stipulated throughout the research study why certain research methods and the 'diffusion of innovations theory' was chosen. This promoted confirmability since it provided transparency when describing the steps and methods followed in the research process from the start through to reporting the findings.

5. Conclusion

5.1. How the Research Problem/Purpose/Question were Answered

The research problem and research purpose informed the research question where the following section answers the research question “How is 3D printing influencing manufacturing businesses in Durban KZN?”. Although the findings discussed above have answered the research question, the following discussion will elaborate further on how the research question was answered.

The findings demonstrate that the potentially disruptive technology of 3D printing has already started to diffuse into businesses in Durban which brings many benefits and a few challenges to these businesses. In the case of Jerry, he was made aware of 3D printing through social networking which became clear through various points in the study that a lot of Jerry’s awareness and adoption of 3D printing is linked to online technology such as WhatsApp and online marketplaces in SA whereas Tom had a simple conversation with his friend about 3D printing.

In the first theme of ‘Keeping up with the times’, it can be seen that both business owners became aware of 3D printing through their respective networks. They both recognised the need to implement the technology into their businesses as a new way of manufacturing to be more innovative and forward thinking to keep up with the times.

In the second theme of ‘Cost reduction’, both business owners managed to save costs with the implementation of 3D printing which can be regarded as an influence 3D printing has on manufacturing businesses in Durban KZN. Adopting the technology has reduced costs in their businesses compared to other ways of manufacturing which has been beneficial. However, there were some challenges identified which included not being able to produce in large volumes and the difficulty in sourcing materials.

In the final theme of ‘Simplifying manufacturing processes’, both business owners highlighted the advantage 3D printing has in simplifying the process of manufacturing and preferred using the technology to other ways of manufacturing (relative advantage) even though there were a few negatives involved with the technology.

Overall, 3D printing has the potential to disrupt multiple manufacturing businesses and their supply chains. However, it can be seen from the findings that both participants have reaped the benefits of the technology in their businesses.

5.2. Implications of Findings for Future Practices

The research revealed that 3D printing has influenced manufacturing businesses in Durban in several ways. The findings have highlighted the disruptiveness of the technology and the impact it can have on the business' supply chains. The findings have also identified the benefits 3D printing has brought to the two business owners who have adopted the technology as well as the challenges it can pose. These findings can provide insight to other business owners in Durban who may be interested in adopting the technology. Having identified the disruptiveness as well as the benefits and challenges of the technology can assist business owners in making future decisions about adopting the technology. Whilst the research identified the disruptiveness, benefits, and challenges, it also highlighted that 3D printing has not been adopted on a large scale which creates uncertainty about the long-term impacts of the technology which other business owners can take into consideration.

5.3. Research Success and Possible Future Research

The research conducted was a success in terms of answering the research question at hand and gaining an in-depth understanding of the influence 3D printing has had on manufacturing businesses in Durban. The findings including the disruptiveness, benefits, and challenges, allowed us to gain a more in-depth understanding of the influence the technology has which can be used by other business owners in the future. The research was also successful in contributing to closing the gap in the literature since there was minimal research conducted on the influences of 3D printing.

Future research can be conducted into the influence 3D printing has had on manufacturing businesses given that it is still a relatively new technology and the influences have not been prominent thus far. Due to the limited scope of the research, the sample size was made up of 2 participants which means a larger sample size could

be used in the future to provide a more in-depth understanding of the influence of 3D printing.

5.4. Ethical Implications

The researcher ensured ethicality in the study by taking important ethical issues highlighted by Arifin (2018) into consideration. The issue of informed consent and voluntary participation was taken into consideration where consent was given voluntarily and both participants understood what was being asked of them (Arifin, 2018). The business owners were informed about the research and had a choice to either participate or decline. Both participants agreed to participate after a thorough explanation of the research process. Business owners were required to present written informed consent which was done over electronic mail. They were given the opportunity to address any concerns and had the choice to withdraw from the study at any time as their participation was voluntary. The anonymity and confidentiality of the participants was preserved throughout the data collection and analysis as well as the reporting of findings since they were given pseudonyms (Arifin, 2018). Given the circumstances of COVID-19, the researcher conducted interviews individually via online Zoom video meetings which were password encrypted and participants information and recordings were concealed thereafter.

