The investigation of a framework for the commercialisation of technological innovations through start-up firms in South Africa

Thesis submitted in accordance with the requirements

of the University of Liverpool for the degree of

Doctor of Business Administration

By

William Simon Makwinja

July 2022

Declaration

I declare that no portion of the work in this thesis has been submitted in support of an application for another degree or qualification of this or any other university.

Acknowledgements

I would like to thank the participants in this thesis for giving me access to their firms and allowing me to conduct the processes of the action research.I also acknowledge the experts for their support in refining the findings and providing a quality control function.

Special thanks are are also in order to Dr. Paul Ellwood, my supervisor, not only for his academic supervision functions but also for giving me the encouragement I often needed to get to the end of the program. Gratitude is also extend to my my second reviewer, Dr C. Senaratne who gave me detailed feedback. I extend the thanks to Dr. Helena Forsman, my initial supervisor and all friends and colleagues who have played different roles in my journey, including that of just asking the question, “how is the thesis going?”.

Finally, I acknowledge my children, Kondwani, Takondwa and Chimwemwe for their unconditional support throughout the entire program.

Abstract

Innovation is central to economic growth of a country: an idea that can be traced as far back as in the writings of Schumpeter (1935). Further down the years, Solow (1994) argued that sustained productivity and growth can only be reliably achieved through technological innovation. Universities, laboratories, research centres and companies are generally regarded as the commercialisation parties. However, entrepreneurial start-ups are increasingly being recognised as key contributors to technology innovation even if they have limited resources and face the extra task of launching a business entity in addition to launching a new product. Support for such start-ups through the commercialisation activities is extremely limited in South Africa. This DBA thesis project addresses this gap in practice and aims to develop a 'framework for the commercialisation of technological innovations through start-ups firms in South Africa'.

The thesis project was conducted in an action research collaboration with three entrepreneurial start-up firms. An initial framework template was constructed after a review of the existing research literature. Data were collected through field note observations and participant interviews which were used to refine and contextualise the template framework. The updated framework template was then further refined and validated through a focus group composed of three experts in technological innovation commercialisation in South Africa.

The final 'framework for the commercialisation of technological innovations through start-ups in South Africa' represents the main actionable knowledge from the project. It comprises twelve identified support intervention themes: finance, networks, collaborations, business management processes and associated skills, commitment, facilities/infrastructure, marketing, testing/certification, mentorship, product packaging/definition, risk management and personal aspects.

The thesis concludes with the implications of the framework for key actors involved in supporting and mentoring technology start-up companies in South Africa. The framework could also be used by other players in technological innovations

commercialisation like policy makers, commercialisation agencies as well as the innovating start-up entrepreneurs.

Keywords: innovations, commercialisation, start-up, action research, framework

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CHAPTER 1: INTRODUCTION

1.1 Introduction

This research aims at developing a framework for the commercialisation of technological innovations through start-up firms in South Africa. The South African Government has acknowledged that technological innovations form a strong part of the efforts to stimulate its slow growth economy. The framework, developed through an action research collaboration with three start-up innovation firms, should assist policy makers, innovators and aspiring mentors and supporters of other start-ups in planning and executing their activities. The study is also meant to be a part of the emerging research for the unlocking of the benefits of innovation in South Africa and perhaps also in other developing nations. In this, it aims to assist in the understanding and implementation of appropriate practices for commercialisation success as well as capacity development.

1.2 Purpose of the study

The study aims at establishing an in-depth understanding of the interventions for commercialization of technological innovations through start-ups in South Africa and developing a practice-based, actionable framework from that understanding. The framework and associated results are meant to aid aspiring mentors and supporters of technological innovations commercialisation in this context.. The framework can also be used by the founders of the innovation start-ups as well as other parties including policy makers and commercialising agents.

1.3 Background

Innovation is central to economic growth of a country and the acknowledgement of this fact can be traced as far back as in the writings of Schumpeter (1935). Further down the years, Solow (1994) put forward an economic growth theory that argued that sustained productivity and growth can only be reliably achieved through technological innovation. Universities, laboratories, research centres and companies which include small, medium and large firms are generally regarded as the commercialisation parties

(Gbadegeshin, 2017). This study focuses on start-up firms that also play the same role, be it with limited resources and without established business structures and hence have also an extra task of launching a business entity in addition to launching the product (Stayton & Mangematin, 2016).

Start-ups are increasingly being considered as an essential part of the innovation eco-system. Start-ups contribute to the economic growth in different ways such as being part of the supplier base for corporations (Homfeldt, Rese & Simon, 2019), helping to rejuvenate industrial economic zones like ports (Witte, et al., 2018), and commercialisation of university and research institution's research (Lindholm-Dahlstrand, Andersson & Carlsson, 2019).

The economy of South Africa has largely depended on raw material exports and it is now being argued to consider adding value to these materials in order to realise better returns and create employment. This requires the country to explore technologies that can yield better returns and technological innovations answers well to this call. The country has also embarked on a Fourth Industrial Revolution (4IR) program in order to address the historical low development level.

By comparison, China, a developed country, has been pushing for a policy that will see it move away from resource intensive economy to innovative economy and they planned to, amongst other things, raise reaserch and development (R & D) intensity from 1.75% of GDP in 2010 to 2.5% by 2020 (Gosens, et al, 2018). This, compared to South Africa where the R & D funding was at 0.77% in 2014/2015 and planned for 1.5% in 2020 (Governement Printer, 2016/2017). The 'systematic problems' of difficulty in bringing innovation to industry and low R & D funding have over the years been acknowledged by government through publications such as the Ten Year Innovation Plan (Government Printer, 2008), National Development Plan: Vision 2030 (Government Printer, 2011) and National Development Plan: National Diagnostic (Government Printer, 2010).

Specifically, the Ten year innovation plan termed the government challenging goals as 'innovation chasm' needing to be addressed through improving access to finance,

creating an innovation-friendly regulatory environment and strengthening the National System of Innovation (NSI). The responsibility for monitoring the NSI was mandated to the National Advisory Council for Innovation (NACI) who generates monitoring and evaluation reports every year. Their 2017 paper on technology and innovation indicators (NACI Secretariat, 2017) found that government contributes significantly to the South African venture capital industry, which is good news for innovation and technology commercialisation in small and medium enterprises (SMEs). However, they indicated that the output pillar evaluating this government's deed incorporates both the economic and social effects of innovation both of which were found to be underperforming. This can only mean that the funds they are pumping into the industry are not producing the desired effect. My observation is that most of the start-up firms they fund do not succeed in their businesses. The recent launch of a specific commercialisation fund that comes with a business mentor in order to ensure success by the Department of Trade and Industry is consistent with my observation.

South Africa's need for innovation development and implementation has constantly been emphasised by the World Bank amongst other commentators. A paper published by the World Bank (2017) noted that although the country had just gotten out of a recession, the low growth of the previous two years as well as other domestic factors meant that the country would still experience hardships. The critical contributing factor to this was presented as the insufficient innovation efforts by the private sector, especially when comparing with peers within the past ten years. The report indicated that there was a drop in private research which was at least 40% lower than what it was in 2009 (World Bank, 2017, p9). Creating a supportive and conducive environment for entrepreneurship and in particular for technological innovations start-ups was among the several recommendations the report cited.

An earlier publication by the World Bank (2010) had placed innovation at the top of their programs in developing nations including South Africa. The publication was aimed at documenting innovation policy formulation guidelines for governments of low to medium income economies. The writers acknowledged the uniqueness of start-up innovators as well as the different levels of readiness for each country. It argued that each country should firstly assess its infrastructure, existing policies, skills, technology

designated zones, etc. before embarking on the policy formulation journey. The need to treat each country, or even region, uniquely in the innovation development and implementation was also echoed by others including Xiao and North (2017). Research literature has put forward several support intervention areas that are necessary for technological innovators (including start-ups) to launch their innovations (Meijer, et al., 2019; Xiao & North, 2017; Choo, 2007; Christensen, Ojomo & Bever, 2017), and more specifically in South Africa (Rogerson, 2008 & Booysen, 2011).

It has been reported that both the government and business have insufficient mechanisms and possibly resources to address the ever growing community of innovators, particularly in the hi-tech industries (ESASTAP, 2015). A scan in literature and general media and my general observation seem to indicate that there is a growing number of incubator and cluster establishments and corporate support in the developed nations which ensures that the majority of the start-up innovations are natured (The World Bank, 2010; NACI, 2017, Xiao & North, 2017). However, this does not appear to be the case in South Africa. The government resources and support processes that exist in South Africa do not seem to be adequate enough or appropriately targeted throughout the innovation cycle to offer the required nurturing. The commercialisation phase of the cycle does not seem to be appropriately funded and supported with the resulting consequent that research innovations fail to reach the area where business investors see production and orders to ease their worries over risk. This fact was also expounded by InfoDev, a global innovation and entrepreneurship programme in the World Bank who had this to say about start-up financing and support, "…. at infoDev, we always hear from entrepreneurs, start-ups etc. that access to finance is key. The growth of innovative, early-stage enterprises in developing countries is often hampered by a lack of both appropriate financing and targeted technical assistance." (African Business, 2013). Even Venture Capitalists in these developing nations are getting less interested in funding the early developments of innovative start-ups (ESASTAP, 2015)

In the absence of adequate formal systems like university centres, research centres, incubation and clustering to assist start-up innovators, volunteer mentoring could be one of the mechanisms the support could be imparted. Volunteer mentoring is one

way where those entrepreneurs who have made it through the innovation route and are now established can assist those start-up innovators not lucky enough to be in the formal systems. Because of affordability and exposure challenges inherent in South Africa, the volunteer mentors may also have to provide other support functions to ensure the sustainability of the development process. It must be emphasized that I hold the opinion that other alternative solutions should also be investigated.

Currently South Africa is faced with various economic challenges. One of the ways to address these challenges is through the implementation of technological innovations especially via start-up firms. However, the process of commercialisation is not entrenched and critical interventions that need to be considered in these operations are not investigated and captured fully.

There are different paths that technological innovative ideas take in order to become products and get to the market. These include through university and research institutions, large corporates and incubators and accelerators. All these different paths have some support structures for the successful commercialisation process. It should be taken into account that in most of the corporate commercialisation cases, the innovator and the entrepreneur for a single innovation may not even be the same person. There is also a special path for technological innovations which is through small start-up firms. Quite often, this path hardly has support structures and the same innovators have to take the innovations from development, industrialisation through to market adoption. Most of these hi-tech start-up firms close their business within 2 years of operations or even earlier before they successfully implement their ideas. However, critical support interventions that need to be considered for the successful commercialisation of technological innovations through these start-ups are not investigated and captured fully particularly from a South African perspective. Therefore this study aims at developing a framework for the commercialisation of technological innovations through start-ups in South African which can inform the design of support interventions by mentors and other technology commercialisation players including policy makers and implementing agencies.

This study aims at identifying the required interventions, testing them through real life experiences using action research and also looking out for any other needed interventions and mechanisms that may not have come up in the literature. The identified interventions would then be used to develop a framework that is intended to guide practitioners, particularyly mentors and supporters in technology innovation commercialisation through start-ups in South Africa. It is also hoped that this will enrich knowledge on technological innovation development and implementation and add to a growing number of research in this field in the country and perhaps other similar developing countries.

1.4 Context

1.4.1 My background

I started off my career in the aerospace technologies where I worked briefly in an airline in the early 80s. I got into management roles in 1992 and left the corporate world in 1998 after attaining the role of executive director. In the past twenty four years I have been in private business where I have founded or co-founded six viable companies, two of which I am still a shareholder. One of the companies was sold and the other two had to close down. My focus industries/services have been defence and aerospace, energy, Information and telecommunication technologies (ICT), and quality assurance and inspection services. I have also undertaken various roles and projects within government and industry associations related to industry sector development (Department of Trade and Industry), and Research & Development foresight programs (Department of Science and Technology).

Currently, my time is divided into consulting in monitoring and evaluation, technical policy and strategy formulations and implementations and serving on some boards. The boards I am serving on include the South African Council for Outer Space Affairs and the Technical Advisory Board of a newly formed incubation and accelerator program for hi-tech innovations.

I also voluntarily assist a number of start-up technological innovation start-up firms with strategy and sometimes provide small seed capital funding. I plan to work with

three of the main innovation start-ups I am currently involved as the specific empirical context for this thesis research project. As I am getting closer to official retirement age, this is the area I plan to focus on and I am encouraging my colleagues in my age group to consider sparing their time for our innovators needing direction and support. I notice that a number of high-wealth individuals in the country are now pledging growth capital and some limited venture capital funding for hi-tech innovation projects but little is being done to investigating the necessary support interventions and developing mentoring capacity. I have yet to encounter a focused mentorship program by any of the venture capitalists in the country in any of the start-ups they invest in.

1.4.2 The technological innovation start-ups

The study was conducted by following the product commercialisation processes of three innovation start-up firms that I was involved with at the start of the study. Each of the three start-ups had been founded by two main partners who formed the participants group of the research. Expert practitioner critic and validation for the research, was provided by three external successful technological innovation entrepreneurs (experts) who formed the focus group. In order to maintain the confidentiality agreement with all the participants, the three companies were referred to as projects 1, 2 and 3. The participants were referred to as participant 1A, 1B, 2A, 2B, 3A and 3B and the experts were referred to as expert 1E, 2E and 3E.

1.4.3 Innovation start-up 1

Innovation start-up 1 was involved with the use of satellite imagery to produce applications for smart agriculture, land use planning and monitoring, flood mapping, etc. The imagery was from freely available satellite data and also paid-for data in the case of dedicated or higher resolution requirements. The first task of this start-up was to capture the imagery from the satellites and through specialised software coding and use of research information, develop an interpretation of the data thereof as required by clients. An example is the development of a product that can be used to indicate the nitrogen content of a plant remotely without visiting the actual farm. The next step was to automate this exercise so that the system could collect data and process it without human involvement. Finally, user-interface software was developed allowing

users/clients to view their requirements in a friendly and easy to understand format in accordance with their subscription rights. The products from this exercise are used in the agriculture sector, government planning and monitoring departments, mining operations, disaster management operations, mineral exploration, insurance industry etc.

I was approached by the two owner scientists, identified as Participant 1A and Participant 1B in the study, during the conceptual phase of the innovation to assist them with the challenges they were facing. The challenges included the lack of resources like high speed and large volume development platform, access to market and the whole process of managing a start-up.

1.4.4 Innovation start-up 2

Innovation start-up 2 was about commercialising research on the production of low cost carbon nanotubes. This innovation involved collaboration between a lawyer and a nano scientist identified as Participant 2A and Participant 2B respectively. The innovation comprised of several components, the first of which was to investigate the design and fabrication of a plant (reactor) to be used in the production. Although this plant was considered a prototype, it was also envisaged that it would be used for initial production of commercial nano tubes. The second component involved the investigation of the right catalyst and the associated beads and vapourisation method. The last component involved investigating the types of gasses to use and the associated flow rates for optimum production.

The start-up was located within the facilities of a large research institution where there was also a collaborative agreement for knowledge and test facilities access. The commercialisation process included the testing of production samples and constantly revisiting the components described above in the quest for the eventual production of the desired low cost single-walled carbon nano tubes.

In this start-up, the participants' main challenges were associated with the project management for manufacturing of the reactor as well as for the actual product production. In addition they also lacked management expertise for their start-up. At

the time they asked me to provide the appropriate mentorship and support, their start-up firm had already raised venture capital funds from a local developmental bank and was already investigating the plant design and fabrication. In this project, like in Innovation start-up 1, both participants were not involved full time with the project.

1.4.5 Innovation start-up 3

Innovation start-up 3 was developing a business based on a pyrolysis technology for converting a number of waste materials into bio char, bio oils and bio gas. The two innovators of the technology (referred to as Participant 3A and Participant 3B in the study), started their start-up in 2010. The duo built at least two prototypes and imported one plant from overseas in the period 2010 to 2017 all of which had constant technical problems and hence never got to produce the desired quality nor the desired quantities. In spite of the project attracting huge interests from both government and industry because of its sustainability and clean environmental advantages, it never got any external support and funding. The concept of the project firstly involves the collection of the intended type of waste materials (e.g. biomass) and preparing it by pre-drying where required and chopping it into fines like saw dust in the case of biomass waste. The production process involves preparing material and feeding them through a drier to remove the moisture and then through a heated oxygen-free chamber to make the bio char. The smoke produced during the burning process is then collected and distilled into bio-oil. The remaining gases after all the oil has been extracted from the smoke is collected and used for burners as well as electricity generation through gas generators. The bio oils are separated and fractionated into bio-diesel and various organic chemicals like acetic acid, furfural, euginal, octanaic acid, propoanoic acid, etc. The bio char is used for agriculture, water and air purification, cosmetics, gold separation and medicinal purposes. The resulting business is easily scalable through the making of more plants and introducing further applications of the produced products.

The participants, a mechanical engineer and a commerce graduate, experienced several challenges when they finally decided to manufacture a final prototype unit that would lead to client engangment. Firstly, they had run out of money and were not

getting favourable responses from would-be investors as well as government funding agencies. Secondly, they realised that they lacked sound business and project management abilities. They also expressed the need to have access to different networks that would be required in the commissioning of the first plant, testing of the various products and marketing exercises. It was against these challenges that I was asked to assist them.

1.5 The research approach

The thesis project was conducted by using the action research approach with I, the researcher being involved in the three hi-tech innovation commercialisation innovation start-ups introduced above. At the onset of the study, although all projects were in the process of technology development, I requested to review the specification and market offering of the eventual product. This was to ensure that any further specification definitions and testing and or certifications are aligned to the final product and also most importantly the market need.

Although my participating role was that of a mentor, I also played the role of providing support in the form of network introductions, training, seed funding, planning, and initial external party's engagement meetings. There were six participants, two from each start-up and a further three technological innovation experts who helped with the refining and validation of the framework. The study data was collected through field notes and interviews and analysed by using a Qualitative Template Analysis method.

1.6 Research objectives and questions

The objective of the thesis is to develop a practice-based, actionable framework for the commercialisation of technological innovations in the context of start-ups in South Africa. The framework would aid mentors and other technology commercialisation agents as well as other interested parties such as other technology start-ups and policy makers. Comparable start-ups and support agenicies in other developing countries with similar economic challenges could also benefit from the framework.

In order to develop the desired framework, two questions were used as guidelines. The first question was seeking to identify the support interventions that the start-ups would need in order to commercialise their technological innovations successfully. The second question was seeking to find out how mentoring could assist in the commercialisation process given the support interventions identified.

The questions used are as the following:

Question 1: *What support interventions are needed in the commercialisation of technological innovations through start-ups firms in South Africa?*

Question 2: *What are the implications of this analysis for mentors and other technology support agents who seek to aid the commercialisation of technological innovations within this context?*

1.7 Overview of the thesis

This research is organised into seven chapters, the first of which is this introductory chapter. The introduction chapter starts by relating the purpose of the research and briefly describing the problem that I was intending to help with. It goes on to give the context of the problem as well as the researcher's relevance in it. Finally, it touches on the approach of the thesis.

The second chapter looks at the existing literature in order to create the template framework for the commercialisation of technological innovations. The literature review explores technological innovations and their economic benefits, start-ups and the associated entrepreneurships, technological commercialisation and mentorship. The key output from the review is an initial commercialisation framework template that will be contextualised through empirical research. Chapter 3, the methodology chapter, describes the selected action research design approach for the empirical research including types of data to be collected, the collection methods and finally the analysis method. The findings of the thesis are presented in chapter 4 leading to the refinement of the framework template developed in chapter 2. The updated framework template is further refined and validated in chapter 5 through a focus group made up up of technological innovation exerperts. The final framework for the

commercialisation of technological innovations through start-ups in South Africa is presented in this chapter. The final framework is then discussed in chapter 6. Finally, chapter 7 concludes the thesis with concluding remarks, suggested recommendations, limitations and my personal reflections.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The main identified problem that informed this research was the need to assist start-ups to develop sustainable skills for commercialising their technological innovations. In order to form an understanding of the problem and launch into a path for formulating the desired framework, this study mobilises several concepts, namely technological innovation/innovators, start-up firms with the associated technopreneurs, commercialisation and mentorship and hence it is important that each one of these concepts be explored through literature.

The understanding of each of the concepts should include the definitions, benefits, operations, and samples of frameworks where developed. It is hoped that these reviews will all contribute in generating the Theoretical Commercialisation Framework Template. In view of the above, this literature review chapter has been structured in a way that it introduces, defines, and discusses the relevance of each concept in the study, namely: technological innovation in section 2.2, start-up firms in section 2.3, technological innovation commercialisation in section 2.4 and mentorship of innovators in section 2.5. Section 2.6 puts the study in the context by reviewing literature related to the commercialisation of technological innovations in South Africa. Finally, in the concluding section, section 2.7, I have summarised the literature survey discussions and also created the theoretical framework template of the identified themes.

2.2 Technological Innovation

This section offers the definition of technological innovation and places the research's innovations into the specific type of technological innovation as per the definitions. The terms "technological innovation" and "innovation" are often used interchangeably by most researchers. Perhaps this could have been explained by Laurier Schramm (2017, p. 4) who wrote that "'*Technological innovation'* or '*commercial innovation'* are often used to distinguish the 20th century Schumpeterian definition of innovation from that of earlier centuries". Schramm noted that prior to this era, the term 'innovation' had negative connotations as it was

associated with those wanting to challenge religion or politics of the day. Also to note is that in other cases, the use of the term innovation covers technological innovation as evidenced by the World Bank publication (2010) which contained the following statement in the foreword “Innovation, particularly technological innovation, is rightly seen as a key to economic and social development”. The literature used in this chapter has been selected on the basis that ‘technological innovation’ is implied although the term used in the definitions and discussions could be simply ‘innovation’.

The concept of innovation is widely used in daily conversations and thus could have different meanings to different people. In this section, I start by identifying some of the definitions and classifications from a select number of literature and position the type of innovation under study in this research. The definitions also include those of the innovators who may require support and mentoring in their activities of commercialising their inventions. I then go on to show some relevance of the topic of this research in the national economic growth plan by using literature that confirm the economic benefits of innovation.

The study of innovation is quite wide and complex as it cuts across many sectors and disciplines and therefore, its definition varies depending on the discipline (Damanpour and Wischnevsky, 2006). For example, in the context of organisations, Damanpour and Wischnevsky (2006, p.271) posited that the generally accepted definition was focused in organisational innovation and hence it is “the development and use of new ideas or behaviours in organizations”. Whilst the above definition approaches innovation from the field of study, other researchers approach it from the point of view of whether it is a product, a process or a service. One definition that clearly considered innovation as a product was that of Carayannis, Samara and Bakouros (2015, p. 25) which read as: “a new technology that creates new products, hence new opportunities for the industry”. Rose and Winter (2015, p.107), on the other hand, included all the aspects in their definition which reads: “broadly understood as the creation or adaptation of new or existing knowledge, technologies and techniques to solve social or economic problems or bring about economic growth”. The World Bank, in their innovation policy guidelines for developing nations, whilst positing an innovation definition that say “*innovation* means technologies or

practices that are new to a given society" (The World Bank, 2010, p4), emphasized the diffusion to the economy or society aspect of this definition. These definitions, however, fall short of the 'innovation journey' described by Carayannis, Samara and Bakouros (2015) which was represented as creation, commercialisation through to productivity (market adoption). The three activities of the journey are important for this study because they help to point out the study's focus, commercialisation. The creation (invention) of the ideas had already occurred in all the three start-up firms when the study's data collection was starting and it ended before the full market adoption phase.

Perhaps the differing approaches to the definition of innovation could be attributed to its multi-dimensional phenomenom and yet some writers use a unidimensional approach in their definitions. As early as the late nineties, Cooper (1998) observed this challenge and went on to suggest the multi-dimensional approach for innovation. The resulting model was a three dimensional framework whose components were radical versus incremental, technological versus administration and product versus process. Cooper (1998) did emphasize that an innovation could be on more than one dimension at any given time.

My study is best described by firstly considering the activities of innovation (innovation journey) and placing it in the middle activity of commercialisation. Thus the study does not cover the creation of the ideas nor does it cover the market adoption. Secondly, the study is tested against Cooper's (1998) three dimensional framework. From the framework, I can describe the innovations in all the three start-ups as being technological innovations (technological versus administration dimension), of products (product versus process dimension) which are closer to radical than incremental (radical vs incremental dimension).