5.5. Limitations

There were several limitations to the study however, the researcher addressed these limitations accordingly.

Participants may have only provided a brief explanation to the researcher of their experiences with 3D printing even after confidentiality and anonymity were ensured by the researcher (Arifin, 2018). This may have been due to an unclear explanation of the research or a lack of understanding of the research objectives outlined by the researcher. However, the researcher ensured ethicality throughout the study.

Due to time constraints, the researcher had limited time to complete the study which is why a sample size of 2 ($n=2$) was used (Enslin, 2018). This may have provided an in-depth understanding of the influences of 3D printing although further researcher can

be conducted using a larger sample to provide more insight. The researcher had minimal financial resources which only allowed for a select number of business owners to be interviewed (Enslin, 2018).

COVID-19 hindered the initial planned interview process of meeting face to face as the researcher was not able to meet physically with participants due to national social distancing restrictions. The researcher addressed this issue by conducting interviews on online Zoom video meetings.

Load shedding impacted some of the planned interview dates where interviews had to be rescheduled due to no electricity. The researcher managed to agree time slots that suited both the participants where individual interviews were conducted successfully thereafter.

11 834 words excluding in-text citations **(824)** and reference list **(1 144)**.

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Appendix A

Provisional Title: 'Exploration of how 3D printing is influencing manufacturing businesses in Durban Kwazulu-Natal'

Research Purpose/ Objective	Primary Research Question	Research Rationale	Seminal Authors/ Sources	Literature Review – Conceptual Framework	Paradigm	Approach	Data Collection Method(s)	Ethics	Key Findings	Recommendations
To understand how 3D printing has influenced the businesses of early adopters of the technology	How is 3D printing influencing manufacturing businesses in Durban KZN?	The researcher's aim is to explore the influence 3D printing has on different parts of businesses in the manufacturing industry in Durban who use 3D printing. This could give insight into how 3D printing may be disruptive as well as create opportunities and contribute to a competitive advantage for businesses that are looking to adopt the technology in the future.	Professor of communication studies Everett M Rogers (1962) for the 'diffusion of innovations' theory	Theme 1: 3D printing as a disruptive technology Theme 2: Advantages and challenges of 3D printing	Paradigm Interpretivist Phenomenology 3D printing is a new phenomenon that was explored in this study Epistemology Identified up and coming innovations and how they have affected our future lifestyles Ontology A reality that is lived by everyone but perceived differently per person	Qualitative To gain a better understanding of the influence 3D printing has had on businesses and how businesses owners have perceived the technology Population Target population: All business owners who make use of 3D printing in their business operations Accessible population: Business owners in Durban KwaZulu-Natal within the manufacturing industry who use 3D printing in their business operations that the researcher gained access to	Semi-structured interviews have been used with open-ended questions	The researcher had informed consent from the participants that were interviewed since the issues of informed consent, anonymity, and confidentiality were important to the researcher	The understanding how 3D printing has influenced the business owners in Durban Keeping up with the times Cost reduction Simplified manufacturing processes	Future research can be conducted into the influence 3D printing has had on manufacturing businesses given that it is still a relatively new technology and the influences have not been prominent thus far.

Research Problem	Secondary Questions/ Hypotheses / Objectives	Key Concepts	Key Theories			Sampling	Data Analysis Method(s)	Limitations	Key Contribution	
3D printing is a technology that SA has recently been adopted. This technology has disruptive potential which has led to new opportunities for businesses in industries such as the manufacturing industry	To understand how 3D printing has influenced the early adopters of the technology within the manufacturing industry having explored the advantages and disadvantages that the technology brings to different parts of the business and their supply chains.	Disruptive technology Business opportunity Manufacturing industry Supply chain	'Diffusion of innovations' theory' (Rogers, 1962)			Non-probability Sampling method Convenience sampling was used as the researcher already knew manufacturing business owners in Durban who use 3D printing and could gain access to them.	Unit of Analysis Business owners Data Analysis Method(s) Qualitative content analysis was used as the research method to analyse the data collected from the semi-structured interviews The transcribing method used was Verbatim	Lack of understanding Sample size Limited financial resources Limited time COVID-19 Load shedding	The findings can provide insight to other business owners in Durban who may be interested in adopting the technology. Having identified the disruptiveness as well as the benefits and challenges of the technology can assist business owners in making future decisions about adopting the technology.	