As has been seen above, technological innovation, just like innovation itself has been defined differently by different writers. This study will use the Laurier Schramm (2017) definition which states that it is "…the conversion of ideas and knowledge into new and commercially successful products, processes, and services".

The importance of technological innovation cannot be over-emphasized and it has been widely acknowledged by nations including the developed ones. In the UK, for example, in a 2016 speech, the Prime Minister announced “major research boost to make Britain the go-to-place for innovators and investors” (UK Gov., 2016). The government’s pledges included the increase in research and development investment to 2 billion English Pounds per year by 2020 and the establishment of a new Industrial Strategy Challenge Fund in support of priority technologies like robotics and biotechnology. The Prime Minister even went as far as calling for a review of the research and development tax incentives for science, innovation and technological investors. Another European developed country, German, as its commitment to technological innovation, established a “high-tech strategy 2020” which was designed to “transform it from the country of invention into an innovative country” (BMBF, 2019). The United States also showed a focus on technological innovation by increasing the 2017 Research and Development budget by a full 4.1% to $152 billion from the previous year (National Science Board, 2018).

Literature advocates that the success of technological innovation in a nation depends on the partnerships between government and business. Most countries ensure this partnership by establishing a National Innovation System (NIS) at a national level. Below that they establish other linkages like the sectorial Innovation System (SIS), Regional Innovation Systems (RIS), Technological Innovation System (TIS), etc. These innovation systems bring together all the actors including the firms, institutions and government. In view of globalisation pursuits, it was argued that the NIS should also consider cross border actors (Nelson, 1993). From the comparative analysis that Nelson and others conducted over fifteen countries, it came evident that a nation’s innovation system is largely determined by a number of its other broad policies like those for defence, import vs export, education, etc. The availability of natural resources and a sound internal market were also factors that influence the innovation system. A World Bank policy research working paper (Maloney, 2017) supported the NIS approach by showing the diminishing of differences against the neoclassical economic models. Within the NIS, purpose-driven Technological Innovation Systems (TIS) could be established. These provide relevant networks to the actors within it especially firms who have to diffuse the technology in question to

the market. Markard and Truffer proposed what I think is a very concise definition of a TIS which said it is a "….set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product." (2008, p.611). Again as for the NIS, a TIS could transverse across borders into regional blocks or even economic blocks.

This study is undertaken on the premise that technological innovation has a positive effect on the economy of a country, in particular, South Africa. This implies that the firms that are partaking in the innovation businesses achieve an enhanced performance. This claim, can however only be made if the firm's performances are evaluated using a credible and standardised evaluating framework. Unfortunately, the claimed results are inconclusive, mostly because there is a lack of agreement among authors about how to measure the effect of innovation on firm performance (Cruz-Cázares, Bayona-Sáez, and García-Marco, 2013). Sometimes firm performance is measured as innovation inputs like research and development and patents (O'Regan et al., 2006) and sometimes the evaluation considers outputs (Akgün et al., 2009) and some have even gone to add other factors not related to innovation. In the midst of these debates, Cruz-Cázares, Bayona-Sáez, and García-Marco (2013) proposed a different evaluation processes that considered both the input and outputs and also other factors like the time lag between the two as well as the efficiency of the process in between. Considering the trio's definition of technological efficiency which is "..the relative capability of a firm to maximize innovation outputs given a certain quantity of innovation inputs" (p. 1240), I argue that, in the context of this thesis' study, the main component of the 'capability' referred to is commercialisation. Using their evaluation model, they discovered that a firm's performance is directly linked to the capability efficiency as per the definition above. Not surprisingly, to me at least, was the finding that the cost of patenting did not always translate to performance in low and medium-technology firms (LMTs). In my interviews with most of the university Technology Transfer Officers I have interacted with, they view patenting as very costly and are proposing to reduce the number of patents in their care. These results show the importance of

commercialisation which resides in the processes required to convert the inputs, inventions, into a market diffused product.

Technological innovation can be undertaken in large organisation, academic and research institutions, incubators that could be located in the organisations or the institutions or even stand alone and also start-up firms. This action research study is based in small start-up firms whose inventions were created by the participating innovators who are also being considered as the entrepreneurs from a firm start-up point of view. None of the three firms operate within a Technological Innovation System but they are all within the Country's National Innovation System.

2.3 Start-up

2.3.1 Start-up defined

The term start-up started gaining momentum in the 1990 during the Information, communication Technology (ICT) business boom era to refer to the starting up operations of companies that were characterized by high risk and high growth attributes as well as aggressiveness in fund raising. The companies were being started by visionary entrepreneurs with the intention of promoting new ideas, services, or inventions with high market impact (Dewey 2018). Over the years, with the dying of the ICT boom, the term has become toned down a bit in its ambitiousness.

In spite of Dewey (2018) pointing out that the term is now being used by any business that is beginning, definitions that point to its aggressiveness still appear. Slávik (2019, p.1) defined the term as an "entrepreneurial experiment and a very small beginning enterprise that provides a space for self-realization, an opportunity to develop and implement unusual and risky ideas, an unparalleled satisfaction of existing needs and discovery of new needs". A start-up was conceptualised by Slávik (2019) as a living laboratory for enterprise development which could experience high growth but also may go through repeated failures. His study was informed by the acknowledgement that the repeated failures are mostly due to the start up's simplified and narrow focus on business that excludes important aspects like reaching the market and shaping

partnerships. Slávik's paper proposed a business model for start-ups that would help to enhance their performance and avoid failures.

The attribute of repeated failures and the major cause thereof of a lack in business skills was also confirmed by Cosenz and Noto (2018) who put the cause simply as the lack of entrepreneurial skills. They too proposed business models that would alleviate this inadequacy in skills. Their model, which was about entrepreneurial leaning was, in part, based on studies that had identified the role of learning in business evolution as one of the key drivers in business sustainability (Jovanovic, 1982; Pena, 2002).

Although the given definition would seem to imply that start-ups are homogenous across countries, a study on the Hi-tech start-up ecosystems of three different countries, namely Korea, China and Japan concluded that these vary from country to country (Lee, Lee & Kim, 2017). The studies used the start-up life cycle framework which includes technology optimization, fundraising and exit which is geared to overcome development obstacles.

From this brief exploration of the concept of start-up, several concepts requiring commenting on have come up. The first of these is the entrepreneur in the start-up. The brief has shown that start-ups are fully driven by entrepreneurs who seek high growth whilst navigating different risks and perhaps acknowledging the high failure rate of their endeavour. Secondly, it has also shown that this entrepreneur needs help through business models and learning in order to be adequately equipped with the relevant skills. Finally, it has, through the concept of a start-up ecosystem, alerted the reader that these eco systems may be different from country to country and therefore it would be advisable for a study to be conducted in each country before implementing policies and mechanisms for supporting start-ups.

2.3.2 Entrepreneurship and entrepreneurs

The relevance and importance of entrepreneurship in the study of start-up companies has been demonstrated above and its value in unlocking the value of innovation was stressed upon by Adomako, et al. (2016) when they concluded in their paper that firms

with strong Entrepreneur Orientation (EO) perform much better than those with weaker ones. This sentiment was echoed by Hsiao et al. (2013) in confirming that entrepreneurship is critical to both the growth of a company as well as a nation.

According to literature, the definition of the concept of entrepreneurship has been evolving for at least three centuries. Literature tells us that as early as in the eighteenth century, Adam Smith (1776) wrote that the key input factors of economy were land, labour and capital. This list was updated by Schumpeter (1934) with the addition of technology and entrepreneurship. In this definition, innovation was implied into the picture of economic growth and with it then the introduction of a dynamic terrain for the economy where new innovations would mean an enhanced competitiveness for a company. Peter Drucker (1976) further updated the concept by adding in knowledge as the sixth key input.

But all these developments only look at entrepreneurship from the point of view of key input factors and do not offer a full definition of entrepreneurship. Gartner (1988) observed that most literature on entrepreneurship shift its definition to trying to answer the question of who is or what is an entrepreneur. But this shift of focus has still not yielded a definitive definition. At least three main approaches for considering the entrepreneurship have emerged, each with its own followers.

There are those writers like Donald F. Kuratko (2005) who based their definition of entrepreneurship on the trait of the entrepreneur: “The characteristic of seeking opportunities, taking risks beyond securities, and having the tenacity to push an idea through to reality combine into perspective that permeates entrepreneurs.”(p. 578). The trait based definition has also been supported by other writers like Hoppe (2016), Brockhaus, (1980), Brockhaus and Nord, (1979), Hull, Bosley, and Udell, (1980).

With a different point of view on the subject are those writers who advocate the use of behavioural approach by explaining who an entrepreneur is and hence the phenomenon of entrepreneurship. Gartner (1988) challenged the trait approach and pointed out why he believes it is inadequate in defining entrepreneurship. He assembled all the traits and characteristics identified by thirty one (31) papers and

tabulated them. From this tabulation, he observed that not all papers used the same characteristics and traits and in fact, only a few used the same traits and characteristics. Based on his earlier paper, Gartner (1985, p.21) posited that *"The personality characteristics of the entrepreneur are ancillary to the entrepreneur's behaviours. Research on the entrepreneur should focus on what the entrepreneur does and not who the entrepreneur is".* Indeed, some of the traits used in the description of an entrepreneur like risk taking propensity and locus of control have been contested through research (Brockhaus, 1980; Brockhaus and Nord, 1979). The behavioural approach to entrepreneurship may also have taken a turn into a concept called 'entrepreneur mind-set' proposed by among others, Kuratko, Fischer and Audretsch (2020). This concept is based on the premise that entrepreneurship comes about through the entrepreneur's cognitive, behavioural actions and emotional feelings.

The third approach to the provision of understanding of the concept of entrepreneurship is that based on elements associated with the entrepreneurship mind-set which was developed by Kuratko and Morris (2018). The elements were divided into attitudes and behaviours of the entrepreneur. The attitude elements are: I can effect change, I am creative, healthy dissatisfaction, opportunities are everywhere (alertness), I embrace innovation, failure is learning, and I am passionate about my ideas. The behaviour elements are pursuing opportunity, innovating, perseverance, leveraging resources, guerrilla actions, risk mitigation and adaptation (Kuratko and Morris, 2018, p. 15).

It can therefore be concluded that in attempting to provide a description of entrepreneurship, the entrepreneur is defined. However, the concept of the entrepreneur is often used interchangeably with that of the innovator by some writers although each has its own definition. Professor Jeff Makower from Stanford University, for example, in his article on innovator's perspective constantly replaced the term innovator with entrepreneur (Makower, 2017). Perhaps the assumption of these writers is that just because someone has invented an idea/product, they therefore want to start a business and also that they have the skills to penetrate the market with the innovation and therefore they are entrepreneurs. In this study, the link between an

innovator and an entrepreneur will be considered to be commercialisation because in this activity (concept), the skills of both the inventor and the entrepreneur are required to take an innovation from birth to a market success. Now that the vehicle and the person responsible for the activities of the innovation where an invention is converted into a product ready for market have been described, I will discuss the required process, the commercialisation.

2.4 Technological innovation commercialisation

Whereas entrepreneurship has been described as the creation of businesses and innovation has been identified as one of the three components an entrepreneur can use to create the business (Carayannis, Samara & Bakouros, 2015, p.8), commercialisation is critical stage of converting an invention into a product that can be presented to a user for adoption. In spite of its being identified as being critical to the development of economies, it still remains very under-researched. Datta, Reed & Jessup (2013) suggested that this could be because this subject transverses across several disciplines like economics, marketing, strategy, and entrepreneurship, as well as that most of the research in the subject is on the sub-topics such as protection of IP and sources of innovation (p.172).

Generally, technology commercialisation has been described as the process of converting scientific research and development into useful products and services (Wonglimpiyarat, 2015). This definition had already been alluded to earlier on by others including Datta, Reed & Jessup (2013) who used Moore's study (2000) on the stages of innovation to include requirement to ensure that the product has reached the main stream of the market beyond the early adaptors.

Commercialisation starts with a strategy whereby the inventor evaluates the different options that will ensure that their invention eventually diffuses into the market. A market focussed strategy would avail two main options to the inventor: to cooperate or to compete with existing players (Stenard, Thursby and Fuller, 2016) where the former could take the form of licencing out or going into a joint venture with the existing corporates. The cooperation option, however, relies on the technology

having a demonstrative value to the partners otherwise they will not take it up. In this case the inventor would have to continue with the commercialisation until at a point where they can demonstrate value (Marx, Gans and Hsu, 2014).

Literature has introduced many factors associated with the determinants of technology exploitation but most of these could be grouped into the cost dimension and the compatibility dimension (Piruncharoen, et.al, 2011). The cost dimension is mostly associated with commercial valuations of the technology and hence depends on the accuracy of forecasts. The compatibility dimension, however, depends mostly on actuals of such factors as the size and capabilities and mandate of the inventing firm, and the type of the technological innovation. Because commercialisation is dynamic, inventors are argued to continue with the exploitation valuation throughout the process.

The complexity of commercialisation has led researchers to develop several theories for explaining the phenomenon in their research. These theoretical perspectives form the basis for understanding the field as well as informing practice. The perspectives include ambidexterity (He and Wong, 2004), business model innovation (Teece, 2010), dynamic capabilities (Teece, Pisano and Shuen, 1997), resource based view (Amit and Schoemaker, 1993), the learning organisation (March, 1991), innovation networks (Phelps, Heidl, Wadhwa, 2012), and circular economy (Geissdoerfer, Savaget and Hultink, 2017). These perspectives mostly concern established organisations or those start-ups that have already generated revenue from their first innovations. However, these theories do have some bearing on start-ups going through their first innovation commercialisation, and do not yet have an organised business model nor regular revenue. In this section, I will discuss these perspectives as I position my study. It still remains important for mentors of start-up innovation firms to understand these theories so that they instil in their mentees the culture of sustaining competitiveness after the success of the first innovations.

Any organisation would have a business strategy which amongst other issues would focus on the way to be sustainable as well as being competitive.

One such strategy perspective is ambidexterity which O'Reilly & Tushmann (2004) describes as simply the organisation's balancing act between achieving break-through innovations whilst also steadily improving the existing business. Although most literature on ambidexterity addresses strategy in large firms, there is some limited literature that addresses small firms. One such paper was published by Schreuders and Legesse, (2012). The authors, through their five mechanisms, encourage leaders of small businesses to embrace the ambidexterity leadership style and attract executive managers who can also lead and be entrepreneurs and employees with skills for both exploration and exploitation. The resources in the businesses should also be versatile enough to be shifted across projects regardless of project goals. Where internal capacity does not allow both goals of exploration and exploitation to be achieved, the leaders should consider outsourcing some functions or at least one of the goals.

In the case of technological innovation start-ups, implementing an ambidexterity strategy would direct the entrepreneurs to find ways to secure a personal income whilst bringing their technology to first revenue. Self-sustainability during commercialisation poses a lot of problems for most innovators in South Africa. Some of them, including those from two of the three start-ups in my study, stayed in their work places and only worked on their start-ups after hours.

One of the theory perspectives that has a direct impact on first innovation start-ups is that of resource-based view (RBV). This perspective has two dimensions according to Teece, Pisano and Shuen, (1997). The first dimension argues that firms already have assets and they have to develop strategies to exploit these in order to remain competitive. In this dimension, the firms may be at a disadvantage in that they may not be able to adapt to rapidly changing environments. However, it is in the second dimension where start-up firms can achieve the real value of the perspective. The value can be unlocked by the learning, skills acquisition and the accumulation of both tangable and intangible assets .Perhaps one of the main challenges of this theory during its development, has been in the definition of the resources (Wernerfelt, 1984 and Rumelt, 1984). Barney and Clark (2007), based on surveyed

literature, grouped the resources into four main categories which are physical capital, financial capital, human capital and organisational capital which included such things as culture and organisational structures.

A number of writers have conducted studies on technological innovation start-ups based on this view, though mostly through incubators and accelerators. One such study was conducted by Uhm, Sung and Park (2018). Their paper, from a resource-based perspective, compared the practices of accelerators in the USA and Korea on how they sustained start-ups in their innovative programs. The study found that in as much as there were a number of similarities and differences between the accelerators in the two countries, there was one major difference that influenced the low rate of success in Korea. This was the low level of accessibility of mentorship and investment resources. This could well apply to the stand-alone innovation start-ups in my study as they require the same support mechanisms incubators and accelerators need. Other papers on the resource-based view looked at how it impacts academic spin-offs (Lee and Yun, 2020; Powers and McDougall, 2005; West and Bamford, 2005; O'Shea, et al., 2005). Lee and Yun (2020) summed up the resources that have the most impact on the success of the spin-offs as university technological assets, incubator administration, and venture funds. Translating the incubator administration functions to a stand-alone technological innovation start-up would imply efforts on the part of a mentor to assist with the identification of networks for venture capital, collaboration and technical assistance. It will also mean the help to build a business entity by the mentor. The technological assets, in this case, simply means the quality of the invention the start-up wishes to commercialise and whether or not it has been patented.

Another theoretical perspective that other researchers advance and have used in their papers as a basis for further theories is that of innovation-process (Leonard and Senisper, 1998; Leonard and Barton 1995; Maine, Lubik and Garnsey, 2012; Akbar and Tzokas, 2013; Ellwood, Williams, and Egan, 2022). Innovation process was explained, at a highest level of abstraction, by Leonard and Senisper (1998) as a linear process which starts with idea generation followed by development, then adoption and testing, and finally after-sales service or implementation. These writers

posited that within each phase are smaller decision cycles where individual and group choices are made. Other researchers have focussed on specific elements of innovation process theory. Amongst other recent authors, Akbar and Tzokas (2013), used the conceptual phase of the innovation process to base their paper on organisation knowledge creation (OKC), in the context of new product development (NPD). In the paper, the conceptual phase, also termed the front end of the innovation process, was divided into five stages, namely: knowledge-generation, knowledge-evaluation, knowledge-expansion, knowledge-refinement, and knowledge-crystallisation. Although at the start of my study in all the three projects the first two stages were claimed to have been completed, I found that we had to go back to them again and again as we refined the concepts. This forwards and backwards process confirmed Akbar and Tzokas' (2013 p. 1603) observation "…the full complexity of the OKC process and its dynamic nature as reflected in the interplay among stages…". The innovation process front end is crucial to innovation start-ups as it ensures firstly, the technology's alignment to market requirements and secondly an investable concept. Mentors of innovation start-ups are also directed to monitor individual and teams' creativity roles and the conflicts that may arise during the stage interplays.

The whole basis of my acceptance to the role of mentorship of the three projects was that the technologies were defined in such a way that they are aligned to markets, they are fundable and also that it is practically possible to structure their development, manufacture and testing. In order for me to satisfy myself in this regard, I had to delve into each project's 'valley of death' (Markham, 2002) first and consider the challenges. These challenges were expounded by, amongst other researchers, Ellwood, Williams, and Egan (2022) who investigated the innovation processes operating within this stage. These authors developed a framework for managing risk during the 'valley of death' development stages. The risk tool, based on a medical innovation context, covers most of the concerns of aspiring innovators and mentors of technological innovation start-ups. The risks categories covered, based on the five processual mechanisms of the stage were: technology concept, technology performance, clinical and social uncertainty, potential impact and post-valley of death commercialisation strategy.

The role of networks in the commercialisation of new technologies is important because of the interdisciplinary nature of the innovation processes. This is even more so for stand-alone technological innovation start-ups in my study. The complexity of innovation networks has led to researchers adopting different ways of approaching it including from strategic management, sociology, economics, geography and even physics perspectives, (Ozman 2009). Phelps, Heidl, Wadhwa (2012), for example, approached their knowledge networks study from the fields of management, psychology, sociology, and economics. On the other hand, Hoang and Antoncic (2003) approached their network-based study in entrepreneurship from the perspectives of entrepreneurship, sociology, and strategic management. Of particular importance from this paper to innovation start-ups is that entrepreneurial networks, be it at individual or at interfirm levels, are able to easily gain access to resources, including information and advice and also testing facilities in the case of my study's start-ups, from other actors. Being networked with reputable and established individuals or organisations also aids in being trusted by the actors who include venture capitalists.

Eveleens, van Rijnsoever and Niesten (2017), elected to approach their network-based incubation study from the point of view of management only. The discussions in this study will be applicable because, as mentioned earlier in this section, the requirements of incubatees are the same as those of a stand-alone start-up. The only difference is that incubatees get support from the incubators administration whereas a stand-alone start-up gets their support from mentors or directly from networks. Contrary to popular expectation that the 'benefits' derived from a network-based incubation with regards resources, capabilities, knowledge, learning and social capital will all produce positive performance, the study found that some of these benefits may in fact not produce any results. It recommended careful matching of the benefits to the aims and goals of the start-up. Although, the start-ups in my study do depend on networks to a large extent, they could not be defined as 'network based'. However, the theory would direct the start-ups to consider the type of benefit required and match it with appropriate resource owners. Wei, Zhang and Chen (2021) consider the complexities of most of the technologies and incubators such

that they should develop ‘super-networks’ that are based on the dynamic capabilities (Helfat and Winter, 2011) of each incubatee. By extension this is revelant for standalone start-ups and their mentors.

A further perspective relevant for studies like mine that incorporates technological innovations start-ups are those that focus on the technology entrepreneur themselves (Aldrich and Zimmer, 1986; Corbett, 2005; O’Gorman, Byrne, and Pandya, 2008; Autio, et al, 2014; Tidd, 2015, Ferreira, et al., 2016). Technology entrepreneurs were described by Tidd (2015) as those individuals who are driven by the desire to create or change a technology through a new venture. Looking at it from a function point of view in a firm, Shane and Venkataraman (2003) defined technology entrepreneurship as “the processes by which entrepreneurs assemble organizational resources and technical systems and the strategies used by entrepreneurial firms to pursue opportunities” (p. 181). Another definition drawn form a framework that was created in order to ensure that all aspect of the concept are captured was by Spiegel and Marxt (2011) who defined technology entrepreneurship as that which seeks to investigate “…….all questions related to the successful formation, exploitation and renewal of products, services and processes in technology-oriented firms” (p. 1626). This definition by Spiegel and Marxt (2011) is of particular interest to my study because it includes the exploitation of the innovative products beyond the commercialisation and market adoption phases. Although my study did not go beyond the commercialisation phase, the mentoring function in it was meant to ensure that the entrepreneurship of the participants go beyond the start-up phase into one where they start exploiting the first product and exploring for new products.

My concerns regarding entrepreneurship in the start-ups were two fold. Firstly, I was concerned whether the participants were genuine entrepreneurs or not. The Black Economic Empowerment (BEE) policy in South Africa that seeks to redress the economic imbalance from the apartheid era means that black citizens are given preferential opportunities in government funding and procurement. This may have

given birth to opportunists, perhaps even politically aligned, to venture into technological start-ups even it is without the desire to create new products (Tidd,

2015). The first concern was on how I would know that the participants are real entrepreneurs or not in order to accept to the mentorship role. One option is to the use Technology entrepreneur profiling like the one given by Tidd (2015). His profile, amongst other things said that the individual is likely to be at least at Master's level in engineering and science, have around thirteen years of work experience, most probably be between thirty and forty years old and possibly be more driven than their colleagues. Most importantly, they believe they have personal control of outcomes as opposed to others who believe that outcomes are through chance, large institutions or even other people. "More sophisticated psychometric techniques such as the Myers–Briggs type indicators (MBTI) confirm the differences between technology entrepreneurs and other scientists and engineers" Tidd (2015, p. 360) added. Other writers have also written about this internal locus and termed it self-efficacy (McGee, et al., 2009; Huyghe et al., 2016).

Self-efficacy is seen as of particular importance in explaining human behaviour and predicting an entrepreneur's intentions, level of effort and perseverance (Bird, 1988; Chen, et al. 2004; Son, Chung, and Hwang, 2019). This understanding goes a long way in opening up discussions for my second concern, that of wondering whether the participants can sustain their technology entrepreneurial spirit up the end of the study and beyond the start-up phase. The recent revelations that an entrepreneur's self-efficacy can be elevated through education and training (McGee, et al.,2009; Florin, Karri, and Rossiter, 2007) makes me start considering whether it can be included in my mentoring in order to ensure its positive entrepreneurship sustainability.

The list of theoretical perspectives within the technological innovation field is not exhaustive. Each one of them serves a particular purpose and in most cases there are a lot of interplays between them. It is recommended of innovation practitioners to continually revisit them for insights into new developments irrespective of what route they take to commercialising their inventions. The following sections will review literature on the three main routes used by the practitioners in their commercialisation endevours, namely through corporations, research and academic institutions and start-ups as used in this study.

2.4.1 Technological innovations commercialisation in corporations

The challenges of innovators failing to cross the invention-to-market gap were discussed by Markham (2002) who went on to say that these failures are attributed to the innovators lack of skills for commercialisation, entrepreneurship, product development, market value and general business concepts. Markham (2002) described the gap between "the technical invention or market recognition of an idea and the efforts to commercialize" as the 'Valley of Death'. He asserted that in any New Product Development organisation, there must be a 'champion' to take any innovation across this valley of death.

In organisations, Markham (2002) pointed out that on the one side of the valley would be the organisational infrastructure, personnel and required resources for product development and on the other side would be production, distribution and marketing structures (see Figure 2.1). The champion's role is to integrate these two sides.

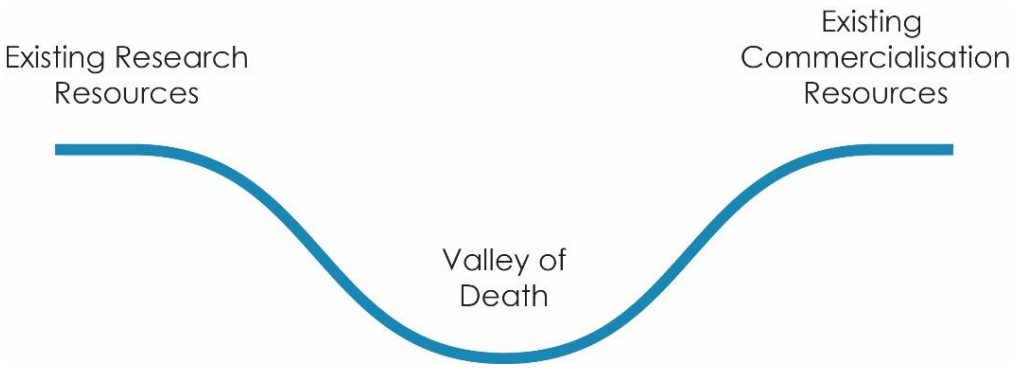


Figure 2.1: Valley of Death Framework (Adapted from Markham 2002)

There are different types of skills required on each side and that the incumbents of these skills often do not understand and appreciate the value of the other skill. The best scenario is where the entrepreneur side appreciates the development skills and even gives their inputs at the start of the development and vice versa the innovators understood and continually gives input to the production and market team.

This bucket of skills required in the entrepreneurial phase had also earlier been discussed by Berry (1996) through his proposal following an empirical study of the management phenomenom underlining corporate transformation of small hi-tech firms. He postulated that policy for small hi-tech firms should also focus on the development of general management and marketing skills in addition to technical skills in order to ensure competitiveness and continued effective contribution to innovation. The main conclusion of Berry's study (1996) was that it is critical for the management of these small hi-tech firms to develop strategic awareness to ensure continued sustainability of their organisations.

The existence of the 'Valley of Death' was confirmed by amongst other researchers, Islam (2017) through the analysis of his study's data in the Micro and Nano Technologies (MNT) area. The study found that the existence of the 'Valley of Death' is a result of a disconnect between the emerging MNT and the marketing demand. Islam concluded: "the need for a pragmatic, integrated technology-push and market-pull model was highlighted, in order to better represent the links between emerging MNT and market demand" (p. 396) with an intermediary body placed in between the two functionalities.

The ability of a corporate to commercialise an innovation had been attributed to different aspects by different researchers. These include protection of IP, marketing, developing, deploying, etc. (Datta, Reed & Jessup, 2013). The trio's work integrated most of these attributes/activities into a single framework from which further studies for the commercialisation of innovations could be identified. In the build-up to their integrated framework development, the writers observed that there is a need to research the innovation-commercialization subject further.

The framework they developed (entrepreneurial activities to commercialise innovations) could be divided into two layers where layer 1 is considered process and layer 2 considered as the component layer. The first layer gives the general processes framework where the processes are Discovery, Development and Deployment. The second layer gives the six components under which the specific decisions and activities are undertaken.

The first process of layer 1, discovery, is where the innovation is identified and specified and matched with an appropriate target market. This process is associated with the first four components of layer 2, namely, source of innovation, type of innovation, market entry, and IP protection. In this study, this process is identified by the theme ‘packaging’ as it is where the innovation is packaged to suite the identified target market to ensure that product developed is presented to the market in the format required.

The second process of layer 1, the development process, is where the product is developed and manufactured. It is related to component 5 of layer 2. In this, the decisions of commercialisation vehicle are made and the initial part of commercialisation, as per the definition of Wonglimpiyarat, (2015) takes place. Finally, the third process of layer 1, deployment and its associate, component 6 of layer 2 involves the deployment activities of the products. The theoretical commercialisation framework they developed is depicted in table 2.1 below.

Table 2.1: Theoretical commercialisation framework

Layer 1 Component	Layer 2 Component	Layer 1	Layer 2	Details
1		Discovery		
	1		Sources of innovation	
				Organisational creativity
				Research & Development
				Alliances & collaborations
				Innovation engines
				Technology clusters
	2			Technology Spillovers
			Types of innovations	
				Product vs. process
				Radical vs. incremental
				Architectural vs. component-based innovations
				Competence enhancing vs. Destroying innovations
	3		Market entry: Competence & capability	
				Entry time assessment & first mover advantage
				Competence analysis
	4		Protection	
				Effectiveness of protection
				Protection vs. diffusion
2		Development: Develop & manufacture the innovation into goods		
	5		Development	
				Designing and manufacturing in house vs. collaboration
				Process of developing the innovation
				Launch pad: Spinout subsidary or joint venture
3		Deployment: sell & distribute the goods		
	6		Deployment	
				Launch time
				Selling and/or licencing and compatibility
				Pricing
				Distribution
				Marketing

Adapted from: Datta, Reed and Jessup (2013).

I plan to borrow this concept of a layering framework in the building of the framework for this study whilst I am also answering to the call for further research. The following section explores the concept of commercialisation in a university or research institution as opposed to commercialisation in an organization.

2.4.2 Technological innovations commercialisation in academic and research institutions

Whereas Datta, Reed & Jessup (2013) and other researchers focus on the commercialisation of innovations in corporates, others turn their focus to the commercialisation of research outputs at universities and other research institutions. In this area of the exploitation of research, output is seen to mostly depend on a champion, just like the commercialisation of innovations within organisations. Likewise, Hsu et al. (2015) concluded in their study in Taiwan universities that the most critical driver in university technology transfer is that of the human capital, in particular, the staff involved in the technology transfer process. Further to this, in considering the critical aspects for the commercialisation of university-spin-off projects, Purchase, Kum and Olaru (2017) observed that the choice of the CEO is very important both because of their experiences, networks etc. as well in how they interpret and manage events along the innovation trajectory. This resonates well with Markham's (2002) call for champions as drivers of commercialisation in corporates.

One of the main challenges of the staff in the commercialisation office is that of working with academics, particularly those from the research faculty, who should be influenced to accept the concept of an entrepreneurial culture as Sideri and Panagopoulos (2018) discovered in their study at an Athens University. They also observed that quite often researchers battle with the thought of transitioning to an entrepreneurial environment as they feel that it impinges on the freedom to research a topic of choice. This is the same problem that was identified in commercialisation in corporates and arguably, one of the best ways to resolve it is to bring the researchers and the commercialisation staff to appreciate each other's function in the product chain. Kergroach, Meissner and Vonortas (2018, p. 527) opted for the policy route in addressing this dilemma as captured from their statement: "policy decision makers in advanced systems try to

cultivate cultures (behaviours) which bring the research and the transfer missions under one umbrella seamlessly, combining curiosity and scientific rigor with application-oriented transfer.”.

The failures to operationalise research were also discussed by D’Amico, O’Brien, and Larkin (2013) who called it the metaphorical ‘chasm’ in studying the failures of US government funded research to reach operational stages. As in Markham’s (2002) paper, they cited lack of appropriate skill and the absence of a driver (champion) and added on commitment and funding as the causes of the failure. The problems of commitment and funding were so prevalent, they said, to the extent where in their study, they did not find any project that had been adequately funded.

The journey from an invention to a commercialised product/system requires the driver to have different skills at different points according to D’Amico, O’Brien, and Larkin (2013). At the start of the journey, the driver should be good at generating ideas and producing a proof of concept whereas further on in the journey, the driver should produce a prototype. Further down the line, the skills set required changes to those of industrialisation and production.

In their paper based on lessons learned on the technology transitioning of US government funded projects, D’Amico, O’Brien, and Larkin (2013) identified key challenges of crossing the chasm (valley of death) and introduced some suggestions for ensuring a smooth technology transition. Some of the major challenges they discovered were the lack of suitably qualified/experienced staff, infrastructure, resources, tenacity and difficulties with bureaucracy. Amongst the recommendations was that of ensuring that early on in the project, a technology road map is developed.

Perhaps the success factors of commercialising an innovation starts at the innovation itself. Nerkar and Shane’s (2007) empirical research on the determinants of an invention’s commercialisation success concluded that the characteristics of the invention itself have an effect on its success. The characteristics included the age of the invention, its pioneering nature and the broadness of the invention’s scope or its patent. Concurring with this finding, a Swedish study (Lundqvist, 2014) on university

based incubators, amongst other things revealed that Information and Communication Technology (ICT) ventures have a shorter 'valley of death' and hence easier to cross than other types of ventures.

Although innovation is quite easily described as a journey from invention through commercialisation to product adoption, in the daily practice of the journey, it is prudent to define the progress through a number of stages/milestones. A NASA framework for assessing the maturity of technologies on the life cycle line was captured by Mankins (1995) through a NASA white paper. The framework divided the journey into nine levels of maturity of a technology and the levels were defined as follows:

- TRL 1: Basic principles observed and reported
- TRL 2:Technology concept and/or application formulated
- TRL 3: Analytical and experimental critical function and/or characteristic proof of-concept
- TRL 4: Component and/or breadboard validation in laboratory environment
- TRL 5: Component and/or breadboard validation in relevant environment
- TRL 6**:** System/subsystem model or prototype demonstration in a relevant environment
- TRL 7: System prototype demonstration in a space environment
- TRL 8: Actual system completed and "flight qualified" through test and demonstration
- TRL 9: Actual system "flight proven" through successful mission operations.

This framework was developed in 1974 by Stan Sadin, a NASA researcher (Banke, 2010) with seven levels only and later, in 1990 updated to include 9 levels. Since its full definition, other organisations have also adopted it with minor adaptation to suit their operations. These include the US' Departments of Energy (US DOE, 2009), Defence (Sauser et al., 2009) and Homeland Security (Mc Garvey, Olson & Savitz 2009). The system has also found use outside of the USA. The European Space Agency adopted it (ESA, 2008), for example. The system is constantly being reviewed and proposals made for its update. Straub (2015), for example, has been motivating for the inclusion of a 10th level which is defined as 'flight proven'. This study also uses

this model to define the position of each product on the TRL continuum. The study, in all three start-ups starts from TRL 5 where the technologies are ready for prototyping and testing in the relevant environments and ends at TRL 8 where the first-off production plants have been manufactured and production started and early stage marketing has commenced.

The Technology Readiness Level framework (TRL) and the 'Valley of Death' model were well combined by Upadhyayula et al. (2018, p. 407) to form a framework that allows one to see the full picture of an innovation as it progresses through its life cycle and transverses the valley of death as shown in Figure 2.3 below.

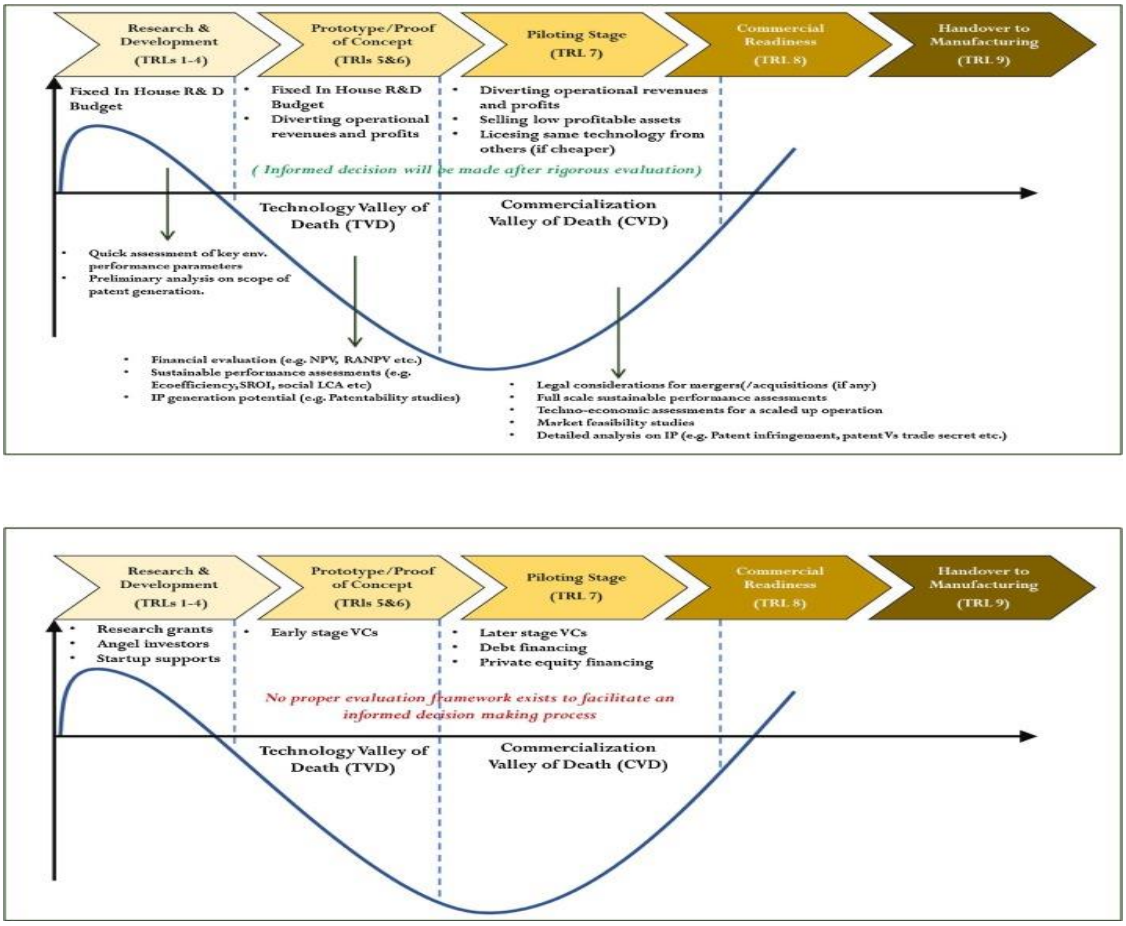


Figure 2.2: (source: Upadhyayula et al., 2018, p. 407)

(a) Typical emerging technology evaluation process in global innovation driven companies

(b) Emerging technology evaluation process in academic institutions/research labs

This framework was developed as a combination of a typical emerging technology evaluation process in global innovation driven companies, (a) and a typical Emerging technology evaluation process in academic institutions/research labs, (b). It was meant to show the lack of the evaluation framework within the valley for the academia commercialisation process and the presence thereof in the corporates' process. It is the lack of this evaluation framework for academia that reduced the probability of their innovations crossing the valley according to them. Upadhyayula et al. (2018) were inspired to develop the framework following their assertion that a lot of academia-developed innovations never get to be commercialized because of the lack of a proven framework that aids in informed decision making for innovations entering into the

'valley of death'. The challenges of not having a proven framework experienced by academia is also experienced by innovating start-up firms

In the description of the 'valley of death' by other writers like Markham (2002), the 'valley' was only limited to the technology development phase (TRLs 5 and 6) and the commercialisation aspects were placed after the valley. However, Upadhyayula et al., (2018) shifted the commercialisation phase (TRL 7) back inside the valley because of the low levels of success in this stage too.

Perhaps of importance in this framework is the link between the TRLs, the 'valley of death' and the associated typical funding and commercial activities throughout the process. Unfortunately in South Africa and most other developing nations, universities and other research institutions deposit their research outputs at the onset of the 'valley', TRL 4, and expect industry to get involved from there onwards. On their part, Industries wait at the exit of the valley, TRL 8 for intellectual properties ready for commercial purposes. There seem to be a lack of champions and possibly funding to drive technologies through the valley.

Another aspect that has at times been singled out as a cause for the transition failure is government policies. This view does not get shared by all researchers. A desktop study in Australia on the barriers to university research output commercialisation, amongst other things in its conclusions, noted that there is an effort on the part of government structures to give direction on the role of universities in the commercialisation of its research and in what format should government support be (Harman, 2010). The paper also revealed the call for more funding into the universities for research commercialisation by some academics whilst government was going on the route that universities do not have adequate capabilities in this area and would rather explore other avenues of ensuring the success of research output.

The lack of entrepreneurial skills and other attributes at universities was also cited by other writers including van Geenhuizen and Soetanto (2009) and Gredel, Kramer & Bend (2012). Some ways of addressing this dilemma has been to encourage stronger networks between academia and industry (Bourelos, Magnusson and McKelvey,

2012) and also to look to university based incubators that would take the research output to the point where it is commercially ready (Lofsten & Lindelof, 2005; Bergek & Norrman, (2008).

Perhaps one sure way of accelerating commercialization at universities is through these incubation programs. Literature is clear on the advantages of using incubators for research commercialisation (Culkin, 2013). The incubators provide a platform for turning research into functional products ready for industrialisation in preparation for markets. However, incubators are not without their challenges and therefore need to be managed well in order to realise their benefits fully. Xiao1 and North (2017) in their study involving 215 Technology Business Incubators (TBIs) across 90 Chinese cities concluded, amongst others, that the provision of development facilities including laboratories, equipment and entrepreneurial mentorship are key to speeding up the early development of resident projects. The authors also described the concept of 'paths' along the innovation category. In their description, the paths are separated into two categories: the commercialization and the technical categories. Thus decisions on key events along each path could have major impact of the convergence of the paths, affecting the success of the business.

2.4.3 Technological innovation commercialisation in start-up firms

The concept of incubators can also be used in the case of start-ups. Sometimes, though, incubators are not always the answer for innovation start-up. Although having had more difficulty with her first start up which was self-sponsored and finding it easier with her second start up, Kirkpatrick (2015), still proceeds to advise one to consider their innovation and circumstances before favouring the incubation model. The main questions to ponder on at the onset of a start-up are to do with space and facility requirements such as laboratory equipment, internet, and back-up power for freezers, etc. Kirkpatrick (2015) writes of the many incubators available for life sciences star-ups in the USA, allowing for options for an aspirant start-up.

Unfortunately for most innovators in South Africa, and most probably in other developing nations as well, the option of an incubator is not always available although most of their barriers are what the incubators address. For these innovators the

support mechanisms on both the left hand and right hand sides of the 'valley of death' as described by Markham (2002) are not readily available. In addition to this shortfall, the young innovators would have more challenges. A research conducted by Cho, et al. (2013) did confirm this dilemma for developing nations' young innovators in the health services sector. The authors attributed the failures to the complexities of a country's National Innovation Systems and its environment as well as global dynamics which impacts technology, business and social sectors and which may in turn have an effect on the discovery and development of innovations. In their literature based research, the above authors noted that innovators, irrespective of whether they are in high income countries or developing nations, required mentorship, training and support in order to cross the chasm.

The commercialisation challenges for Small, Medium and Micro Enterprises (SMMEs) seem to remain the same even in the developed world. SMMEs entering the renewable market in Holland who were surveyed indicated finance, networks, certification, human capital and product development as some of the major challenges (Meijer, et al., 2019). Elsewhere, in China, technical support facilities and mentoring came out tops in enhancing the performance of start-ups in TBIs (Xiao and North, 2017 and Choo, 2007). The innovators participating in this research, who face the challenge of taking their innovations through the development and deployment phases, crossing the valley of death in the process, with all its many challenges without organisational or institutional backing do certainly need these identified support interventions.

Human capital has been consistently mentioned as a challenge in commercialisation. This study sees this as being into two categories. The first of this is to do with the pool of qualified and experienced resources start-ups would have access to in their growth and this is a function of the government policies and implementation which are beyond the scope of the study. The second is to do with the innovators themselves having the capability to commercialise and be entrepreneurial and this is the one aspect that the study will consider. One of the ways this second challenge can be addressed is through mentorship. My role in all the three projects of this study was that of a mentor and therefore I decided to investigate the mentorship as a stand-alone theme.

2.5 Mentoring technological innovators

In literature, the benefits of mentoring are widely acknowledged. Robinson (2001) as cited by Abiddin (2006, p. 107) posited that arguably mentorship is the best way to transfer knowledge and skills between individuals. Roberts (2000) acknowledged the complexity of the concept of mentoring and noted that there was a lack of consensus as to what constitutes mentoring in literature.

Katherine F. Schrubbe (2004), in the field of education, approached mentorship from the activity point of view rather than positing a definition. She put mentorship as a process where a mentor would take a protégé and offer them inspiration, guidance and encouragement which if successful leads into a motivated, productive and good researcher and teacher.

This study uses the approach of Schrubbe (2004) who described the characteristics of a good mentor through the three 'C's, namely competence, confidence and commitment. The study also relies on Dawson (2014) who argued that it is pointless to continue creating more definitions considering that Crisp and Cruz (2009) had counted up to 50 different definitions of the concept in literature. In trying to assist researchers on the concept to converge to a common language, Dawson (2014) proposed the use of a framework rather than using any of the different definitions or even creating new ones. The proposed framework was made up of sixteen design elements which he said that they are the basis for any mentoring model or intervention in one way or another. The sixteen design elements that form the framework (Dawson, 2014, p. 140) are the following:

1) Objectives: the aims or intentions of the mentoring model;
2) Roles: a statement of who is involved and their function;
3) Cardinality: the number of each sort of role involved in a mentoring relationship;
4) Tie strength: the intended closeness of the mentoring relationship;
5) Relative seniority: the comparative experience, expertise, or status of participants;

6) Time: the length of a mentoring relationship, regularity of contact, and quantity of contact;
7) Selection: how mentors and mentees are chosen;
8) Matching: how mentoring relationships are composed;
9) Activities: actions that mentors and mentees can perform during their relationship
10) Resources and tools: technological or other artefacts available to assist mentors and mentees
11) Role of technology: the relative importance of technology to the relationship
12) Training: how necessary understandings and skills for mentoring will be developed in participants
13) Rewards: what participants will receive to compensate for their efforts
14) Policy: a set of rules and guidelines on issues such as privacy or the use of technology
15) Monitoring: what oversight will be performed, what actions will be taken under what circumstances, and by whom
16) Termination: how relationships are Ended

My engangment as a mentor with the three start-ups used some of the elements as guidelines. The tailoring was necessary because my engagement with the start-ups could not be concluded as a mentor only because the use of the action research approach in the study also required me to be a participant and preferably one who can initiate changes. In addition, the study also includes the need to investigate support interventions which means that I would also be offering tangible support assistance. However, a good understanding of the elements is necessary in that I should be paying particular attention to any occurrence, throughout the study, that may have implications related to them and include these in the results.

The importance of mentoring young innovators has been drummed up by a lot of writers over the years (Wahyudi & Tileng, 2017; Cohn, Katzenbach & Vlak, 2008; Cole, 2015; Emerald Publishing, 2009). One of the most powerful and clear messages amongst these proponents, and one that is applicable to South Africa is that by Cho et al. (2013. P. 163) who said: “Young innovators in both high income countries (HICs)

and low and middle income countries (LMICs), who aim to achieve equitable health outcomes through innovation, must receive the proper mentorship, training and support so that they are better able to navigate complexities and mitigate gaps in skills, knowledge or resources during the innovation process". Cho et al. (2013) in their conclusion, strongly called for more rigorous research and evaluation in order to investigate better programs for mentoring, training and supporting innovators for the success of their field of global health. Although the article is located in the health sciences, the statement is true for the rest of the hi-tech innovators and even beyond.

Mentorship has also been placed in the top three support interventions in the commercialisation of technological innovation. One such example is the Chinese Technology Business Incubators (TBI) study covering over 215 TBIs across 90 cities and run over a five year period which placed entrepreneur mentoring in second place after investment in technical platforms with respect to affecting speeding up the early development of resident firms (Xiao & North, 2017).