Appendix B

Semi-structured Interview Questions (Data Collection Tool)

1. Tell me about how you heard about and got into using 3D printing in your business?
2. What has the experience been like with 3D printing?
3. What was it like to implement 3D printing in your business?
4. How has 3D printing changed your business?
5. How has your experience with 3D printing changed over time?
6. What would you say are the main advantages of 3D printing to your business?
7. What would you say are the main disadvantages of 3D printing to your business?
8. Would you recommend 3D printing to other manufacturing businesses that have not implemented the technology yet?
9. Please could you tell me why? (Follow-up question)
10. Do you have any relationships with other business owners who use 3D printing?
11. Can you tell me more about that relationship? (Follow-up question)
12. What are your thoughts about the likely growth of 3D printing in South Africa?

Appendix C



HONOURS RESE, RESM and RMET ETHICS CHECKLIST

Student name: Anastassios Kostakis

Title of the research: 'Exploration of how 3D printing is influencing manufacturing businesses in Durban Kwazulu-Natal'

	Yes	No	Comment: Supervisor/ navigator/lecturer
Are you using human subjects in your research?	X		
I intend to use human subjects - I understand that I will not conduct research with human subjects under the age of 18 and other vulnerable groups. - I understand I can only proceed once I receive an ethical clearance letter.			
Interviews/ Focus groups An example of the <i>written consent form</i> I intend to use is attached.	X		
I will record the interview/focus groups and the sample of the letter where I ask for permission to do so is attached.	X		
I plan to use an interview schedule: The example of my research instrument is attached.	X		
I plan to use a questionnaire: The example of my research instrument is attached.	X		
I plan to use a gate-keepers letter: The example of my letter is attached.		X	
I plan to do research on an IIE site/with IIE students/staff/artefacts and I filled in the application for permission to do so. The application is attached. I understand I can only proceed once I receive IIE Approval for this.		X	

Signed: student... ..

Appendix D



CONSENT FORM TEMPLATE

Explanatory information sheet and consent form for participants
To whom it may concern, My name is Anastassios Kostakis and I am a student at the IIE's Varsity College Durban North. I am currently conducting research under the supervision of Amanda Cox about the influence 3D printing is having on businesses in Durban Kwazulu-Natal within the manufacturing industry. I hope that this research will enhance our understanding of the influence 3D printing is having on businesses in Durban within the manufacturing industry. I would like to invite you to participate in my study. In order to explain to you what your participation in my study will involve, I have formulated questions that I will try to fully answer so that you can make an informed decision about whether or not to participate. If you have any additional questions that you feel are not addressed or explained in this information sheet, please do not hesitate to ask me for more information. Once you have read and understood all the information contained in this sheet and are willing to participate, please complete and sign the consent form below.
What will I be doing if I participate in your study?
I would like to invite you to participate in this research because it will assist me in gaining an in-depth understanding on the influence 3D printing is having on manufacturing businesses. If you decide to participate in this research, I would like to interview you and ask you questions regarding your experience with 3D printing and how it has influenced you and your business. You can decide whether or not to participate in this research. If you decide to participate, you can choose to withdraw at any time or to decide not to answer particular interview questions.
Are there any risks/ or discomforts involved in participating in this study?
Whether or not you decide to participate in this research, there will be no negative impact on you. There are no direct risks or benefits to you if you participate in this study. You might, however, indirectly find that it is helpful to talk about your personal experience with 3D printing. If you find at any stage that you are not comfortable with the line of questioning, you may withdraw or refrain from participating.
Do I have to participate in the study?
• Your inclusion in this study is completely voluntary. • If you do not wish to participate in this study, you have every right not to do so. • Even if you agree to participate in this study, you may withdraw at any time without having to provide an explanation for your decision.