Complementing this call for the mentoring of innovators is the call for mentoring of potential entrepreneurs by Deepali, Jain and Chaudhary (2017) through their study on the topology and effectiveness in the Indian context. The authors argued that when policy makers are developing policies on entrepreneurship, they should also consider policies of the associated mentors. Their study identified at least 20 different types of mentors in the entrepreneurship sector and advocated the careful matching of mentors and mentees. Surprisingly, contrary to popular belief, their study found that potential entrepreneurs preferred mentors from academia and others with varied experiences other than those from industry.

This preference by mentees for academia mentors could be challenged by an earlier study on Surrogate entrepreneurs run in 170 Swedish Universities over a fifteen year period (Lundqvist, 2014). In the study, Surrogate entrepreneurs are defined as those experienced entrepreneurs that are brought from outside university incubators to act as mentors. The study concluded that those ventures within university incubators that practised surrogate entrepreneurship performed better that those that did not.

Whilst concurring with other researchers that mentoring is indeed critical for the survival of start-up enterprises, Deakins et al. (1998) warned that it should not be too interventionist but well balanced and the proper training of the mentors was key to achieving this balance. Amongst other findings, Deakins' (1998) study also found that mentoring alone is not sufficient to giving life to start-ups but the provision of support by the mentor in form of networks, etc. is crucial.

Other writers on mentoring have even gone further in analysing other aspects of mentoring like the different models (Kumar, 2018) and the communication strategies in a mentoring relationships (Lefebvre & Redien-Collot, 2013). On the communications aspects, from their empirical study at a university incubator in France, Lefebvre and Redien-Collot, (2013) discovered that there were four main strategies associated with the interpersonal communication in the mentorship process. The four strategies are persuasive, engagement, criticism and provocative and each seeks to achieve its own goals. The authors recommended that entrepreneur mentors need to understand what they want to achieve from a project at any point in time in order to select the most appropriate communication strategy.

Going deeper into mentoring, another empirical study in the same country, China, started off with the position that entrepreneur mentoring had not been effective enough because of the heterogeneity of the mentors as they had different experiences and knowledge as well as that most mentors were government employees who may not have the intention of mentoring in themselves (Ting, Feng & Qin, 2017). Through quantitative method, they discovered that for an entrepreneur mentorship to be effective, the mentor should have the right intentions that will ensure active care, personal demonstration and responsibility. They, thus, recommended the spurring of enthusiasm amongst mentors. Perhaps this is a call for volunteer mentors as advocated in this study as they are likely to be self-motivated.

In addition to this finding and recommendation, Ting, Feng and Quin (2017) also discovered that the mentee intention and level of absorption and the matching of the mentor and mentee also have significant effect on entrepreneur mentoring. In addition, they proposed training of entrepreneur mentors in order for the Chinese government

to create more mentors considering that there was a shortage of experienced mentors in the country.

The need for managing the mentoring process was also picked up elsewhere in America. Upon realising that it's MD and PhD. students play a vital role in mentoring young undergraduates in the laboratories, Weill Cornell, Rockefeller, and Sloan-Kettering Tri-Institutional MD-PhD Program created a mentor-training program for its MD-PhD students (Gotian, 2016). In the paper, he stressed that having subject matter knowledge alone does not equip one to perform the roles of a mentor.

Whilst Dawson's (2014) sixteen design elements for mentoring were targeted at providing a universal definition of mentoring, a more innovation/entrepreneurship framework had earlier been developed by Choo (2007). A telephone based research in organisations that provide innovation commercialisation services culminated into this mentoring framework for technopreneurs. He developed the framework on the back of his understanding that hi-tech organisations, particularly SMEs are continually being pressured to produce very innovative and high quality products at a fast pace to rise above competition. He observed that the pressures were made worse by the constrained resources available to these firms. Choo (2007) further noted that in most parts of the world, various profit and non-profit incubators have risen up to provide support services to help alleviate the challenges and he saw a gap of mentorship within the support which he believed needs to be provided in a systematic manner. In his own writing, Choo (2007) highlighted the scarcity of empirical research on the role of mentoring in start-ups and, he questioned whether intra-organisational developed programs would translate into business start-ups.

Choo (2007), in his research, discovered that there were four non-negotiable key aspects that drove success in mentoring and he termed these 'processors of success.' The four processors are the quality of the mentor, the capabilities of the incubating organisation, the management of relations and finally but not least, the provision of support services. The resulting framework is summarized in Figure 2.1 below:

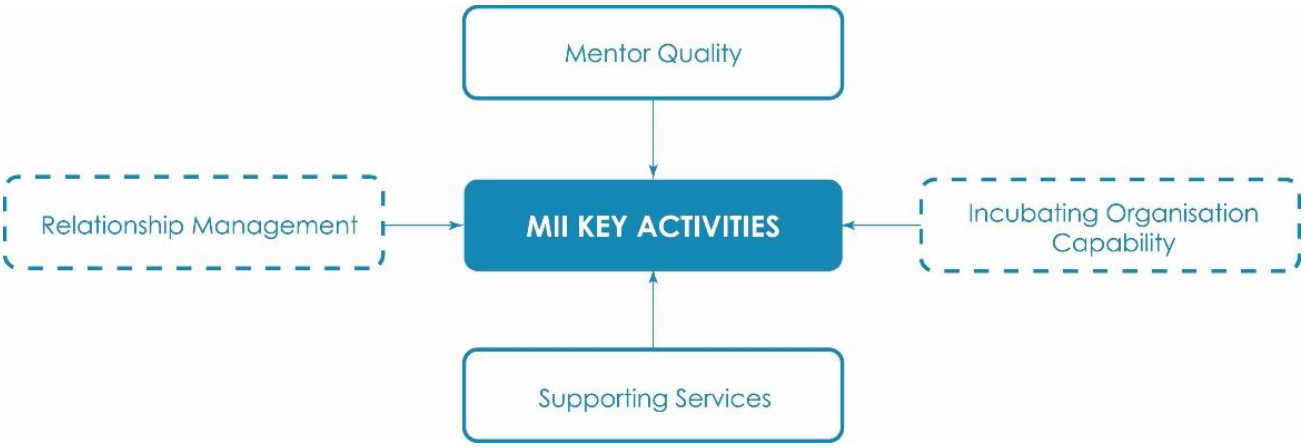


Figure 2. 3: Processors of success (Adapted from Choo, 2007:p. 160)

In this study, the relational management aspects are largely dictated by the action research approach which requires that the researcher be part of the study and also have the power to make some changes in the activities and evaluate their effectivity. The incubating organisation capabilities aspect is not considered in the study as the commercialisation is not taking place in an incubator. The supporter/mentor is therefore required to assist in the realisation of the functions that could have been undertaken through the incubation process. Thus, quality of mentorship and support services are the only processes of success in the study's set up.

The revelations in the above review could then suggest that those innovators operating outside of the organised institutions like incubators, the start-up firms in this study, have to have networks that would provide them with access to development and prototyping facilities, amongst other infrastructure business requirements. Thus the role of mentors, who should be appropriately qualified and matched, in these self-sponsored transition journeys from innovator to entrepreneur has to be extended to cover the ensuring that support (networks, facilities, technical assistance, etc.) are provided for in order to give the process a chance to succeed.

2.6 Technological innovation in the African and South African context.

The importance of technological innovation in Africa and South Africa in particular has been covered by several researchers and policy makers. The challenges

associated with innovating the technologies have also been captured in the papers and statements. In the African context, a study by Setayesh and Daryaei (2017) of eight Islamic countries which included Nigeria and Egypt, presented a strong correlation between innovation and economic growth indices further strengthening the importance of innovation in the quest for such growth. The study also linked innovation with human capital and research which basically argues that in national innovation policy particular attention should be given to researchers/innovators. The World Bank has also weighed in on the importance of innovation to the economy and has produced innovation policy guidelines for developing nations (Word Bank, 2010). The World Bank Institute went as far as declaring in the publication that innovation was at the top of their programs. They encouraged nations particularly developing ones, including South Africa, to study success stories from other nations and incorporate the innovation fundamentals in their policies.

At a national level in South Africa, the link between innovation and economic growth was emphasised by the Department of Science and Technology's white paper which posited that: "A national system of innovation can only be judged as healthy if the knowledge, technologies, products and processes produced by the national system of science, engineering and technology have been converted into increased wealth, by industry and business and into an improved quality of life for all members of society" (Government Printer, 1996, p. 19). In support of its statement, the South African government has developed an inclusive National System of Innovation (NSI). It has also generated other related policy document like the White Paper on Science and Technology (Government Printer, 1996) revised in 2019, the National Research and Development (Government Printer, 2002) and the Innovation Towards a Knowledge-based Economy, 2008-2018: Ten-year Plan for South Africa (Government Printer, 2007).

However, in spite of the realisation of the importance of innovation in the development of a nation's economy, the level of technological innovation still remains very low in Africa. The low levels of innovation could be explained by looking at some of the factors that have impact on it. Christensen, Ojomo and Bever (2017) identified four major obstacles for the lack of innovation/entrepreneur growth

in Africa. The four obstacles were institutionalised corruption, lack of infrastructure, shortage of appropriate skills and finally, the low market base both at middle class and lower levels of the economy. The study also found that there are those home grown businesses that are following the 'pull economy' type of business innovations who seem to be doing well in the midst of the obstacles. Another challenge affecting innovation and entrepreneurship growth articulated in the paper was that the promises of a booming middle class as well as poverty alleviation projects business in Africa were not materialising and therefore causing multi-nationals to pull out of the continent. Without doubt, this would make venture capital (VCs) funders very risk averse and perhaps leading to low game changing/disruptive innovation funding.

In both the academic world and industry, it is widely known that the challenges in developing innovations and entrepreneurships in developing countries like in Africa are not always the same as those experienced in developed countries. An interview with key World Bank officials on innovation in Africa gave some insight into the challenges faced in the developing nations (African Business, 2013). The interview clearly identified targeted technical assistance and appropriate financing as major challenges to early stage enterprises. The World Bank officials strongly recommended the use of incubation systems which would invariably include mentoring and support provision programs to reduce these early stage risks. Infrastructure and market access were also mentioned as key enablers to the success of innovations in Africa.

On the African continent, South Africa is rated high in its capabilities for innovation as was shown in the study that looked at the level of technological innovation in eight African countries. This evaluation was based on their international exchange as well as other factors such as public investment, real gross domestic income and foreign direct investment between 1981 and 2013 (Ngameni and Khan, 2019). Another study that ranked South Africa at the top was the cluster analysis conducted by Mayor, de la Hera, and Ruiz (2012) that evaluated the technological innovation capability of thirty countries in Africa based on literature on national innovation capability. South Africa was placed in a group of its own way ahead of the other countries who were grouped into three levels. The study considered three factors: Governmental and business technological effort, the technological infrastructure and human capital (Available

Base) and the protection of intellectual property and innovation results. South Africa's lead in this was helped largely by the large number of patents it registers and it was placed third and sixth respectively in the other two factors.

Although it is rated high on the continent, South Africa still experiences low level of innovation by world standards. This low level of innovation implementation was confirmed by amongst others, Lubango and Pouris (2010), who observed that most technological innovation patents in South Africa are not absorbed and of those that are absorbed, the majority get used in foreign industries with very few being commercialised in the country. Perhaps the low levels of absorption of the research and development could be attributed to the chasm that is widely experienced in the country where most of the research institutions and universities fail to get industry to take on their research. Industry is more interested in innovations that have already crossed the 'valley of death' (Markhan, 2002) and the institutions and universities do not have the resources to take the product across this 'valley'. In one specific case of challenges with the commercial implementation of university-developed research for waste valorisation technologies within the mining sector, Stander and Broadhurst (2021) found that technical and financial feasibilities were amongst the vital factors affecting uptake of inventions. A similar study conducted in several local government-funded universities investigated the reasons for the low commercial implementation level. The research attributed the challenges to four main factors which were the lack of funding, limited entrepreneur culture, weak links between universities and industry and the low priority view for commercialisation by university management (Bansi, 2016). Apart from the need for a champion in commercialisation activities in the country, the inadequacy of the entire human capital for the tasks has also been constantly indentified. Human capital deficiency was identified as a shortfall in the quest for the commercialisation of university research output by Gachie and Govender (2017) in their study regarding the commercialization of higher education institutions' research within the country's National System of Innovation. Amongst other challenges hampering sustainable research commercialisation, they identified a lack of adequate commercialisation skills and the conflicting priorities between focusing on educating against on entrepreneuring by the university staff.

There is still an effort, though, by universities across South Africa who are experimenting with launching enterprise entities that aim at commercialising research in order to address the need to generate “third stream income’ amidst the diminishing funding (De Villiers and Steyn, 2009). This arrangement is still not without its challenges. It is still being affected by the weak relationships between industry and the academic instituions.

Even in the case where an invention has been commercialised, sustainability of the entities is not guaranteed as was observed from the study conducted by Glenda Kruss (2008) where she researched three high-technology university research spin-offs. In the study, two of the spin-off failed outright due to misalignments between the firm and the market and between the university and the industrial sector. The third struggled further on in its early life as a result of misalignment between itself and a critical global supplier. Kruss concluded that it is difficult to sustain competitive spin-off firms in South Africa because of the fragile nature or limitations of the country’s system of innovation.

Technological innovation in industries in South Africa has also got its challenges and there are a number of studies on the subject. One such study is on innovation in the water sector by Rose and Winter (2015) which concluded that in spite of the efforts by government over the twenty year period (1994-2014) to strengthen the innovation systems in the country, “…the current innovation policies are not yet effective in changing practices, outcomes and impacts on the knowledge economy, and in meeting the developmental agenda”. The study recommended, amongst other things, the promotion of knowledge-related infrastructure and data sharing and the strengthening of funding and support for entrepreneurships and start-ups. They also advocated for the creation of competency centres for industrial design and the establishment of market analysis capabilities.

Another study of commercialisation by South African industry looked at the challenges of the Carbon Capture and Storage (CCS) technological innovation system (TIS). The study, by Ko, Zigan and Liu, (2021) exposed a number of factors that could also play a role in technological innovation in the country, and by extension in other emerging

economies. The study showed that the TIS approach, in its current form, does not take into account the required focus on political and institutional dynamic that were necessary to support the effective commercialisation of new technologies in emerging economies. This could be in line with what Bergek, et al. (2015) identified as a 'political context structure' amongst three other structures that she said interact with TISs. The study also came up with two other recommendations worth considering in any TIS in the country. The first of these was the need for a strong alignment between government policies and resources allocation for the effective implementation of innovation. The second was a call for government to establish clear political mandates and legal frameworks to manage the interests and objectives of incubaters, corporates and start-ups, in order to ensure investor confidence. The study found that "market structures, as well as institutional and system structures, need to function well to avoid failure when introducing new technology innovation" (Bergek et al., 2015, p 8). South Africa has several technological innovation systems, one of which is that of the 'hydrogen economy'. The department of Science and Innovation in partnership with industry is concluding plans to turn the rich platinum belts in the country into hydrogen which will be the catalysts for the initiative (ENGIE Impact, 2021).

The management research literature in South Africa seems to be rather limited when it comes to technological innovation in start-ups. However, aspects of this are to some extent contained in literature on Small, Medium and Micro Enterprises (SMMEs), entrepreneurship, and in some cases start-up businesses in general. This section will therefore rely on papers on these for its review. From the SMME literature, it would seem that the main prevalent call is on investment into this business area (Berry, et al., 2002; Rogerson, 2008; Booysen, 2011). Other challenges uncovered in the South African SMME innovation environment include low market base (Berry, et al., 2002), human capital and training (Rogerson, 2008 & Booysen, 2011) and government regulations on SMME support (Rogerson, 2008; Rose and Winter, 2015).

An empirical study focusing on factors influencing the establishment of start-ups in South Africa, particularly in Gauteng, the country's economic hub identified four main factors influencing the development of start-ups (Van Vuuren, and Groenewald, 2007). These were personnel management and involvement; role models; effective time

management; and support from partners and mentors. A similar study in another province, Kwazulu-Natal, this time looking at the bankability of start-ups advocated the preparation of a good feasibility study and business plan and selecting the appropriate seed capital funder (Bamata, 2018).

It is widely accepted that the survivability of start-ups is greatly enhanced through incubators. That said, most of the incubators in South Africa are business incubators and do not pay particular attention to technological innovation start-ups. Most of them focus on general entrepreneurship. Some of the ones I visited had enterprises in them who had been resident for over five years with no plan for growth or exit. It seemed the incubators in this case are there to offer cheap accommodation and in some cases access to market. However, there are some success stories. One in particular is the Gauteng Climate Innovation Centre which one could say is based on the TIS framework although it is not documented as being such. A case study conducted on the incubator (Gonsalves and Rogerson, 2019) confirmed the classical aim of an incubator of providing support for access to funding, markets, facilities, networks and mentoring. The incubator also offered business and limited technical training as well as limited seed capital. The management of the centre emphasized that their main offering is mentorship and they pay special attention to this support intervention. Surprisingly, the incubates also rated mentorship as the most valued intervention they received. Access to funding was rated second with networking third and infrastructure fourth. Intellectual Property protection was also mentioned in the rating.

From the foregoing, it is becoming clearer that in spite of the realisation of the importance of technological innovation in an emerging country like South Africa, commercialising the available inventions still remains a challenge. The challenges emanate from several quarters including government policy, systems of innovation, institutional inadequacies as well as the expected commercialisation entities like corporates and start-ups. Technological innovation start-ups in particular, with a much more constrained resource challenges require a special consideration and hence the need for targeted studies for them.

2.7 Conclusion

The intention of the literature review was firstly to obtain an understanding of the four concepts associated with the research, namely, technological innovation/innovators, start-up firms, technological commercialisation and mentoring, and secondly, to investigate the support interventions that have been identified as being needed to successfully commercialise inventions through start-up firms.

In summary, the literature has provided basic understanding of the four streams of literature and how they relate to each other. Section 2.2 has firstly described technological innovation and also shown its importance in assisting with the growth of a country's economy. The different types of technological innovation have been described and located within the various innovation frameworks. From the frameworks, the innovations in all the three start-ups have been identified as technological innovations of products which are closer to radical than incremental.

As this action research study is conducted in start-ups, section 2.3 has been dedicated to describing these firms in addition to the technopreneurs that create them. The literature has revealed the growing importance of start-up firms in the commercialisation of technological innovations. Section 2.4 has firstly defined commercialisation of technological innovations and also touched on some of the frameworks used by other researchers. This section has also described commercialisation of technological innovations within large organisations and research/academic institutions before going on to describe it in the context of start-ups, where this study was conducted. From this literature, the 'Valley of Death' framework developed by Upadhyayula et al. (2018) based on the Technology Readiness Levels Model (Mankins, 1995) and the Valley of Death framework (Markham, 2002) was chosen to form the combined innovation, commercialisation and entrepreneurship base of my research. The typical emerging technology evaluation process in academic institutions/research laboratories (framework b, fig. 2.2) will be used as it is closer in application to the self-sponsored commercialisation situation especially from TRL 4 to 7. Challenges associated with the activities related to commercialisation have been identified and some solutions suggested. One of the key suggestions was the use of a structured mentoring process.

Section 2.5 has been dedicated to describing the concept of mentorship and how it relates to the commercialisation of technological innovation particularly in start-up firms. Of particular interest in this section, Dawson's sixteen design elements (2014) have been used in the study to guide my mentorship contract with each of the start-up firms. The final section, section 2.6 has been dedicated to investigating the state of affairs regarding the commercialisation of technological innovations in South Africa. This has set the argument for the need to investigate further the needed interventions where inventions are being commercialised by start-up firms.

Throughout the literature review, in keeping with the thematic approach to data capture and analysis, I identified themes related to interventions needed for commercialisation and thereby constructed a Theoretical Commercialisation Framework Template (Table 2.2). This framework will be used to guide the action research project with the three collaborating start-ups. In short, the framework will guide avenues of action (including data collection) and reflection with the start-up entrepreneurs. The details of the action research methodology are discussed in the next chapter.

Table 2. 2: Support Interventions for commercialisation Framework template

No.	Theme	Sub-theme	Identified in literature
1	Finance		
1.1		Funding	D'Amico, O'Brien, & Larkin (2013); (Harman, 2010); Christensen, Ojomo & Bever (2017); Meijer, et al. (2019); Berry, et al. (2002); Rogerson (2008); Booysen (2011); African Business (2013)
2	Networks		
2.1		Networks	Geenhuizen & Soetanto (2009) and Gredel, Kramer & Bend (2012); Markham (2002); Meijer, et al. (2019)
3	Collaboration		
3.1		Collaboration	Bourelos, Magnusson & McKelvey (2012)
4	Human Capital		
4.1		Human Capital	Hsu et al. (2015); Gachie & Govender (2017); D'Amico, O'Brien, & Larkin (2013); Christensen, Ojomo & Bever (2017); Rogerson (2008) & Booysen (2011); Meijer, et al. (2019)
4.2		Champion/CEO	Markham (2002); Purchase, Kum & Olaru (2017)
4.3		Technical skills	Berry (1996)
4.4		Development skills	Datta, Reed, & Jessup (2013)

4.5		Deployment skills	Datta, Reed, & Jessup (2013)
4.6		Product development	Meijer, et al., 2019; Markham (2002)
4.7		Commercialisation skills	Gachie & Govender (2017); Markham (2002)
4.8		Industrialisation skills	D'Amico, O'Brien, & Larkin, (2013)
4.9		Production skills	D'Amico, O'Brien, & Larkin, (2013)
4.12		Training	Cho, et al. (2013); Rogerson (2008); Booysen (2011)
5	Commitment		
5.1		Commitment	D'Amico, O'Brien, & Larkin, (2013)
6	Entrepreneurship		
6.1		Entrepreneurship	Geenhuizen& Soetanto (2009); Gredel, Kramer & Bend (2012); Markham (2002)
7	Facilities/infrastructure		
7.1		Facilities	Xiao1 & North (2017; Kirkpatrick (2015); Christensen, Ojomo & Bever (2017); D'Amico, O'Brien, & Larkin (2013); Choo (2007)
7.2		Infrastructure	D'Amico, O'Brien, & Larkin (2013)
7.3		Resources/expertise	D'Amico, O'Brien, & Larkin (2013)
8	Incubation		
8.1		Incubation	Lofsten & Lindelof (2005); Bergek & Norrman (2008); Culkin (2013)

9	Policy		
9.1		Government policy	Cho, et al. (2013); Berry, et al. (2002); Rogerson (2008); Booysen (2011); Rose & Winter (2015); Berry (1996); Harman (2010)
9.2		Corporate policy	
9.3		Institutional policy	Kergroach, Meissner and Vonortas (2018)
9.4		Bureaucracy	D'Amico, O'Brien, & Larkin (2013)
10	General Management		
10.1		Tenacity	D'Amico, O'Brien, & Larkin (2013)
10.2		Technology roadmap	D'Amico, O'Brien, & Larkin (2013)
10.3		Strategic awareness	Berry (1996)
10.4		Intellectual property	Datta, Reed, & Jessup (2013)
10.5		Evaluation framework	Upadhyayula et al. (2018)
10.6		Business processes	Berry (1996); Markham (2002)
11	Characteristic of invention		
11.1		Characteristic of invention	Nerkar & Shane's (2007); Lundqvist (2014)

12	Entrepreneur mentorship		
12.1		Entrepreneur mentorship	Xiao1 & North (2017); Cho, et al. (2013)
13	Market		
13.1		Marketing skills	Berry, et al. (2002); Rogerson (2008); Booysen (2011); Christensen, Ojomo & Bever (2017); Islam (2017); Datta, Reed & Jessup (2013)
13.2		Low market base	Berry, et al. (2002); Rogerson (2008); Booysen (2011); Christensen, Ojomo & Bever (2017)
13.3		Market value	Markham (2002)
14	Certification		
14.1		Certification	Meijer, et al., (2019)
15	Mentorship		
15.1		Mentorship	Xiao1 & North (2017); Cho, et al. (2013); Wahyudi & Tileng (2017); Cohn, Katzenbach & Vlak (2008); Cole (2015); Deakins (1998); Deepali, Jain & Chaudhary (2017); Choo (2007)
15.2		Confidence	Schrubbe (2004)
15.3		Competent	Schrubbe (2004); Ting, Feng & Qin (2017); Gotian (2016); Choo (2007)
15.4		Commitment	Schrubbe (2004); Ting, Feng & Qin (2017)

15.5		Mentee level of absorption	Ting, Feng & Qin (2017)
16	Support		
16.1		Support	Cho, et al. (2013); Deakins (1998); Choo (2007); African Business (2013)

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This study was conducted with the objective of investigating the interventions required for the commercialisation of technological innovations in South Africa through start-ups and generating an actionable framework from the findings. It also had another aim of assisting the innovators to succeed with their endeavours and ensuring that they learn from the experience for future commercialisation projects as well as any mentorship roles they may embark on. In order to achieve this, the following two questioned are used and the methodology is so planned that it answers these questions:

Question 1: *What support interventions are needed in the commercialisation of technological innovations through start-ups firms in South Africa?*

Question 2: *What are the implications of this analysis for mentors and other technology support agents who seek to aid the commercialisation of technological innovations within this context?*

The study was conducted in three hi-tech start-up firms (introduced in section 1.3.2) that were all in the processes of commercialising their technologies. The technologies involved were not invented in a corporation or a university but by the innovators themselves and as such did not go through formal research processes. At the time the study data collection started, initial invention (research) had been completed and each one was ready to start with the commercialisation process.

Each company had two main founders, all first time entrepreneurs but with qualifications ranging from first degree to doctorate degrees and also with several years employment experience. These six innovators were the main participants of the study. Complementing the number of the participants was another three more who were brought in to refine and validate the findings of the study based on their experience in commercialisation of technological innovations and also their successes

as entrepreneurs. In all the three companies, my role was that of mentor for both commercialization and business management and supporter through the provision of some funding and any other requirements that emerged in the process. My involvement came about through invitations for assistance by each of the companies. I have been a private entrepreneur for well over twenty years and I have commercialised two technologies and also founded and sold several companies.

A depiction of the scaffolding process, which this study plans to utilise, was the 'research onion' presented by Saunders, Lewis and Thornhill (2019). In this depiction, the process starts from the onion's outer layer which contains both ontology and epistemology (the philosophies). This is followed by a layer for the approach (inductive vs deductive), then that of the methodological choices (quantitative vs qualitative). The three inner layers contains the strategy, the horizon and the techniques and procedures respectively. The horizon layer will not be considered in the study. The study's research design is described below, layer by layer. Two other sections are added to the design after the section of methods and techniques. These are the discussions on the quality of the research and that of the ethics considerations. Then finally the chapter is summarised in the conclusion section.

3.2 The research philosophy

Most writers on research practices seem to agree that in any research, the researcher will make a number of personal assumptions that will evidently direct the research question, approaches, methodologies, strategies and methods (Creswell, 2013; Easterby-Smith, Thorpe and Jackson, 2013; Johnson and Duberley, 2012; and Saunders, Lewis and Thornhill, 2019). These assumptions are generally drawn from ontological and epistemological philosophies. Awareness of these philosophies, Easterby-Smith, Thorpe and Jackson (2013) wrote, "can both increase the quality of the research and contribute to the creativity of the researcher" (p17-18).

Ontology is defined as "the nature of reality and its characteristics" (Creswell, 2013 p.20). Each of the sciences, natural and social have their differences in the way they see reality. The natural sciences, in general, see there being only one truth (realism)

or whilst acknowledging its existence, deem it to be obscure (internal realism). Research in the social sciences, on the other hand, are divided between those who say there are many truths (relativism) and those that do not acknowledge the existence of truth (nominalism). In this study, I take the view that my result will represent only one framework view and any other researcher would come up with a different framework hence I follow the relativism position.

Epistemology which is described as being about the best ways of enquiring into the nature of the world (Easterby-Smith, Thorpe and Jackson, 2013). As for the ontology, the natural and social sciences has their own debates anchored by positivism and constructionism, respectively. The debates within each science are about the strength of each characteristic, where one is strong positivism and normal positivism and the other is normal and strong constructionism. The positivism philosophers believe in using objective research methods where the researcher is outside the research. The constructionism philosophers, on the other hand, takes the view that reality is subjective and socially constructed by people. They allow for the researcher to be in the research. In this study, the results will be unfolding as the participants experience their daily activities and also I will be present in those daily activities. Thus the social constructionism characteristic is assumed for the study.

3.3 The Approach to theory development

Going back to the ‘research onion’ depiction, the second layer was that of approach to theory development also called the thought process of reasoning by Cooper and Emory, (1995). In any research, the researcher is required to use a logic in order for them to come to an inference. The two common types of reasonings used in research are deductive and inductive.

Deductive reasoning involves identifying a theory and testing it through rigorous research methods to establish an inference that is said to be conclusive. Inductive reasoning, on the other hand, employees a bottom-up approach that starts with collected data and develops theories that explain the meaning of the data (Saunders, Lewis and Thornhill, 2019). Those research designs that involves moving from theory to data and back to theory, etc. are known as abduction reasoning (Saunders, Lewis

and Thornhill, 2019) or complex reasoning (Creswell, 2013)and are a combination of both the deductive and inductive reasonings.

This study will follow the abduction/complex reasoning as it will start with the development of themes from collected data to develop theory, (inductive reasoning), and then constantly test the themes through engagement with expert participants (deductive reasoning).

3.4 Methodological choice

The next onion peel following that of the approach to theory development is that of methodological choices which are drawn from the philosophies and approaches to theory development (Saunders, Thornhill and Lewis, 2019). The distinction between the methodological choices in research is very loose as researchers have been known to use both of them at different stages in a single research. However, it is generally considered that the realism ontology and positivism epistemological philosophies are associated with a deductive reasoning and a quantitative methodological choice. In the same vein, qualitative choices are associated with an inductive reasoning and relativism and social constructionism philosophies (Saunders, Thornhill, and Lewis, 2019).

Creswell (2013) suggested several instances when qualitative research can be used. One of these instances, he wrote, is when a problem or issue needs to be explored in a group or population and the variables to be identified cannot be easily measured or heard as the voices maybe have been silenced. Another instance he mentioned is when the researcher intends to develop a theory because the existing ones do not adequately capture the issue being explored. The objective of this study, to explore an issue of challenges in commercialising technological innovations in South Africa as the current practices do not seem to adequately capture the complexity of the challenge, fit into these qualitative use instances.

Thus, the study has now been positioned through the process of research as flowing from the philosophical assumptions (relativism and social constructionism), through

the approach of theory development (inductive) and to the methodological choice (qualitative). The next stage in the process is now to locate the study in the appropriate strategy as suggested by Saunders, Thornhill, and Lewis (2019) and Creswell (2013).

3.5 Research Strategies

One of the advantages of qualitative research is that it comes with multiple strategies making it easier for the writer to select a more suitable method for their study and therefore creating a link between one's philosophies and the choice of methods to collect and analyse data (Saunders, Lewis and Thorpe (2019).

None of the strategies is more superior to the other as each one is a specific plan of how one will go about answering their specific research. The choice of a strategy in a study would therefore be guided by, among other things, the following: the research question and objectives, the associated philosophical biases, and other pragmatic considerations which include the access to data and availability of knowledge and other resources (Saunders, Lewis and Thorpe, 2019).

Using these guidelines, I have considered the intentions of my research which is about investigating the development of a framework for technological innovation commercialisation and came to the acknowledgement that I have to be very close to the activities of the participants under study. In this, I have the option of observing a mentor and supporter on a project and documenting the activities to create the framework, but I think that this would not allow for a full and meaningful investigation. Therefore I have opted for Action research, a strategy that allows me to be close to the commercialisation activities but also to be able to alter certain parameters of the process in order to consider different outcomes without affecting the efficiency of the processes. One of the several ways that this study will benefit from the use of action research is contained in a simple statement by Zuber-Skeritt and Perry (2002, p.173) which argued as follow; "Essentially, we argue that action research is one way of conducting research within a learning organisation that can benefit both the organisation and the body of knowledge."

The many different modalities of action research means that one needs to have an understanding of most of them in order to determine which form would suit the objectives, epistemology and ontology intentions of the study. Thus the understanding of the different modalities as described below is beneficial for the aspirant user of the methodology.

3.5.1 Action research modalities/forms

Action research is very well known for its rich diversity which Cassell and Johnson (2006) said is inspired by the different philosophical stances which systematically lead to constitution of distinctive forms with the attendant conceptions of social science. Reason and Bradbury (2008), in acknowledging this wide variety of forms for action research, referred to it as “a family of practices of living inquiry”. Table 3.1 illustrates some of the differences in the action research modalities and perspectives.

Lack of consistence in the approach to the family of practices goes to show how complex and perhaps also yet more appropriate the very diverse human sciences are. The different modalities also means that in doing action research, one needs to understand each one well and also to have an understanding of what it is they want to achieve in their study. In spite of the large number of options available, this study could not be linked to any one modality entirely. Modalities like the cooperative, corroboration and participatory action research all seemed to be good contender modalities. However, participatory action research seemed to have more aspects suited for the intended theory development.

Table 3. 1: The different modalities/perspectives of action research

	Coghlan (2011) (modalities)	Coghlan & Brannick (2014) (modalities)	Raelin (2009) (Modalities)	Cassell & Johnson (2006) (Perspectives)
1	Action learning	Participatory action research	Cooperative inquiry	Experimental action research practices
2	Action science	Action learning	Action learning	Inductive action research practices
3	Appreciative inquiry	Appreciative inquiry	Action research	Participatory action research
4	Clinical inquiry	Clinical inquiry research	Action science	Participatory research practices
5	Cooperative inquiry	Cooperative inquiry	Cooperative inquiry	Deconstructive action research practices
6	Developmental action inquiry	Learning history	Cultural-historical activity theory	
7	Intervention research	Collaborative management research	Developmental action inquiry	
8	Learning history	Reflective practice	Participatory (critical) research	
9		Evaluative inquiry		

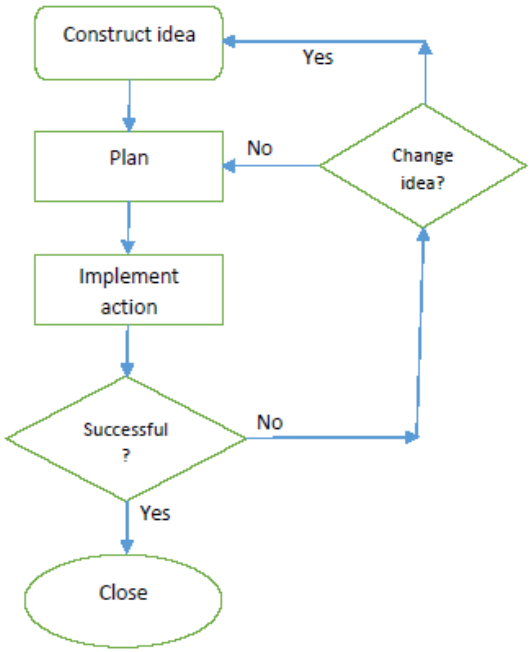
3.5.2 Participatory Action Research (PAR)

The definition of Participatory Action Research (PAR) is based on the joining of three important ideas, namely research, action, and participation each being important in its own right (Hal, et.al, 2015). The presence of the three concepts, especially research and action which have a lot more different meanings in themselves, also bring with them the methodological pluralism. An attempt to describe the three concepts was put

forward by Glassman and Erdem (2014) by presenting them with what they saw as co-occurring concepts and processes. Thus participation was linked to an Italian concept, Vivencia, which is about the full experience of an occurrence by being a participant in it. In the case of action, the co-occurring word identified was praxis which is about developing ideas into action and engaging. It goes further to describe the processes of action one takes in order to change conditions they face. Finally, for the concept of research, Conscientisation which is to do with self-realisation and reflection on ones actions is identified.

In the context of this study and in keeping with the three concepts of PAR described above, the participants from each respective start-up and myself will all participate to bring about the commercialisation (the change) of their inventions and also reflect on the ensuing activities. Where, upon evaluation, the change does not lead us to the desired condition, we will repeat the process of enacting the change. In doing this we will be performing the 'action research cycles' as described by Coghlan and Brannick (2014). Figure 3.1 depicts the research cycle as will be performed in the study.

Figure 3. 1: The Action Research Cycles



My actions in this study will be conducted through two streams of activities. The first of the streams is that of business management and incorporates those activities required in order to assist the participants to start-up and manage their respective companies. This stream has minimal iterative processes as most of the business management processes are tried and tested and all we had to do is implement them. The second stream, the one of technology commercialisation, on the other hand, was constantly going through the iterative cycles of action. By its nature, the commercialisation process is an iterative process in that one is breaking into new grounds where failure of initiatives are inevitable and hence most of the times requiring one or more trials of each initiative. Examples of this are more prominent in the technology or product testing processes where formulations are planned for, formulated, tested and where the result is not satisfactory, the process is repeated..

3.6 Methods of data collection and analysis

There are several methods for collecting qualitative data and this allows the researcher to use their creative abilities in exploring their subject (Easterby-Smith, Thorpe and Jackson, 2013). These methods include the use of natural language (interviews), observation, and interaction.

Easterby-Smith, Thorpe and Jackson (2013) do warn of the potential problem of access to the data source irrespective of which modality is used. Although in action research one feels that this may not be a problem because of the insider researcher advantage, internal organisational politics could create a problem. For example, this could also be the reason for being denied secondary access (Coghlan & Brannick, 2014). As an employee of the company, certain departments of the organisation could be off-limits to certain policies or simply due to internal politics. The negative politics could even prevent one being allowed to conduct the research in the first place. Björkman and Sundgren (2005) proposed taking a “political entrepreneurship” approach in the quest for a successful insider researcher. In this approach, amongst other things, the researcher has to have capabilities to select topical research issues, use and diffuse the results and also be able to work on positioning oneself very well.

Because in action research data comes through the engagements with others and the interventions one makes throughout the action cycle, Coghlan and Brannick (2014) suggested replacing the general term, “data collection”, with “data generation”. The actual observations, these authors noted, could be formal or informal, like discussions over coffee. One of the critical parts of data generation is in documenting reflections for all the cycle’s occasions. The documentation should include as a minimum, the following questions: who collected the data? When was it collected? What was collected and why was it collected?

The two main methods of collecting data that were used in the study were field notes and interviews. The data were collected for a period of fifty five weeks from each of the three start-up companies through two main methods, namely, field notes and interviews. The methods were used to collect data in the following ways:

- Field notes comprising of records of observations, interventions, meetings, personal reflections on events, external engagements, etc. from within the project/study,
- Records of formal interviews with the innovator participants,
- Records of formal interviews with the expert participants.

The data collected was analysed using the Template Analysis technique which is described in section 3.6.4. The flow of the process of data collection and analysis is depicted in figure 3.2.

Figure 3. 2: Data collection and analysis flow diagram

3.6.1 Field notes records

Field notes, also known as scratch notes were previously a researcher's own personal and private notes recoding their observations and interviews. However, in the 1980s, these notes started finding use as additional layers of data for interpretation and analysis by nurse researchers (Phillippi and Lauderdale, 2017). These authors state that the use of the field notes has now come to be widely accepted as being an essential part of rigorous qualitative research. Furthermore, they go on to comment that the notes "….aid in constructing thick, rich descriptions of the study context, encounters, interviews, focus groups and documents valuable contextual data" (p.1). The importance of keeping good systematic field notes for qualitative research is also echoed by amongst other writers, Creswell (2013); Thorpe (2011); and Mulhall (2003).

The field notes in this study were recorded in the form of a weekly diary termed 'The Weekly Field Notes Log Sheet'. The log sheets were kept for each of the three start-up companies for the full duration of the data collection period, fifty five weeks. The recordings included the following: observations, events, mentoring and support interventions, general discussions with the participants, external engagements and my personal reflections on any of the items above. The field notes records were collected in two different categories. The first of these was concerned with mentoring related events/activities/issues whilst the second one was related to matters of support provided during the commercialisation process.

As the recording progressed I constantly examined the data and compared it to the Framework Template (Table 2.2) from the literature review process. The examination was aimed at picking out from the data any of the theoretical framework themes and sub-themes and updating the framework. A tick was added against each theme and sub-theme each time it appeared in the notes. At the end of the study, all the ticks were used to confirm the occurrence of the related theme or sub-theme and where there was no tick, the theme was removed from the framework. The data was further examined for any themes and sub-themes that emerged in the field notes. This exercise resulted in the input to the 'updated commercialisation framework template".

3.6.2 Interview records

Writers on qualitative research do concur that interview is the most commonly used method for data collection in qualitative research (Cassell & Symon, 2004; Easterby-Smith, Thorpe & Jackson, 2013). This popularity of the method also comes with it the wide variety of variations in its use. Cassell and Symon (2004) posited the following variations as the most used: depth; exploratory; structured; semi-structured; and un-structured. They also argued that at all times, the researcher needs to bear in mind the goal of the interview. They proposed the following as the goal: "…….to see the research topic from the perspective of the interviewee, and to understand how and why they come to have this particular perspective".

Wengraph (2011) goes to the detail of advising researchers to properly index and label their data material. The systematic approach goes further to require the researcher, in their data collection preparations, to consider what type of questions would be appropriate for the research problem. Patton (2002) posited six types of questions and their intended use. The six types are the experimental and behaviour questions, the sensory questions, the feeling questions, the demographic questions, and finally the last two which I think will be more prominent in the questions for the interviews in this study: the opinion and value questions and the knowledge questions. The opinion and value questions will be seeking to find out from the participants what they have experienced and the knowledge ones will be seeking to establish what facts they have understood from the experience.

The participants in this study were required to describe their opinions on the experiences they had gone through during the particular phase of the project. Proper planning and a proper structure was necessary to investigate the participant's understanding of facts presented. I also checked if the study participants had grasped the concept of mentoring.

The main source of these records were the formal interviews conducted with each start-up participating team separately. The semi-structured interview questionnaire included six questions five of which were used to examine the experiences in relation to the Commercialisation Framework template developed in the literature review. The

sixth question was used to fish out any additional issues or emerging themes and sub-themes that the participants may have faced during the period.

All the six questions were posed at two different times during the data collection process duration which was fifty five weeks. The first of these times was close to the halfway mark (approximately 26 weeks from start of study) and the second one was conducted at the end of the study period. The data were collected through audio recording and transcribing the recording. Any other relevant observation during the interview were also captured on a log to be used as latent data (Assurroudi et al., 2018) during the analysis. The interviews were conducted in person with each participating team (from each start-up) separately. The template questionnaire for the interviews is included in appendix 1 of the study. The resulting transcripts were interrogated for any data relating to the themes and sub-themes in the framework template. A tick was added against each theme and sub-theme each time it appeared in the notes. At the end of the study, all the ticks were used to confirm the occurrence of the related theme or sub-theme and where there was no tick, the theme was removed from the framework. The data was further examined for any themes and sub-themes that emerged during the interviews. This exercise resulted in the input to the 'updated commercialisation framework template'. Together with the inputs from the field work, a full updated framework for the commercialisation of technological innovations through start-ups in Soouth Africa was developed.

3.6.3 Focus Group with commercialisation experts

This data comprised of a formal interview with the three experts identified as E1, E2, and E3 in the study. The interview was conducted in the form of a group discussion (focus group) with all three of them at the same time. The experts, all of them engineers, were selected on the basis of their experience in technological innovation start-up processes as well as their being still involved in assisting novice entrepreneurs. Two of the experts were at the time running their own multiple technology companies and were also both involved in various consulting activities related to innovation both within government and private sectors. The third one was running a university third stream income initiative which involved the

commercialisation of the university's research as required. He was also a co-founder of a technology company that was being run by his partner. The experts were brought in the study in order to refine and validate the results of the study by commenting on the collected data from their experienced positions. I had decided to use more than one expert in order to enrich the discussion. The interview used the updated framework template developed following the field notes and participant's interview sessions as a basis. All discussions were recorded and the recording transcribed for use in analysis. The transcribed data was examined for any extra information that needed to be re-examined in the updated framework template. The resulting updated framework was the final one, the "Framework for the Commercialisation of Technological Innovations through start-ups in South Africa".

3.7 Data analysis

The collected data was analysed by using the Template Analysis which is a technique for thematically organising and analysing data. This technique emphasizes on the flexibility and pragmatic use of coding (King, 2012) and it has already been widely used in organisational and management research (Brookes, et. al. 2015).The "Framework for the Commercialisation of Technological Innovations Template" (Table 2.2) was used as the initial template for the study. It was developed from the themes and sub-themes observed from the literature review chapter by taking advantage of the fact that the technique does allow for the development of a template from a selected part of the dataset (King, 2012). This template was then continuously updated by interrogating the data collected throughout the study period (55 weeks) of each project, and so enriching it to the point where the final 'Framework for the Commercialisation of Technological Innovations through start-ups in South Africa' was established. The enrichment was done by firstly consolidating the updates from the field notes records and the interviews of the participants separately. The updated template was then subjected through a refinement and validation process by using the focus group interviews with the three experts (cf. Figure 3.2). Any themes or sub-themes that had been identified in the original template but did not manifest in the collected data were discarded from the final framework. Themes or sub-themes that emerged from the group discussions were incorporated in the final framework.

3.8 Research quality

The methods for the evaluation of the credibility of qualitative research have always been a source of tension amongst qualitative researchers (Angen, 2000). Angen further asserts that epistemology is the key to the assessments of rigor in qualitative research and that most of the tensions around rigor are based on different epistemology leanings by the researchers. Thus qualitative research should ideally include the consideration of one's epistemological biases at the beginning of a research.

Further to this, Bengtsson (2016) reminds researchers that, like in most activities, the credibility of a qualitative study starts with good planning. Bengtsson (2016) further states that during this phase, the researcher should identify all external and internal resources and consider their experience of what is to be studied for the purposes of minimizing own biases in the study. In line with this contention, the discussion on the quality of this study has taken the line of thought of Carter and little (2007, p.1326) which is based on the premise that qualitative research "….should be able to explain itself by presenting and arguing for an internally consistent set of elements: research epistemology (justification of knowledge), methodology (justification of method, and method (research action)"

In view of the fact that research and thesis papers are most likely to be attacked on methodological and hence epistemological philosophies grounds and that research seeks to produce accurate and beyond everyday observation results, it is subjected to validity, reliability and generalizability testing (Easterby-Smith, Thorpe and Jackson, 2013). To minimise the risk associated with the narrative that qualitative research studies are often not considered to be good in replicating the results to a larger population (generalizability) I used three different start-up firms as data sources instead of only one. In addition, the use of the experts' focus group to refine and validate the updated framework added an extra dimension of data and critique; thereby further minimising the said perceived risk. The focus group also enhanced the quality of the action research approach by providing an additional iterative cycle of data

collection. The reliability of the research was also increased through ensuring that the data collection and analysis instruments, namely: field notes, interviews, focus groups and template analysis were based on standard tested techniques.

Whilst qualitative research in general has particular requirements regarding quality (Easterby-Smith, 2008), action research also has its own challenges and hence has its quality criteria. My study was guided by the criteria put forward by Coghlan and Brannick (2014) which requires of a good research to contain the three main elements of “a good story, rigorous reflection on that story and an extrapolation of usable knowledge or theory from the reflection on the story” (p16). My story is focussed on the important need for technological innovation commercialisation in my country, South Africa. The rigourous reflection occurs in response to the use of three different start-up firms and two different tried and tested methods of data collection; and further refinement and confirmation by three outside experts with experience within the country. The resulting commercialisation framework should be an aid to mentors of other technological commercialisation projects in addition to aiding the innovators themselves, technology development agents and even policy makers.

3.9 Research ethics

Qualitative research and by extension action research is generally considered an emerging inquiry and as such ethical issues can arise at any stage of the research. Creswell (2013) went as far as suggesting the stages of the research and their associated ethics. The associated ethics issues he posited are in line with the ‘ten key principles in research ethics’ put forward by Easterby-Smith, Thorpe and Jackson (2013, p95). The first seven of these principles are aimed at protecting the participants and the organisations and ensure that there is: no harm, dignity, informed consent, privacy, confidentiality, anonymity, and avoid deception. These were covered by the formal university ethics process as described below.

A formal ethics process, approved by the university ethics committee, was followed for this study. One of the first things I did was to send formal “invitations to participate” letters to all the three start-ups and three experts involved which they all accepted. All

the participants were given the assurance that they could withdraw at any time if they felt that they were being compromised. They were also provided with details of the University's program office in case they had complaints they intended reporting.