Will my identity be protected?
I promise to protect your identity. I will not use your name in any research summaries to come out of this research and I will also make sure that any other details are disguised so that nobody will be able to identify you. I would like to ask your permission to record the interviews, but only my supervisor, I and possibly a professional transcriber (who will sign a confidentiality agreement) will have access to these recordings. Nobody else, including anybody at the IIE's Varsity College Durban North, will have access to your interview information. I would like to use quotes when I discuss the findings of the research, but I will not use any recognisable information in these quotes that can be linked to you.
What will happen to the information that participants provide?
Once I have finished all interviews, I will write summaries to be included in my research report, which is a requirement to complete my Honours in Management. You may ask me to send you a summary of the research if you are interested in the final outcome of the study.
What happens if I have more questions about the study?
Please feel free to contact me or my supervisor should you have any questions or concerns about this research, or if there is anything you need to know before you decide whether or not to participate. You should not agree to participate unless you are completely comfortable with the procedures followed. My contact details are as follows: Anastassios Kostakis The contact details of my supervisor are as follows: Amanda Cox

Appendix E



CONSENT FORM FOR PARTICIPANTS

I, _____, agree to participate in the research conducted by Anastassios Kostakis about the influence 3D printing is having on businesses in Durban Kwazulu-Natal within the manufacturing industry. This research has been explained to me and I understand what participation in this research will involve. I understand that:	
• I agree to be interviewed for this research.	
• My confidentiality will be ensured. My name and personal details will be kept private.	
• My participation in this research is voluntary and I have the right to withdraw from the research at any time. There will be no repercussions should I choose to withdraw from the research.	
• I may choose not to answer any of the questions that are asked during the research interview.	
• I may be quoted directly when the research is published, but my identity will be protected.	
Signature	Date

Appendix F



CONSENT FORM FOR AUDIO OR VIDEO RECORDING

Consent form for participants	
I, _____, agree to allow Anastassios Kostakis to audio record my interviews as part of the research about the influence 3D printing is having on businesses in Durban Kwazulu-Natal within the manufacturing industry. This research has been explained to me and I understand what participation in this research will involve. I understand that: • My confidentiality will be ensured. My name and personal details will be kept private. • The recordings will be stored in a password-protected file on the researcher's computer. • Only the researcher, the researcher's supervisor and possibly a transcriber (who will sign a confidentiality agreement) will have access to these recordings.	
Signature	Date

Appendix G



11 August 2020

Student name: Anastassios Kostakis
Student number: 16029883
Campus: Varsity College Durban North

Re: Approval of HBCM Proposal and Ethics Clearance

HONOURS ETHICAL CLEARANCE LETTER

Your research proposal and the ethical implications of your proposed research topic were reviewed by your supervisor and the campus research panel, a subcommittee of The Independent Institute of Education's Research and Postgraduate Studies Committee.

There are some aspects that you still need to address in your proposal. You will need to address these aspects in consultation with your supervisor before you may proceed (see below):

Please note: **Your fieldwork may only proceed once you address the following issues:**

- Your **research questions need refinement**. Your supervisor needs to sign off on these and your final interview schedule or questionnaire.

In the event of you deciding to change your research methodology in any way, kindly consult your supervisor to ensure all ethical considerations are adhered to and pose no risk to any participant or party involved. A revised ethical clearance letter will be issued.

We wish you all the best with your research!

GENERAL CONDITIONS TO BE FULFILLED IN RELATION TO RESEARCH

Permission is granted to proceed with the above study subject to the conditions listed below being met and may be withdrawn should any of these conditions be flouted.

Please note: The panel has not considered the merits, accuracy or ethical soundness of the research. The only merits examined are the use of The IIE as a sample.

Permission is granted subject to the following conditions:

1. The researcher(s) will need to obtain informed consent in writing from all of the participants in his/ her sample if the study is not anonymous.
2. The researcher(s) will need to obtain Gatekeeper approval/permission letter/s and have handed this to the supervisor for verifying.
3. The researcher(s) may only use the data collected for research purposes and in no other way.
4. Photographs of human subjects may only be taken if relevant to the research, informed consent was obtained, and even with informed consent, the photographs may not be published on any online platforms.
5. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.
6. No names or identifying information of participants may be used within the research and the research must be voluntary.
7. Please make it clear that the information will not be used punitively in any way and participants may in no way be counselled/advised based on this.