The invitations included my commitment of confidentiality. All the data collected from all the three start-ups as well as the three experts is kept safe in my home office where I conduct the study from. This data will not be shared with any other person except for my research supervisor or any other university official that may ask for it for verification purposes. It will also not be used for any other study unless I specifically make a separate request. I will keep the data for a further five years after the completion of the study after which I will destroy it.

In the study, none of the company or participants names are used. The companies and participants are referred to by project and number codes which have been described in the introduction chapter of this study. All their information and the collected data is kept in my computer system which is password controlled.

The last three principles ensure honesty and transparency, accuracy and lack of bias of the research. The first of these is covered in the declaration of my roles in the three start-up companies in the introduction section. The other two issues are contained in my 'research declaration statement' and I commit to adhere to them throughout the study. In addition to making the declarations in addressing these three principles, a need still exists to reflect further on the potential conflicts among my three roles in the study. The first two roles, those of a mentor and a funder (in some of the cases) require of me to ensure the success of the three start-up firms. The third one, that of a researcher only requires that the data are collected and analysed rigorously regardless of a failure or a success. The challenge here would be in the amount of effort I dedicate to each role. There is a danger that the researcher role may start taking a back seat in my pursuit for the success of the firms leading to poor quality of collected data. The adherence to the formal mentorship contract with the firms using the applicable elements from Dawson's sixteen design elements (2014) kept me from getting too involved in the management of the firms thus allowing me enough time to also focus on the research role. Although not a formal academic argument, my personal desire

to ensure the success of an actionable research in the field of technological innovation which is my main post-retirement activity played a part in motivating me to pay the necessary attention to the researcher role. The need to achieve successful commercialisation in the firms as required by my mentor and funder roles may have also played a positive role in achieving the success of the study. This need forced me and the participants to keep trying out alternative courses of action where we encountered challeges in the processes thus enriching the quality of the action research.

In this study, I did not experience the challenges of access as an inside researcher in an organisation, because all three start-up firms had only two innovators/owners in each. In addition, I was invited to assist as an expert and also a provider of other tangable support. Thus I had a good measure of power over the owners. I did not have any challenges to primary or secondary access to the firms as cautioned by Coghlan and Brannick (2014) nor did I experience any resistance to my suggested interventions. One of my worries was that the participants will give me the full authority to effect my interventions, and thus managing the firms on their behalf denying them the opportunity to practice their roles of “participants” fully.. I had to follow the advice of McCarthy (2014) of encouraging participation and ensuring scheduled meetings regularly. Irrespective of this position of advantage, I still had to observe research ethics practices.

3.10 Conclusion

The chapter could be considered to be divided into three different parts. The first part dealt with the description of the research philosophies, and associated methodologies and strategies and the related justifications of the associated choices in the design of the study (sections 3.2 to 3.5). The second part was concerned with the descriptions of how this study will be conducted (section 3.6). Finally, the last part contained supporting discussions of the design and implementation of the study, specifically the discussions on the quality, validity, and the ethical considerations observed throughout the study (section 3.7 and 3.8).

CHAPTER 4: RESEARCH FINDINGS

4.1 Introduction

The previous chapter explained the action research methodology to be employed including the collection and analysis of data for the study. The data were collected from three different start-up companies who all had one project each and hence, I use the word ‘projects’ where necessary instead of ‘start-ups’ in this chapter. The constraints of the DBA thesis study period led to the research starting after the products had been defined already in each project and ending at the stage of enganging early adopters.

This chapter firstly describes each of the projects in section 4.2 before going on to briefly describe the practical details of data collection in section 4.3. The results that relate to the themes in the *Support Interventions for Commercialisation Framework Template* (Table 2.2), are presented in section 4.4 along with any related sub-themes. Section 4.5 details those themes that emerged during the empirical work and their associated sub-themes. Finally, the themes and sub-themes captured in both sections 4.4 and 4.5 are used to update the framework template from the literature review chapter (Table 2.2) to create the *Updated Framework for the Commercialisation of Technological Innovations through Start-ups in South Africa* (Table 4.1).

4.2 The projects

The study was conducted by following the commercialisation process of three projects in which I had been invited by the participants to mentor them and offer other management and in some instances, funding assistance. All the three projects had already gone through the product definition phase (TR Levels 1 to 3) (Mankins, 2004) and were entering the commercialisation phase (TR Levels 4 to 7). However, because of some of the challenges discovered during the commercialisation phase, we had to revisit the product definition phase for all three projects. This was done in order to ensure alignment between the emerging information on market requirements and the defined product offerings. The study was completed as the products were entering the market penetration phase (TR Level 8).

The projects are described below.

4.2.1 Project 1

Project 1 entails the use of satellite imagery to produce applications for smart agriculture, land use planning and monitoring, flood mapping, etc. The imagery was from freely available satellite data or paid for data in the case of dedicated or higher resolution requirements. The first part of this project was to capture the imagery from the satellites and through specialised software coding and use of research information, develop an interpretation thereof as required by clients. An example is the development of a product that can be used to indicate the nitrogen content of a plant remotely without visiting the field.

The next step was to automate this exercise so that the system could download the data from multiple satellites and process it without human involvement. Finally, the last step was to develop the user-interface software which would allow users/clients to view their requirements in a friendly and easy to understand format. This software also included subscription and billing mechanisms. The products from this exercise are used in the agriculture sector, government planning and monitoring departments, mining operations, disaster management operations, mineral exploration etc.

This project started with two scientists, participant 1A and 1B, with expertise in remote sensing, agriculture and ecology organising themselves into a start-up company although they were each still working in their respective companies. Through their networks, my name was suggested as someone that could help them to commercialise their ideas. After a few informal discussions with them, and confirming that their start-up business was not in conflict with their employer's businesses, we agreed to meet formerly so that we can establish exactly what their expectations were from me and this formed the basis of the meeting's agenda. Their expectations of my involvement were clear and simple, they said: "We are just scientists in employment and have no idea how to start and run a business and most importantly to take our products to the market".

As to what products they intended producing, I noted that they had based their decision on what they were able to develop which were well over fifteen different types. To this, I suggested that we give ourselves at least a month to scan the markets and come back to select a maximum of three products that we could use to kick-start the business. The meeting also established that there was a need to acquire a high speed, large volume storage computer/server to be used as a development platform. At the end of the meeting, we agreed that my roles on the project would be as a mentor and a funder (loan) for the purchase of the development platform with the option that the loan could be converted into equity at a later stage. I used some of Dawson's Sixteen Mentoring Design Elements (2014) to define the mentorship agreement. The data were gathered from September 2018 to June 2019.

4.2.2 Project 2

Project 2 was about commercialising research on the production of low cost carbon nanotubes. This project was a collaboration between a lawyer and a nano scientist identified as Participants 2A and 2B respectively. The Project comprised of several components the first of which was to investigate the design and fabrication of a plant (reactor) to be used in the production of the nanotubes. Although this plant was considered a prototype, it was also envisaged that it could be used for initial production of commercial scale quantities. The second component involved the investigation of the right catalyst, the associated beads and vapourisation method. The last component involved investigating the types of gasses to use and the associated flow rates for optimum production. This last component also included the product optimisation and characterisation testing.

The project was located within a large research institution with which the start-up entered into an assistance agreement for acess to knowledge and test facilities. The commercialisation process included the optimising of the products through repetitive testing of production samples for the eventual attainment of the desired single-walled nanotubes. As in start-up 1, they were introduced to me through their networks and I was also approached to assist with mentoring and management processes. The start-up had already raised venture capital funds from a local developmental bank and was already investigating the plant design and fabrication. In this project, like in Project 1,

the participants were not involved full time with the project. Participant 2B was in fact resident outside the country.

4.2.3 Project 3

Project 3 was based on the pyrolysis technology which is used for the conversion of biomass, rubber and plastics into bio char, biofuels and bio gas. The two innovators of the technology (referred to as Participant 3A and Participant 3B in the study), were both involved on a full time basis in the start-up and had also committed their funds and other necessary equipment. The start-up had been running since 2010 and in that time they had built at least two prototypes and imported one plant from overseas before getting to the point where they invited me to join them. Both the owners' built prototypes and the imported plant had constant technical problems and never got to produce the desired quality nor the desired quantities. In spite of the project attracting huge interests from both government and industry because of its sustainability and clean environmental advantages, it never received adequate funding.

The concept of the project involves collecting different types of waste and converting it into fine materials like saw dust in the case of biomass. The sources of the raw materials include wood chips and saw dust from timber and pulp processing companies, waste plastics, rubber from tyres and other sources, processed sewage waste, etc. The prepared materials are fed through a drier to remove the oxygen and then through a heated oxygen-free chamber to make the bio char which is used for agriculture, water purification and glod extraction. The smoke produced during the burning process is collected and distilled into crude oil. The remaining gases after all the oil has been extracted are collected and used for electricity generation through gas generators. The oils are separated and further fractionated into bio diesel and various organic chemicals.

I got involved in the project when the decision was made to redesign the plant as a 30 metric tonne a day fast pyrolysis plant. The data was collected between September 2018 and June 2019. The resulting business is easily scalable through the making of more plants or making the plant bigger which would involve a slight redesign.

4.3 Findings

The findings are arranged thematically where both the findings from the field notes and from the participant interviews are discussed under each theme. The arrangement of the themes is in accordance with the themes contained in the framework template (Table 2.2).

4.3.1 Finance

The *finance* theme was confirmed at my inception meeting in each of the three projects. In projects 1 and 3, it was established that I will have to provide some support in the form of *seed capital* whereas project 2 confirmed that they had already sourced *venture capital* funding from a development agency bank which had also promised to provide *growth funding* for scaling up of the business. The inception meeting for project 1 further established that the *seed capital* from me could be enough to acquire the processing platforms, contracting software developers and establishing a marketing strategy. Project 3 on the other hand required a mixture of *seed* and *venture funding* for constructing a full production prototype and the development of market ready products and then *growth funding* for the scaling up of the business.

When I had to take project 3 to the venture capital funders, I discovered that they had no financial models. "*Our main challenge should be clear to you sir. We approached you because no investor was interested in us and you looked like a soft target*" said participant 3A jokingly during the interview. Indeed, I found that they had not organised themselves into a start-up with a business plan and a financial model. They had been focussing on the development of the technology. I had to bring in an external expert to assist with the development of a funders' acceptable business plan. Upon interacting with the developed financial model, participant 3A, looking excited, commented: "*I think this is why all the funders we approached did not want to engage with us. They didn't like our financial spreadsheets. This is the real deal model*". This presented to the study a further sub-theme of a *bankable business plan*. I also discovered that a well prepared *business plan* is one of the major factors

that led to Project 2 being funded by a development bank from the onset of the project.

In spite of the newly professionally-prepared business plan, project 3 failed to raise funds from at least two venture capitalists. We understood that this was because of the failures of several waste biomass projects in the country. We were also informed that we needed to show proof of off-takers of our products for any funding to be awarded which was surprising requirement of a venture capitalist. The difficulty of getting funds from venture capital in the country was also echoed by a number of delegates at a Trade and Industry Department investment conference we attended. Some delegates attributed this to the fact that most of these were run by accountants who are trained to avoid risk as much as possible.

After some deliberations with the project participants, it was agreed that I should approach my networks for *crowd funding* and raise the funds as and when required. This process brought to light a new sub-theme of *realistic budgeting*. The participants almost always under-estimated the funding requirement figures they gave to me to source. In their defence, participant 3B said “At every corner of the process there is a hidden requirement for funds. For example, in the one instance, we found out that the universities we had targeted for some testing didn’t have all the required laboratories equipment and we had to go to commercial ones whose costs were very high”. The tight budgets resulting from the *crowd funding* process also forced the participants to adopt very tight *cash flow management*. In particular, the project had to ensure that the available funds were used only for those items that were within the critical path of the project and as promised to the funders. This occurrence added to the finance theme the sub-themes of *managing obligations to funders.*

All the three sub-themes, *realistic budgeting*, *cash flow management* and *managing funder’s obligations* also surfaced in project 2’s execution. The funders requirements had been that the equity funds provided should cover the development of the working prototype as well as the necessary working capital. However, the project had been constantly running behind schedule and thus fast consuming the available

working capital. The partners unanimously agreed: "*We have to drastically cut our personal cash withdraws from the working capital funds if we are to meet our obligations*". This forced the participants to pay attention to their *budgeting* and *cash flows* as well as ensuring that they *comply with the obligations of their funder*.

4.3.2 Networks

The network theme was evident from the onset of my journey with all the three projects. I was introduced to all the projects through their *networks* as someone that could assist with the commercialisation process of their inventions. Throughout the commercialisation processes, my networks would prove very invaluable in determining the different successes. In project 1 for example, following several failed attempts to engage with the identified potential clients, it became clear that the participants needed help. It was clear that the *potential clients* were not interested in meeting the new start-up without a product to offer. I then introduced them to one of my *network* colleagues who runs an established company with complementary products and both agreed on a collaborative marketing approach. The new partner introduced the participants to his client base who formed the potential client pool for the project. This partner was the third to be introduced to the participants. I had initially introduced the start-up to two other potential collaborators but their businesses did not quite fit in the project's planned product lines and so the relationships were abandoned during the initial engangement phases.

Project 2 had major challenges regarding networks. Participant 2B, the scientist, was not a local South African and had just come in the country for this start-up. Participant 2A, on the other hand, though being South African was from a legal background and so had minimal interactions with the local technical environment. Thus, the team would to a certain extent, rely on my networks. I used the initial product definition to introduce the team to my networks in the defence, aerospace and space industry players so that we can refine the product definition. This was quite easy for me to do as my background is in aerospace, I have worked extensively in the defence industry and I also have substantial stake in a company in the industry. Further, I am currently serving on the South African Council for Outer

Space Affairs which also acts as a regulator of the space industry. I also used my networks to organise visits for the participants to several institutions that had 3D printing capabilities to print nanotube composite material, a critical component in the product definition and marketing of their product. I also *introduced* the participants to some *domain experts* and associated institutions that were helpful in refining the reactor design as well as testing of the products. In the case of project 3, my networks were particularly useful in the *finance model development* and crowd funding and the identification of product test facilities.

The networks were not only provided by myself in the projects. The participants themselves had already established their own by the time I got engaged in their projects. Project 1s networks included those of satellite operators for the supply of free or cheap data as well as technical experts that would assist with product development. Participant 2A had already used his networks to raise funding from a development bank in the country. Participant 2B had several contacts in different institutions outside the country that would help in further product development and testing. The *networks* for project 3 participants proved useful in the identification of fabrication organisations and potential clients. They also introduced to the project other product test facilities.

The participants also created new *networks* through workshops and seminars they attended during the course of commercialisation processes. I had to attend some of the events as I noticed that some of them required some help in creating networks during the events. I observed that studying the list of speakers and participants before the event and paying attention to introductions and subject knowledge speakers and participants during presentations was very helpful in identifying the potential networks. This would then be topped up by having the courage to approach and engage the identified individuals at any opportunity during the event and even after.

One may argue that it could be possible to manage any of these projects without using existing networks. However, I found that the uniqueness of the projects, especially, in South Africa, made it difficult to find the relevant services or even to convince funders

and others of their value. Using networks allowed participants to easily identify and engage the required *experts, institutions, collaborators as* well as markets. Participant 3B attested to this in his comment on the mentorship support intervention "*Your mentorship role in connecting us with all these academic and product laboratories has been of tremendous help to us because our products depends so much on credible test results for national registration as well as marketing".*

4.3.3 Collaboration

The theme of *collaboration* in this study includes the organisations that the start-ups teamed up with in different business activities as well as those suppliers who added value in the eventual development of the products. Project 1 experienced both types of collaborators. In the first instance, the *partnership* between the project and a private remote sensing *software developer* saved the project. The skills for remote sensing software development, which are critical for automating the data acquisition and processing of satellite data are very scarce in the country and hence cannot be easily insourced or contracted. Participant 1A explained their new strategy and went on to say that they chose one of the smallest and easiest components to automate and gave it to the developer to code it for early product demonstrations. In parallel, they embarked on a slow program of automating the rest of the components with the developer. However, all their attempts at enticing the developer to join the start-up on a full time basis were in vain. The participants also had to turn to the free online courses given by some institutions like MIT for equipping themselves with some of the development skills. "We both enrolled ourselves for the Python software development course and we could code by the end of the three months course duration." Equipped with this skill, they said that they were able to work with the developer to speed up the progress.

The success of projects 2 and 3 depended heavily on working *(collaborating*) with competent specific *reactor fabrication companies*. The fabricators were crucial in refining the concept reactor designs to ensure manufacturability as well as fabricating the first-off plant. Because of their involvement in the initial phase, it would be ideal for them to also be contracted for the ramping up of a project.

However, the experience for both projects was that these initial contractors were not as competent as the participants had hoped. In both projects, we attributed this occurrence to the *selection of collaborators* as was summed up by participant 3B "We were naïve to follow a recommendation that this fabricator's workmanship was very high", adding that: "This decision cost us the very valuable investment we got and also time unnecessarily". A number of changes, especially in the strength of materials had to be done on the unit by the current fabricator who is from the sugar mill environment during commissioning. In addition the second plant which they have been contracted to fabricate is costing half the quoted amount by the first fabricator. The benefits of paying attention to selecting an appropriate sub-contractor were demonstrated through the smooth service delivery by the web-based system developer in project 1. Further advantages were demonstrated through the selection of some of the product testing facilities in project 3. In fact, one of the facilities proved very invaluable to the project that the start-up ended up offering them some profit share in the business.

4.3.4 Human Capital

In this study, Human capital discussions are confined to people skills only whereas the business processes are contained under the theme of General Management (section 4.4.10). At the start of the data correction, I decided to consider Human capital from two separate perspectives. One was in relation to general management skills related to a business start-up and the other was skills related to commercialisation of hi-tech innovations.

Throughout the execution of all the three projects I kept noticing that all participants were focussing almost all their energies on the technical skills of the project at the expense of those skills that are to do with managing a start-up company. None of them, for example, paid attention to the skills required to meet government regulations like compliance with taxes and other levies, company and labour relations act and others. "But we thought that with your management expertise, you will take care of those requirements", commented one participant. At this point, I had

to make it clear that my role was that of a mentor and such skills had to either be learned and practiced by them or contracted in.

The above incident revealed the general lack of willingness to *delegate responsibilities,* be it for workload purposes or for bringing in necessary expertise, by all the study's participants. One may argue that this was in part due to funding constraints. I found it hard to support this notion as I did not see any attempt to include the costs of such services in the budget indicating that there was no will to bring in help. Others would argue that start-up innovators do not like delegating because they fear losing control of the start-up as well as their technology. At least one of the participants confirmed this argument by saying that "*You bring an accountant in your start-up and then they start telling you what to do. In any case you will never progress because to them, they will not let you take any risk*".
This 'fear of losing control' notion was further confirmed in projects 2 and 3 where it was discovered that hired technical staff were not *empowered* enough to perform their envisaged tasks. In the one project, it took the absence from work of one supervisor for us to realise that the hired staff are much more capable that we were meant to know. After the realisation, we restructured the teams to promote some of the staff, a move which proved fruitful to the project.

As a mentor, I insisted on regular planning and progress review meetings throughout the projects where general management activities would be identified, planned for and monitored. These meetings served to impart general management skills to the participants. I also occasionally arranged for discussions with external subject experts during the review meetings so that we should get different insights into the required management skills. I complemented this *on the job training* with *external training* by arranging a two day business management overview workshop for two of the participants. I thought that given sufficient spare time, each of the six participants should complete an accredited management cause like a post graduate diploma in management.

The second perspective from which I considered the observations was that of human capital in technological innovations' commercialisation. I set off to confirm the sub-

themes that related to commercialisation processes identified in the Template. The first sub-theme I looked at was that of the criticality of a *champion* (sub-theme 4.2, Table 2.2). In as much as each project had only two main shareholders both of whom had committed to the start-up, I noted that there was always one participant in each project who took the lead in ensuring the project's success. This *champion* was not necessarily the more knowledgeable on the technology but one that could be characterised more with abundance of energy and enthusiasm and having the appropriate vision.

All the technical participants, one each from projects 2 and 3 and both from project 1 had basic knowledge of the product development related *skills (product development, industrialisation, and production skills).* However, none of them had experience in any of them and I used my role as a mentor to guide them. I found that those technical participants with some industrial experience had better skills that those without industrial experience. Very few ad hoc courses are offered for these skills in South Africa.

In the pursuit of the development of market and technical networks and self-development, decisions were made within each project that participants should strive to attend seminars and workshops at any opportunity. It was observed through the participants that by developing their own networks of high calibre experts through these events, they felt *empowered* and enthusiastic with their roles. One participants summed it all by saying that "*I didn't realise that our invention has such potential in several sectors. My motivational levels have now shot up*". These events added to the *external training* sub-theme narrative as well as that of *empowerment* within the human capital theme. Training of reactor operators was also a necessity for both project 2 and 3 and by the end of the study, project 3 had developed a training program internally.

The *Technical skills* sub-theme was evident in all the three projects but more so in project 1. "*After refining our product concepts following the feedback from the potential clients and embarking on producing the first product, we came across the second big hurdle in the project*" participant 1B reflected. South Africa is still in its

infancy regarding geo-spatial development capabilities although it has been a consumer of related products for some time. The participants said that they soon realised that there is a scarcity of software developers who also understand geo-spatial/remote sensing. In their own words, this challenge was a deal breaker: "*We had to decide between giving up for a while or working with the one developer we knew who was very busy with other projects*". Participant 3B also indirectly alluded to this expertise shortage in the country by his concluding remarks during the interview sessions, "*I wish to mention the technical knowledge, commitment and dedication of my colleague here. A lot of waste biomass mass projects have started and failed in this country but now we are perhaps the first ones to successfully commercialise one*".

Self-development within project 2 was reinforced in different ways. One participant attended a *product related external course* whilst the other participant spent some time conducting further research on the optimum fabrication materials for the reactor. Towards the end of these activities, I took one of the participants to *visit several institutions* (from my *networks*) that had 3D printing capabilities to print nanotube composite material. The participants also had an opportunity to *consult with specialists (professors)* at the research centre on issues related to the other various methods of manufacturing carbon nanotubes. I also brought in a *Principal Researcher from the research institution who had several years' experience in dealing with the carbon nano tube interested industries*. From the guest's presentation, I noted anxiety on the faces of the start-up partners. "*We didn't think it is that complicated to convince industries to include our nano tubes in their products considering the many advantages which includes enhancement of strength to weight ratio, conductivity, corrosion resistance etc*."

4.3.5 Commitment

The commitment to the start-up in each of the three firms was different and this was also reflected in the way the projects were managed and the successes and failures thereof. The commitments were measured by the time each participant dedicated to the respective project and the contribution of any other resources including funds and equipment. In project 1, both *participants kept their full time jobs* and worked on

the project after hours. *None of them had committed any resources* in the start-up other than their personal involvement. In the course of the study, both participants left their employments to take up other jobs that allowed them some freedom to attend to the start-up a little more. During the interviews, they did acknowledge that time allocation to the project was one of the major challenges for them. "*Because both of us were still in our employs, it was not possible to achieve our desired progress, and worse still, the expectations of the potential clients*". They both echoed saying also that they could not leave their employments because they felt that this business ramps up very slowly, putting pressure on working capital. Asked whether a commitment by one of them to be full time in the project would not be beneficial, they said that they didn't feel confident that the business would scale up fast enough to support the required working capital. Besides, they said, once the hurdle of developing and automating the solutions was done, a junior scientist could be employed to maintain it. "*Our only involvement would be in the continual development of new products and marketing exercises and we think that this may require only one of us to work full time and the other to support on a part time basis*", said participant 1A.

In project 2 on the other hand, although, like in project 1, *both participants were in full employment elsewhere*, only participant 2B was in the country. The *ad hoc availability of participant* 2A, who was the main scientist, impacted negatively on project schedules and also in technical quality. It was also difficult for me to arrange necessary meetings for them especially the technical ones.

Project 3 presented a picture of a normal start-up where *both participants were committed to the project on a full time basis*. The participants had also *committed their personal funds and other equipment* as necessary. This was a welcome situation as the project was also by far the largest of the three. "*Failure is not an option for us. We have committed everything we had*" commented participant 3A. Here, again the statement made by participant 3B at the end of their interview applies. "*I wish to mention the technical knowledge, commitment and dedication of my colleague here. A lot of waste biomass mass projects have started and failed in this country but now we are perhaps now the first ones to successfully*

commercialise one". As a mentor and partial investor, I felt comfortable with the execution of the project. It also afforded me, as an action researcher, multiple opportunities to try out different plans.

4.3.6 Entrepreneurship

The study did not make any specific findings on entrepreneurship as it was intended to track technological commercialisation and not entrepreneurship and so the developed framework will not contain this theme.

4.3.7 Facilities/Infrastructure

The framework template identified infrastructure and other resources like expertise as components of this theme. All three of the projects in the study required *product testing* and some input from *external experts*. They also all required *reference publications such as journals*. The required test equipment, especially that for projects 2 and 3 would have required a lot of funds to procure and also time to set up, particularly those for project 2 whose procurement and set-up time would be well more than a full year.

Project 2's location inside a research centre afforded it easier access to world class *test facilities* for its products. The close proximity of the test facilities allowed for ease of constant testing of the products, which was a requirement for product optimisation and characterisation testing. The project was also fortunate in that the centre was at the time experiencing lower volumes of scheduled product to tests. In spite of the ease of access to the test equipment, the testing was not all conducted as planned because of the unserviceability of some of the equipment The poor state of test equipment was also noticed in most academic institutions which we approached. One facility manager's commented that sometimes the equipment remain unused for long periods of time and so they default on servicing and in some cases even misplace operating manuals. "*I think we should commercialise these facilities to earn some funds for maintenance whilst assisting external innovators*" she observed.

Project 3 used a combination of commercial test facilities and those in academic institutions. The observation on this project was that the commercial facilities were a little more expensive but they were very responsive. These would book in a product for testing and test overnight whereas academic institutions required several approvals before booking in a product for testing and would normally not test outside working hours.

The need for *external expertise* to advise on certain areas of the project was there for all three projects. Through networks at research and academic institutions, all participants reaped the benefits of the advises. One participant did mention a caution, though, that some professors tend to be too theoretical and one has to infuse their advice with practical knowledge on the ground. *Access to publications*, in particular journals proved to be problematic in some instances. Journals are considered expensive for start-ups in South Africa and where the search for an appropriate one more often goes beyond the abstract into the introduction and beyond, means a purchase must be effected. Because of copy right requirements, institutions were not willing to give access to their libraries unless there was a formal academic or business agreement with the projects.

4.3.8 Incubation

The study did not make any specific findings on incubation as the focus was on stand-alone start-ups and so the developed frame work will not contain this theme.

4.3.9 Policy

The study did not make any specific findings on policy as the focus was on what the start-ups have control over and so the developed frame work will not contain this theme.

4.3.10 General Management

This section is best read together with section 4.4.4, Human Capital that discusses the skills associated with the processes discussed here.

Of the six sub-themes under this theme identified in the framework template (table 2.2) only three of them *Tenacity*, *Intellectual property* and *Business management processes* were confirmed in the study. The other three, *Technology road map*, *Strategic Awareness*, and *evaluation frame work* were not observed in the study largely because all the three projects were housed in small start-ups without extensive management structures.

Each of the three projects went through troubled periods where abandonment was an option but in the end all of them persevered and survived up to the time the study ended. Project 1 was troubled with specialised software development skills shortage in the country whilst project 2's troubles came from lack of adequate test facilities and multiple product test failures. Project 3 on the other hand was troubled with funding shortages but the participants showed the characteristics of *tenacity* in all the cases.

The innovations for all the three start-ups in the study were based on widely known technologies (in developed nations) and hence it was always going to be difficult to patent any one of them. Project 1 had no intentions of protecting any of its products whereas project 2 had planned to protect the process it would finally settle on although this had not been reached by the end of the study. Project 3s technology dates back to the ancient Egyptians era but the *process* the project developed was so unique that they were compelled to *protect* it as a number of large international organisations are trying hard to achieve the quality of products produced from their reactors.

The *Business management process* sub-theme includes all those processes that a firm needs to run efficiently as well as legally. These include planning and monitoring, finance, organisational development, marketing, production (or project management), logistics, and legal compliance. Although silent but equally important within the business processes sub-theme are the awareness of the division of responsibilities and accountabilities between the shareholders, board members and operational staff as well as the adherence to meeting times and keeping of the

associated minutes. Finance, Organisational development (Human Capital) and marketing have already been elevated to themes in the Template framework. *Project Management*, *legal compliance* and *Planning and Monitoring* will be considered under this theme as own sub-themes.

Although some of the components of legal compliance are resident in some of the themes or sub-themes, there are some that are worth mentioning here following observations during the study. As a mentor, I think I spent a considerable amount of time trying to get the participants to respect *compliance* issues. Notably of these was the tax, labour laws, health and safety and environmental requirements. It was as if the participants thought that compliance to these would only start once the start-ups have started production and are profitable. The company's Articles of Association requirements like composition and management of the board of directors, and others were also far from the minds of the participants. Unfortunately all these are critical in ensuring the registrations of the start-ups as well as in most fund raising business plans. Most of these would typically be included in a business management course. It was just that none of the participants had attended any such courses. Only one participants had knowledge of most of them because he had his own practice.

One of the most glaring observation under this sub-theme of *business management processes* was *project management and* its component of quality assurance and the associated document management. Although some of the participants had some knowledge of widely accepted industry quality standards, none of them seemed to observe any of this. Armed with the excuses of tight schedules and the small size of their organisations, they attempted to ignore established, tried and tested project and product standards. This led to some problems including one where in one project, the understanding of the deliverables by a subcontractor were not in line with the project's expectation. In another instance, superseded drawing packs were issued for production. Perhaps one other most obvious problem was that of the wrongful selection and contracting of fabricators for two of the projects. Quality assurance and document management components require that all processes be carefully planned, documented, reviewed and controlled. I had to assist all three start-ups to create these processes and also to create a project management procedure based on the

Project Management Institute Body of knowledge that had been introduced in South Africa in the early 1990s through the Institute's chapter in the country. Based on these challenges, I decided to elevate *Project management* to a sub-theme of *General Management* because of these observations and besides, the start-ups' businesses were based on project executions.

The challenges with the selection of the fabricators and the eventual constant supervisions led to the emergency of the *contracting* and *supplier management processes* sub-themes. Some of the challenges with the fabricators were that their importance in the innovation process elevated their status from mere sub-contractors to collaborators/partners because of their contribution in product development. This, it was observed, created expectations of automatic contracting for the production stage where intellectual property and costing can be easily manipulated. Although supplier management and contracts management can be considered as a part of project management or even business management processes, its impact in this study had convinced me to elevate them to sub-themes.

Some of the challenges I discovered in all the projects when I joined them could be attributed to lack of planning. The haste contracting of subcontractors and freezing of design data packs attests to this assertion. I therefore decided to institute vigorous processes for planning and progress monitoring in all of them. Participant 2B confirmed the importance of planning during the interview session as follows: "*If we had taken time to plan for the project at the start, we would have known of the challenges of the test equipment, raw material availability as well as the availability of the local skills. Maybe we wouldn't have even considered going to commit to investment. I am a little worried about the success of this project now*". This observation was also echoed by participant 1B who added that he had learned that proper planning in a project was very critical. "*From the first time we met potential clients, we started promising dates for live demonstrations which we never met and so putting our credibility in question. All this drama could have been avoided had we sat down to plan our activities first before making commitments*"

A new sub-theme, *commissioning*, become evident in the study. Both project 2 and 3 experienced major delays and budget overruns during this stage despite appropriate

planning for it. The fact of the matter is that there are a number of unknowns that could crop up at any time. Sometimes it is just a matter of component failures and at other times it could be due external parties as it was in project 3. During the fabrication of first unit, I called for a pre-commissioning meeting to generate a process flow and allocate responsibilities. The required activities related to the preparation of the selected building were communicated with the landlord and they promised to perform accordingly. By the time we brought the reactor to start installing and *commissioning*, the building was not yet ready and we had to work with the landlord to get it ready. "*We shouldn't have lost the two months we spent preparing the building if we had monitored the landlord closely*. *We should know by now that promises don't mean much for some people*" commented participant 3A

4.3.11 Characteristic of invention

The study did not make any specific findings on the characteristic of the invention because of the low number of inventions under study and so the developed frame work will not contain this theme.

4.3.12 Entrepreneur mentorship

The study did not make any specific findings on entrepreneur mentorship as entrepreneurship was not part of the study and so the developed frame work will not contain this theme.

4.3.13 Market

The one common observation in all the three projects was that marketing activities *need to commence at the invention stage*. This is irrespective of whether the intended product is categorised as a market pull or a market push. It is necessary for the creation of *early adapters* of the product. The early adapters would have bought into the intended product as it is being developed and in most cases they would have given their input of requirements. But the engangment with early adapters did present its own challenges in at least two of the projects. "*We were always avoiding client engangment because we did not trust some of them with our early revolutionary concepts*" participant 1A said. "*These guys have been known to steal*

your concept and give it to someone to produce it for them", Project 3 participants had the same apprehension too in contacting some of the potential clients, especially those from large corporates with the resources to launch their own projects. Perhaps the fact that most of the potential clients were identified through trusted networks helped to calm the participants. Thus, the sub-theme of *marketing activities timing* is introduced at this point. Also emerging in this theme was the sub-theme of *optimum information sharing*. Information shared during the initial marketing stages should be adequate enough for product awareness but tight enough to protect the technology secretes.

Marketing skills was identified in the framework template as one of the sub-themes. Skills has already been covered as a sub-theme of Human Capital theme (section 4.3.4) and as such this section can only emphasize on the importance of having or hiring this skill at the commencement of commercialisation. Regarding the *market base* sub-theme, the study did not include the conducting of a marketing study in relation with the size of the market for any of the three projects. It only focused on the market needs by interrogating identified potential clients. Thus this item would not be included in the developed framework. The same argument is also made for the *market value* sub-theme.

There was a realisation that all three projects would be producing multiple products aimed at different markets which required different marketing strategies. In all three, a common decision was made to firstly produce products for a single market for each project until profitability was reached when other products would be introduced as necessary. Project 3's products, as an example, were even more complicated as each of the multiple products could be sold either unprocessed, semi-processed of fully processed. Specifically, the three main products had multiple market sectors. The char could be sold as is, briquetted or activated for either water purification, soil enhancement, or other cosmetic and pharmaceutical uses. The condensed crude oil could be sold as is, or separated into wood vinegar, bio diesel and tar, or separated into bio diesel and different chemicals which could also be processed to produce other products such as fertilisers, herbicides, surfactants etc. The third main product, the gas could be marketed as is, or separated into different gases or even be used in generators for electricity production. These complications introduced the sub-theme

of *marketing strategy*. The strategy would include the decision on which product to focus on initially, the creation and utilisation of early adapters for the eventual sales of the product, the pricing, and finally the considerations for adding on the other products. Also embedded in the marketing strategy is marketing approach especially where the technology or products being offered are new to the market. Both the geo spatial remoting sensing services of project 1 and the carbon nano tubes of project 2 are new technologies not widely known in South Africa. As such the approach had to include *educating the users* as well as providing a lot more sample products. During a discussion between project 2 participants and a nano technology expert I brought in for general market awareness, one participant observed: "*We didn't think it is that complicated to convince industries to include our nano tubes in their products considering the many advantages which includes enhancement of strength to weight ratio, conductivity, corrosion resistance etc*". The guest explained that most companies do not easily embrace change. "*They typically sit on the side lines waiting for the few early technology adapters to show the way*", he explained.

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4.3.14 Certification

In this study, the products of project 2 and 3 required either *formal certification* or product *characterisation* before being sold whereas those of project 1 required a user testimony only. The study observed that *product certification* is closely linked to the theme of *facilities* which in turn derives a lot of benefits from *networks.* In spite of these close linkages, I have decided to still maintain *Certification,* as a separate theme with the only change that the new theme term would be *testing as* not all the tests were for certification purposes.

There was always pressure from some of the participants in the projects to take some products to the market without certification or proper testing. An example was in project 3 where the participants wanted to start selling the bio diesel based on internal testing. I must admit that I felt conflicted with this idea because on the one hand, I was convinced that the diesel was of the right quality based on the tests we did on several engines and on the other hand, I do know of the consequences of selling un-certified or un-registered fuels. Problems experienced by the user further down the months or even years could always come back to haunt you. Besides, I

come from a certification background. I had to insist that we follow the international norms as well as local standards for every product. This could be seen as being *ethical* in offering products to the market.

The study also observed that the start-ups had to do a lot of product tests and also to get the potential clients involved in the tests. This was because the technologies/products were relatively new in the country as discussed in the marketing theme (section 4.4.13). One point in case was the activated charcoal from project 3. Although there is a lot of literature about the use of activated charcoal for soil enhancement, South African farmers have not taken to this yet. Normal char as opposed to activated one is advocated in literature and we think that this is just because of the hassles of activating. The participants knew that activating the char and infusing it with other additives like trace elements adds a lot of value in enhancing the soil and so they were offering it as such. The team had to introduce the potential clients to the process of activation, the testing for pore structure, adsorption, and surface area and the advantages of this for their soil enhancement programmes. The *testing* of the activated char was also required for the generation of the Material Safety Data Sheet (MSDS) and the CAS number, both of which are necessary for the Department of Agriculture registration of the product and also for shipping purposes.

4.3.15 Mentorship

The field notes observations for mentorship in the study are mostly based on my experiences, as a mentor, during the projects' executions. The one question I kept asking myself throughout the execution was "*could any of the three start-ups have achieved any measure of success without any external support?*" My opinion based on the experience is that they would have struggled to achieve any measure of success. The external support could have been through an incubation program, contracting an experienced consultant to do most of the required tasks for them, or employing the use of a mentor. In this case, all three start-ups had elected to use a mentor and therefore restricting this study to that type of external support.

The required mentorship support I observed was at two different levels. The first level was at a basic management of a start-up firm. This level is perhaps what could be easily contracted out to a consulting firm. This could have, however, denied them the opportunity to learn on the job how to start-and run a firm. A well run mentorship would give the participants an opportunity to practice the running of a firm. The second level of the support was for the commercialisation itself which also included the management of the project and development of the product. Here, I found myself relying heavely on my vast experience in design and development, and quality assurance and technological projects auditing within the defence and aerospace as well as information and communication technology (ICT) sectors. The value of the mentorship was echoed by both participants and captured in participant 1B's statement which also elevated other themes. "*The value of the mentorship provided to us cannot be over-estimated. It saved us from drowning in despair following the developer saga and also gave us access to potential client networks*". The participant went on to say that "*Although we did not get to run a start-up fully, we got to appreciate the product development and marketing aspects of a business. Perhaps, in hind sight, you should have pushed at least one of us to jump from the comfort of employment and run the start-up on a full time basis*". Although the study did not require the evaluation of the success of the mentoring interventions, certain instances presented the opportunity to do this. An example was in the case of project 1 where I had assisted them to partner with an established company in order to access their existing market. The participants acknowledged that "*the partnering with a seasoned entrepreneur, who was also a soil scientist, was like taking a short cut route to a destination*". Participant 1B added that he had learned that proper planning in a project was very critical: "*from the first time we met potential clients, we started promising dates for live demonstrations which we never met and so putting our credibility in question.All this drama could have been avoided had we sat down to plan our activities first before making commitments*" he concluded, sounding very frustrated. It was clear that they made the commitments without due regard for the software development challenges which they had already been aware of. On my part, I felt that as a mentor, I should have advised them accordingly, after all, that's why they required to be mentored.

As the projects progressed, I became increasingly aware of the need to address the support interventions that were being discovered in the study. I felt that I was more *confident* with my *competency* for the technical related interventions like certification/testing, networking, product development, etc. However, I needed to seek external help from colleagues on some of the general management interventions like fund raising and management accounting, product branding, management of psycho-social bust-ups, etc.

Although I had used some of Dawson's sixteen design elements (2014) to formalise the mentorship relationships in order to manage the expectations from both parties, I found myself in constant doubt as to whether I was breaching this or not. The first challenge emanated from the dual role I was playing in the start-ups. As an action researcher, I sometimes felt the need to sometimes initiate and even implement a change in order to observe the result. However, as a mentor, I sometimes felt that this was overstepping my *mentorship agreement* although the acts themselves were covered in the research ethics agreement. The second challenge was being created by both the participants and myself. It felt that the participants were pushing me to overstep the *scope agreement* and take a role closer to that of an operations manager for their projects. In some instances where any of the participants were weaker in their activities, I would feel inpatient and have to urge to take over the management at that point. Perhaps this was because I had *committed* a little more time on the firms and hence making it easy for me to intervene a little more than the *agreed scope*. This challenge was alleviated largely due to including it as a standing agenda point on the each start-ups scheduled progress meetings as well as my constant reflection on the relationship agreement.

The enthusiasm of the participants with the mentoring process, considering they requested it themselves, allowed for an easier *absorption of the guidance* by them. This allowed me to easily provide the support with respect to the interventions. Some indications of the appreciation of the mentoring intervention by the participants could be found in the comments by participant 3A. "*We are grateful for your introducing to us sound start-up business and project management processes. Developing a technology is great but it only makes business sense when there is a business in which*

to commercialise and operate it", commented the participant. Another mentorship support intervention that was singled out by the participants was that of introductions to networks as stated by participant 3B *"Your mentorship role in connecting us with all these academic and product laboratories has been of tremendous help to us because our products depends so much on test credible test results for national registration as well as marketing".*

Although a *confidentiality agreement* was included in the mentorship agreement, I observed that there was an intention to keep away some 'perceived' technical information from me. It was perceived because the information had not been patented and in any case, it was readily available in some papers. I do feel that this dilemma could have been addressed during the *meeting that discussed the mentorship agreement.*

From the observations discussed above, it can be said that the mentorship theme and all its sub-themes in the *framework template* were confirmed. The sub-themes had been covered in the mentorship relationship *formalisation* agreement and they included, *confidence, competency, level of involvement and commitment of the mentor,* and *the level of absorption* and *confidentiality agreement acceptance of the mentee.*

4.4 Emerging themes

The themes of product packaging/definition, risk, commitment, and frustrations emerged in both of the updated frameworks. In addition, a number of sub-themes also emerged in some of the template framework themes. This section discusses these new findings.

4.4.1 Product packaging/definition

From the notion that marketing inputs should be considered from the onset of a commercialisation process contained in the Marketing theme (4.4.13) emerged the theme of *Product packaging*. From the marketing perception, it was evident that in each project, the products had to be designed and packaged in a way that clients

would want them in order to secure sales. The design and packaging of the product offering had also to allow for easy *manufacturability* and *scalability*.

The collaboration with an established business in project 1 gave the participants access to potential clients who critiqued the product offering to a point where it was necessary to change some of the product concepts. The benefits of this process were revealed when the finished products were finally offered to the market. Clients were generally happy with the offerings. One client even commented that "*this is exactly what I have been waiting for*". The product was *packaged* in such a way that a farmer client, for example, who subscribed to the service would log in into the system and get reports pertaining to their farm on a five day cycle at a reasonable monthly subscription fee. A shorter cycle offering was also possible at a premium fee in accordance with the relevant satellite's image fees. From the onset, it was clear that their biggest challenge as well as area where most lessons were learned was in the definition of their product. Participant 1B went as far as commenting that "*we now believe that our initial concept of the products would have not taken us anywhere. Our ideas of how we would present our products to the clients were far from the clients' expectations*." His colleague, participant 1A also observed that "*as it turned out, the client wanted end to end solutions whereas we were thinking of providing data and segmented solutions which would not mean much to clients like farmers*"

Because the ranges of the products from project 2 and 3 were very wide, *marketing input* was necessary from the onset in order for the projects to focus on early profitability of their businesses considering the scarcity of funding, especially for project 3. The input were very specific to the point of nano tube dimensions in the case of project 2 and percentage carbon of chemical purity in project 3's case. Farmer clients for the wood vinegar also wanted it to be offered in non-toxic powder form for animal consumption. Thus, we realised that the products had to be offered to the client in a particular format in order to unsure early sales success. In response to one large scale farming organisation's CEO who said "*Give me a proposal of your entire offering*", we proposed wood vinegar and activated charcoal for both his animals and the fields, bio-diesel for his farm equipment and project 1's crop watch

product for farm monitoring. They indicated that they do not like working with small suppliers with single products.

The product packaging, we discovered as expected, was not only *applicable* during the development stages, but also *throughout the project*. Project 2 could not achieve the intended single walled nano tubes which are typically marketed in precision markets like space and aerospace. The team had to settle for a different type of tube characteristic which meant changing the production process and the market trials. After a cooling off period, participant 2A continued to add to the list of the lessons he had learned on the project. "*The careful identification of the product and the intended market would have helped us to decide on how to proceed with the start-up: whether to collaborate with others, or to research more, or even not to start at all.*" Another example of this emerging sub-theme was evident in start-up 3 which had initially defined their main market as electricity generation from both the bio gas and bio diesel and barbeque charcoal and hence they started designing their reactor to produce such. However, the market was telling us that the biggest demand and revenues would be from the char in water filtration and agriculture and the wood vinegar also in agriculture as an herbicide and in oil fracking as a neutraliser to some of the toxic chemicals they use. Thus the product had to be re-defined and be re-designed accordingly.

4.4.2 Risk

Throughout the different activities of the projects, potential risks which could negatively affect the schedules, costs or quality of the respective projects were constantly encountered. Often, these encounters would take the participants by surprise requiring rapid changes in execution plans. Perhaps the biggest risk encountered in the study was that related to the selecting and contracting of subcontractors. Both project 2 and 3 required the fabrication of fleets of reactors from which the final products would be made. Thus the subcontractors were engaged to firstly fabricate or develop the first-off reactor/platform and thereafter would be contracted to fabricate the rest of the fleet. This arrangement brought out the major risk. Because the contractors contributed in the fine tuning of the design of the reactors, they believed that they would be

automatically contracted for the fabrication of the rest of the fleets. However, during the fabrications of the first-off reactors, it become clear to both the start-ups that the subcontractors were not very suitable for the technologies and also that they were not sharing with them information related to the refinements they were making. The intentions of both of them, we later got to understand, was to force the start-ups to use them for the fleet fabrication as well as to have control over the pricing of that phase of the business. I believe that had risk assessment been performed before engaging each of the subcontractors, this risk would have been discovered and therefore a lot more care would have been exercised in the selection of the contractors and also that the first-off contracts would have been crafted more carefully.

Project 1 also had its own subcontractor related risk which was highlighted during the participant interviews. "*After refining our product concepts following the feedback from the potential clients and embarking on producing the first product, we came across the second big hurdle in the project*" participant 1B reflected. South Africa is still in its infancy regarding geo-spatial development capabilities although it has been a consumer of related products for some time. The participants said that they soon realised that there is a scarcity of software developers who also understand geo-spatial/remote sensing. In their own words, this challenge was a deal breaker: The delays in the development of the product platforms also introduced *reputational risk* to the start-up as they had already promised delivery dates to potential clients.

Projects 2 and 3 also had two other common risks. One of them, safety risk, impacted heavily on their respective schedules. *Safety risk*, although being standard in production processes, especially where gasses, oils and high temperatures are involved, was not factored in the projects' scheduling. This risk, in both cases was highlighted by insurance companies upon the start-ups applications for covers. At the most, each firm lost close to a month's schedule in addressing safety issues in addition to spending unbudgeted funds. The other risk was related to *cash flows*. For example, in start-up 3, the risk was always about cash flow as both participants had no any other means of income (maybe from spouses only) and they had already put in a lot of their resources. This risk was partially mitigated by ensuring that they improve on their cash requirements estimates to ensure appropriate timing of funds. I felt that sometimes

they were underestimating cash flow requirements when speaking to crowd funders which I had introduced them to.

Finally, I found it fitting that I should also add a *marketing risk* sub-theme that I had noticed emerging during the study particularly from project 2. The project participants were always aware that producing the desired single walled nano tubes as they planned was always going to be a challenge due to the many variables involved emanating from the reactor's design, input materials as well as the production processes. There was always a possibility that they would end up producing a different type of nano tubes. Participant 2A spoke about initiating marketing with the wrong eventual market as dictated by the type of nanotubes produced. With the above realisations throughout the project's execution, the project always had some hard decisions to make: either to halt everything and try to resolve the product definition and related marketing challenges or treat them as "messy problems" (Calton and Payne, 2003) which must only be understood and contended with. The participants always chose to continue with the project but keep these challenges as standing points on the agenda in the identification of potential clients to engage in marketing.

4.4.3 Frustration

Throughout the study, there were always moments of tension in all the three start-ups which I termed '*frustrations*' in the study. The tensions were mostly from three areas, that of *finance*, test failures and that of *challenges with subcontractors* (covered under collaborators, in the study). I decided to elevate these frustrations to a level of a theme because of the potential impacts they had on the projects as well as the extended amount of times I had to dedicate to tending to them.

The *finance* challenges were mostly about investments and *cash flow management and funding rejections*. Start-up 2 challenges were related to their having gotten equity investment and the funds fast diminishing due to technical and commitment induced delays. In addition to putting more effort on the reactor fabricator, the participants also stopped taking salaries from the investment funds. I do not know why they were taking salaries in the first place considering that they had kept their

employments. Start-up 3, on the other hand, had its frustrations emanating from the *rejections* they experienced from *potential funders*.

In the case of *sub-contractor related frustrations*, project 1 came close to being terminated when the participants discovered that they could not find an available remote sensing developer in the country. The only one who entertained the project could only offer a limited time to the development. The subsequent negotiations with the partially available developer were very *frustrating* to a point where participant 1A said that "*Perhaps we should just pack the project aside whilst we look for developers outside the country*".

The subcontractor related frustrations were also experienced by the participants of both project 2 and 3. At some stage during the fabrications of the fist-off reactors, both pairs of participants realised that they had made errors in selecting the subcontractors as they did not seem to be knowledgeable enough in the reactors. The subcontractors for the project 2 were heating elements experts whereas the desired reactor required expertise in high pressure and temperature combustible gases. In project 3, the selected subcontractors were from the automotive sectors whereas the pyrolysis reactor required expertise in large piping with high temperatures like boilers. Both subcontractors had already been selected by the time I started the study and so we just had to get fully involved with them throughout the development and fabrication of the first-off reactors. The frustration with the mistakes in the selections of the subcontractors were also compounded by the fact that in their early discussions with them, both start-ups gave the impression that the fabrications of the subsequent fleets will automatically be awarded to them. Untangling these impressions from the first-off fabrications came with substantial costs and frustrating negotiations.

Other sources of frustrations were the *failures* of some of the reactor and platform tests as well as product characterisation/certification tests. Although failures are normally expected in most testing processes, I discovered that some participants did not take them well. One participant for example, kept blaming his colleague and also the "*unfairness of the test requirement*".

Throughout the study, I felt that we got better results when both the project's participants were feeling positive about their tasks.

4.5 Updated Framework for the Commercialisation of Technological Innovations through Start-ups in South Africa

From the above confirmation of themes and sub-themes as well as the discovery of new themes and other sub-themes, I updated the Template framework. In the updated framework, I did not include those themes and sub-themes that had not been experienced during the study. I did however, include those themes and sub-themes that had emerged during the study. The updated framework, the Updated Framework for the Commercialisation of Technological Innovations through Start-ups in South Africa is given below in table 4.1.

Table 4. 1: Updated framework for the Commercialisation of Technological Innovations through start-ups in South Africa

No.	Theme	Sub-theme
1	Finance	
1.1		Funding mechanisms
1.2		Bankable business plan/financial model
1.3		Obligation to funder
1.4		Realistic budgeting
1.5		Cash flow management
2	Networks	
2.1		Introductions to potential clients
2.2		Introductions to facilities
2.3		Introductions to technical experts/academic
2.4		Introductions to potential funders
2.5		Introductions to potential partners/collaborators
3	Collaboration	
3.1		With business partners
3.2		With suppliers
4	Human Capital	

4.1		Business Management Skills (Includes start-up business processes skills)
4.2		Champion/CEO
4.3		Technical skills (Includes product design & development, industrialisation, production, and testing)
4.4		Training (on the job and external)
4.5		Empowerment
4.6		Delegation/outsourcing
5	Commitment	
5.1		Full time vs part time in start-up
5.2		Commit own resources
6	Facilities/infrastructure	
6.1		Infrastructure (for product development)
6.2		Resources/expertise (resources include library facilities)
6.3		Test facilities
7	General Management process	
7.1		Tenacity
7.2		Project management processes (Including product development, quality, and document management processes)
7.3		Contracting processes

7.4		Planning and monitoring
7.5		Supplier management processes.
7.6		Patent (Also general protection of technology where patent not registered)
7.7		Legal compliance
7.8		Commissioning
8	Market	
8.1		Marketing timing
8.2		Use of early adapters
8.3		Marketing strategy
8.4		Optimising technology information sharing (to protect intellectual property)
9	Testing	
9.1		Certification
9.2		Product optimisation and characterisation testing
9.3		Product ethics/integrity (ensuring proper testing before sales)
10	Mentorship	
10.1		Mentorship
10.2		Confidence
10.3		Competent

10.4		Commitment
10.5		Mentee level of absorption
		Mentor level of involvement
		Confidentiality agreement
10.6		Mentorship formalisation
11	Product packaging/definition	
11.1		Definition aligned with Market
11.2		Definition aligned with business model
11.3		Manufacturability and scalability considerations
11.4		Continual product definition refinement
12	Risk	
12.1		Quality and schedule and schedule
12.2		Reputational risk
12.3		Safety risk
12.4		Financial risk (cash flow)
12.5		Marketing risk
13	Frustration	
13.1		Frustration with subcontractors

13.2		Frustrations with failures (Reactor and product test failures)
13.3		Frustration with Financial issues (Funding and cash flow)

CHAPTER 5: RESULTS FINDINGS REFINEMENT AND VALIDATION: FOCUS GROUP

5.1 Focus group with experts

This chapter contains the results of the focus group discussions on the combined Mentoring and Support Framework developed in chapter 4 (Table 4.1). The focus group, composed of three experts (1E, 2E and 3E) in the field of technological innovations, met once only at the end of the study after the development of the updated framework. The function of this group was twofold: to critique the updated framework and refine it and also to validate it. Their activities involved going through each theme and associated sub-themes and making adjustments where deemed necessary. The discussions were recorded and transcribed. The results of the focus group's critique of the framework in Table 4.1 were captured in the final *framework for the Commercialisation of Technological Innovations through start-ups in South Africa* (Table 5.1).

5.2 Themes refinement and validation

The summary of the discussions of the focus group are given below themetically

5.2.1 Finance

In support of what has been identified already in relation to finance, the experts added clarity on two of the items. The first of these is that whereas it is crucial to prepare a good and appropriate business plan, it is equally important for participants to be able to present it clearly to potential funders. "I have witnessed a situation where an innovator could not answer questions on their financial model. "*It was clear that someone else had prepared it for him and he had no clue of its contents*" remarked expert 2E.

The second aspect is the observance of the old project management technique of developing a critical path of the development process and ensuring that activities in this path get the priority to the budget. Their experience had shown that quite often

projects suffer from cash flow problems simply because they had been using this limited resource for non-critical activities. They also added that innovators would often not include their salary requirements in the funding requests and hence offer a reduced commitment effort to the project as they seek other avenues of making a daily living.

Contrary to the belief of some participants, and perhaps most innovators in South Africa, that there are not much financial resources in the country for innovation commercialisation, the experts had observed otherwise. One expert said that the main reason for this belief is that there is not a good match between those who have the resources and those who needs them perhaps as a result of corruption or simply lack of innovation evaluation skills. This phenomenon was also observed by myself during the study but it was not investigated further as it fell outside the scope of the study.

With regard to the categorisation of the sub-themes, the focus group felt that realistic budgeting is a component of cash flow management and hence can be removed from the framework. Thus the applicable sub-themes would be: *funding*, *bankable business plans* (with appropriate financial models), *cash flow management* and *obligation to funders*.

5.2.2 Networks

The focus group collaborated the finding of this theme. They noted that in South Africa, the adage that "*It's not what you know but who you know*" seem to be prevalent and introductions by experienced networks greatly speeds business processes. Expert 3E commented that "*the success rate of those innovators I introduces to major funders is very high because they trust me*". He did emphasize, though "t*hat this puts pressure on me to ensure that the innovators I introduce have a well-defined innovation and are prepared for the business*." "*In spite of the widespread use of internet, I find that most innovators do not have an idea of which institutions have what facilities or centres of excellences*." Expert 1E added to the discussion and went on to say that "*Mentors should assist the innovators to identify and approach these facilities"*. There was no new sub-theme that was proposed for this theme.

5.2.3 Collaboration

It was generally agreed by the focus group that suppliers/subcontractors who form part of the product development process can be considered as collaborators and these can make or break your commercialisation process. One of the reasons for this is that whereas you regard your project a priority, in their business it may not be as it is often small (prototype only, no confirmed production). The constant changes of the product definition, a characteristics of prototyping, also requires close management of suppliers. Expert 2E used an example to emphasize a warning in relation to the careful selecting of a supplier during this stage: The expert narrated that "*in one of the inventions I was commercialising, I engaged a supplier to assist in developing and manufacturing a specialised valve. The poor quality and delays by this supplier ended up delaying my entire innovation and I made it clear that I would not be using them for production. However, the supplier refused to hand over the relevant designs and manufacturing processes and threatened to sue me should I try to reverse engineer the valve. I ended up contracting them for part of the production whilst I was developing another valve with a different supplier"*. Based on these supplier experiences and also what the participants in the study went through, the experts suggested that I add *selection and management of suppliers* as an emerging sub-theme. *Collaboration with other businesses* was confirmed as a sub-theme in the discussions.

5.2.4 Management processes and associated skills

Whilst concurring with the identified sub-themes for both the human capital (item 4, table 4.1) and general business skills (item 7, table 4.1) themes, the focus group recommended that the two themes could be merged due to the overlap of their sub-themes. Thus a new theme, Management processes and associated skills, was created.

As in the two superseded themes, this theme was divided into two groups: business management processes and associated skills and technical management processes and associated skills. *Business management processes*, *business management skills*, *legal compliance*, *training*, and *planning and monitoring* were retained for business management. Because empowerment and delegation may, in some cases mean the

same thing, the focus group suggested that we combining these two into one sub-theme although the terms must still remain the same. Thus the new sub-theme was termed *empowerment, delegation and outsourcing*.

On the business management processes sub-theme, amongst other things, the group mentioned the lack of adherence to governance issues like paying taxes and labour relations regulations. "*The one major problem that gave me sleepless nights in one of my earlier businesses was the taxes I owed. I could not take advantages of any of the governments grants I was being offered and I was constantly dreading the day the sheriff of the court would come with a summons for tax default*" said expert 2E. He further said that "*this tax issue, compounded by the unfavourable contracts I had signed, led to the downfall of my first start-up business*".

Employee empowerment, delegation and outsourcing was retained as a sub-theme because of its importance in the growth of a start-up. The focus group noted that quite often the innovators hold on to their knowledge of the processes and that's making it difficult to scale-up resource capacity in the post commercialisation phase when the start-up should grow the business. Expert 2E said he had observed "*that innovators are often afraid of revealing their IP to the newly recruited employees and hence minimise delegation".*

On the technical processes, amongst other things, the experts stressed on the importance of product development and lamented that adherence to good product development practices often lacks. Simple processes like design reviews, testing to purpose and generating test plans are normally not conducted leading to major reworks as certain errors only come to the fore much later down the development process. *Project management* sub-theme was also confirmed as it encumbered other technical processes and skills related to quality, document control, contracting and supplier management and client liaison.

Tenacity sub-theme was considered as a characteristic of commitment and hence the group requested me to move this to the *commitment* theme and combine it with the *dedication* sub-theme.

5.2.5 Commitment

The commitment by innovators in the commercialisation of their innovations was also seen by the experts as an important factor. They commented both on the availability of the innovators as well as their persistence even in the midst of the personal challenges identified elsewhere in theme 12, *frustrations*. The focus group noted that "*Some people go on to create an innovation start-up with partners but contribute very little to the team and hence frustrating everyone*". Expert 1E said. His colleagues concurred with him and added that at the onset of a start-up, the members need to agree on each person's involvement/value add and also the timelines of the intended commercialisation. Thus, if the agreement is that each individual will continue with their daily employment and only work part time on the project, like it happened in Start-up 1 of this study, then realistic timelines needs to be defined. The focus group felt strongly that lack of commitment by an individual not only delays the project, but also creates tension amongst the team members like it happened in Start-up 2 of this study. The two sub-themes of *full time vs. part time in start-up* and *committing own resources* were confirmed. However, the group also felt that in the narrations of my study, I did touch on the issue of *dedication* to the start-up which they thought was a critical component of commitment. Hence we added this as a sub-theme and combined it with *tenacity* from theme 5.4 above.

5.2.6 Facilities

All the three experts are affiliated with academic and research institutions locally as well as internationally. They concurred that most of these institutions do have the much needed equipment for local innovators but they never publicise their availability and in any case a good number of these are normally not functional. Expert 3E shared a case where a researcher had purchased a laboratory equipment for a particular research and forget about it after the research was done and he had now even left the

institution. In support of this notion, expert 1E added that "*it would seem that the institutions never have inventories of all the equipment they have*.". "*I found that researchers in a particular discipline often knew where to find particular equipment in the country and I depend on them for referrals.*" went on expert 1E.

Another observation made by the focus group was related to the *resource/expertise* sub-theme. Journals may not be very expensive but innovation research innovators require to go through quite a number of papers amounting to a lot more money. This hampers the continued research of most start-up participants. We proposed that perhaps government would consider an access process without infringing the copy right requirements of publishers.. This would also fit in with the learning sub-theme of human capital theme. It was proposed that this sub-theme be termed *knowledge resource* as both the publications and different expertise requirements were aimed at enhancing knowledge.

In confirming the sub-theme, *development infrastructure,* expert 2E added that some of the innovations he had been involved with required clean room for the product development.

5.2.7 Marketing

Innovation must give solutions to problems. This is one of the main messages at innovations and commercialisation conferences attended by the participants and the experts agree. Therefore the market should be constantly engaged as discussed under product packaging (theme 10). Expert 1E did acknowledge that the participants in this study observed this golden rule, maybe with the exception of project 2 who didn't engage the market that well. He also explained that in his experience, he had discovered that "*engaging the market early for a survey tends to create the early adaptors group. Potential clients who have been part of the initial engagement tend to buy into the product early*". One other concept the experts introduced was the '*launch customer'*. Their experience was that most products required a launch customer in order to be sure of attaining an early sustainability. Funders also look for financially stable launch partners for their risk mitigation. From the above, although closely

related to *early adapters*, *launch partne*r was proposed as an emerging stand-alone sub-theme under this theme.

Optimum information sharing sub-theme generated a long debated at the focus group meeting. Examples of how much information can be divulged in applications for patents to avoid invention pirating were brought into the debate. In the end it was agreed that it is always a balance between the need to market your idea and also protect it. Thus the word 'optimum' in the sub-theme was seen as providing the necessary caution.

The rest of the sub-themes, *marketing strategy and timing*, whose wording was changed to *involvement in product development* were confirmed.

5.2.8 Testing

The focus group agreed with all the identified sub-themes of the *testing* theme. A comment was made on the optimising testing sub-theme that this is a very challenging one. Often these tests require multiple testing in order to get to an optimum product and therefore requiring cost efficient and easy accessibility of the test equipment. A debate on whether the *ethical* sub-theme should be renamed to integrity practices resulted in the addition of the word *practices* to *ethical* and thus the new sub-theme was *ethical practices.*

5.2.9 Mentorship

The focus group members noted the challenges regarding my roles in the start-ups where, in addition to the intended mentoring role, I also played the roles of a seed capital investor (in start-up 1 and 3) as well as an action research researcher where I had to have a level of authority to influence change. Expert 1E saw a difficulty with these multiple roles for a mentor "*In one of the projects I was invited to mentor, I was also requested to invest. After I put in a substantial amount of money, I found that I no longer acted as a mentor but rather as a dictator because I realised I had too much to lose if the project failed"* I did find the same tendency too especially in project 3 where

I had invested a large sum of money. What kept me in check was the constant need to have unbiased results for my doctoral thesis. Irrespective of this, the group concurred with the mentoring findings in the study. They did recommend, though, that the sub-themes of *mentorship contracting* (9.1) and *Mentorship formalisation* (9.6) be merged into Mentorship formalisation.

5.2.10 Product packaging

The focus group agreed that product packaging is a vital aspect for an innovation to be brought into the market and one expert even went on to say that "*you can have a market without your own product but you can't have a product without a market*". The expert, 2E, gave examples where very good innovation never made it through the 'valley of death' simply due to the failure of innovators to package the products to meet the market expectations. The group reiterated the importance of surveying the market as early as at the conception phase of the innovation. They suggested that the surveys and associated design/product updates should continue up to final stages of the product development and even into commissioning.

"*Manufacturability and scalability should always be in the mind of every designer*", said expert 3A. He went on to give an example where the desired optimum product requires very high temperatures to produce leading to difficulties in sourcing the appropriate heat resisting materials. At the end of the discussions, all the four sub-themes were confirmed.

5.2.11 Risk Management

Expert 1E argued that "*the whole process of an innovation based start-up is a risk*. *The innovators have to content with the risk of failing to convince the market about their product as well as contending with all the challenges of a start-up business*". The focus group agreed that perhaps the practice of '*enterprise-wide risk* assessment' introduced in South Africa in the early 2000s should be applicable for start-ups, especially technological ones. Thus all the business risk sub-themes, *financial, marketing*, *quality, schedule and cost*, and *reputational* identified in the study could be

covered under this. The safety risk could be extended to cover other statutory requirements like environmental, which was considered as an emerging risk for project 3, etc. and be renamed to *statutory risks* sub-theme.

5.2.12 Frustration

Stress is an important consideration factor in any business, the experts agreed. More so in a start-ups where resources are not readily available, partners do get rather agitated with one another. Expert 2E said that in his experience, "*a good match of partners goes a long way in ensuring the success of a start-up*". Expert 3E even jokingly said "*in one project I mentored, I spent most of the time baby-sitting the partners than doing what we contracted for.*" The group suggested that I include a sub-theme of *frustration with other members*. I agreed to this because I also did pick up the phenomenom in the study although it did not emerge well enough to be registered, possibly due to the participants trying to be politically correct with each other. *Frustrations with failures and rejections* were confirmed without any changes.

In any start-up where the product has also to be developed to meet clients' expectations, challenges do happen and innovators do get stressed-up quite often. Challenges like test samples failing, funding proposal being rejected, etc. contribute to the stresses. Here, Expert 1E commented that "*technological innovation start-up business is not for the faint hearted*". These discussions confirmed the sub-theme of failures and rejections. *Subcontractor and finance related frustrations* were also included in this sub-theme as most of the frustrations from these emanate from failures or delays of processes.

A lengthy discussion ensued regarding the naming of this theme. Although we eventually settled on the name *frustration*, it probably did not cover aspects like stress properly.

5.3 Final Framework

From the results of this critique by the experts, I updated the Updated Template Framework (Table 4.1) to create the final *framework for the Commercialisation of Technological Innovations through start-ups in South Africa* (Table 5.1).

Table 5. 1: Framework for the Commercialisation of Technological Innovations through start-ups in South Africa

No.	Theme	Sub-theme	Remarks
1	Finance		
1.1		Funding	Identification of funding needs and type of funding as per project stage(seed capital, venture capital and growth capital), and presenting to the funders
1.2		Bankable business plan/financial model	To be able to prepare (or outsource) a bankable business plan which includes a financial model and also be able to market it
1.4		Obligation to funder	Ensure using funds as agreed with funders
1.6		Cash flow management	Realistic budgeting (including working capital funds), allocation prioritising, and monitoring
2	Networks		
2.1		Networks	General need for networks
2.2		Introductions to potential clients	The need to understand market requirements during the product definition phase has been established in this study. It has been shown one of the ways of acquiring market information for innovation projects is by engaging with potential clients. Young start-up innovators may not have access to decision makers in the client environment and networks can play the facilitation role.
2.3		Introductions to facilities	In South Africa, the majority of laboratory facilities are at universities and research institutions and there is no directory as to who has what. Networks in these institutions helps greatly to identify and contract for these facilities

2.4		Introductions to technical experts/academic	Challenges with the implementation of inventions will always occur and an innovator needs to have access to other experts in country or outside. Networks can greatly help in identifying and engaging these.
2.5		Introductions to potential funders	There are a number of government institutions offering grants and commercial organisations offering investments/loans. There is no directory of these in the country. Although extensive internet search can reveal most of these, networks can assist in in speedily identifying the appropriate one and even facilitate engagement.
2.6		Introductions to potential partners/collaborators	Technological innovations start-ups are often undertaken by younger people who have had not much exposure of the country's business circles. Networks can assist in identifying potential business partners and collaborators/suppliers as well as facilitate engagement.
3	Collaboration		
3.2		Selection of suppliers	The above requirement as well as price, quality and schedule requirements require the skills to identify and contract a good supplier
3.3		Management of suppliers	Proper contracting and monitoring of suppliers during product development is crucial especially because the scope could easily changes due to emerging discoveries.
		Business to business collaboration	Collaboration with other businesses may be required in order to enhance product packaging or to access technology and markets.

4	Business management processes and associated skills		
4.1		Business management skills identification	Skills required to manage a start-up business include planning and monitoring, contracting, recruitment and leading employees, finance and marketing management, quality and health and safety management
4.3		Training (internal)	The internal training of the above identified skills could be achieved through mentoring and on the job training. This training could also be complimented by external training through courses, conferences and workshops.
4.5		Empowerment, delegation and outsourcing	Although this could be under Business management skills above, it is here considered separate as it is seen to be crucial to the up-scaling of the business. Innovators need to empower new recruits in the start-up in order to scale up capacity speedily.
		Project management processes and skills	These include project scoping, planning, project planning and monitoring, project reviews, (potential) client liaison
		Product development processes and skills	Include design reviews, testing to purpose and generating test plans
5	Commitment		
5.1		dedication, tenacity and resilience	w achieving committed to targets and continuing with task even in the midst of challenges.

5.2		Full time vs part time in start-up	Agreement amongst team members on whether all or some members will dedicate their full time on the project. This will help in resource and schedule planning.
5.3		committing own resorces	An agreement on whether members will contribute own resource or not. Funders seem to favour those entrepreneurs that have also committed their resources other than time only.
6	Facilities/infrastructure		
6.2		Development Infrastructure	Other facilities like specialised buildings, cranes, ovens, autoclaves, wind tunnels, clean rooms maybe required for product development and start-ups would not be able to procure these.
6.3		Knowledge resources	Universities and research facilities could also provide guidance to innovators based on their knowledge and experience. Product definition and development sometimes require constant research and start-ups ca not afford journals. A need for government to find a copy right infringement free journal sharing facility would be greatly help. Alternatively, a way for start-ups to be affiliated to the institutions could also be explored
		Test facilities	The development of technological inventions often requires various test equipment, some of which are quite expensive and also are not required once the product is developed and industrialised. Start-ups cannot afford these and hence have to rely on universities and research institutions.

7	Market		
7.1		Involvement in product development	To ensure developed product solves a need in the market and that it is already been accepted as described in theme 10 (Product packaging/definition)
7.2		Launch customer identification and engagement	Importance of identifying a good steady launch customer for good revenue start as well as investor's confidence.
7.3		Market surveys	To acquire the needs of the target market much earlier own in the start-up life as well as on an ongoing basis.
		Marketing strategies	Include the type of products to focus on, the pricing policies, and distribution
		Early adapters	Whereas launch customer is focused on identifying a large single potential first client, this focuses on those different potential clients that seem fine with the technology and are willing to be the first buyers. They many not necessarily be large customers.
		Optimum information sharing	Balance between giving out invention information for funding and other purposes and protecting the information from would be technology copyists.
8	Testing		
8.1		Certification	Where the market requires a certified product though an industry standard like ISO, EN, CE, FDA, etc.

8.2		Product characterisation and optimisation	Where the product has to be identified so that it can be positioned for a particular use/market. Where a required product type/standard has to be achieved by continuous trying, testing and re-trying.
		Ethical practice	To strive to offer to the market products that have undergone the required tests, certifications and registrations.
9	Mentorship		
9.1		Mentorship contracting/formalisation	The agreements between the mentor and the mentee regarding the expectations and management of their relationship.
9.2		Confidence	Throughout the mentorship period, the mentor needs to sometimes step back and observe how confident the mentees are with the execution of their tasks. An example is where the mentor introduces the mentees to contract negotiations and later lets them negotiate on their own with any help. Sometimes Mentees never feel confident and are reluctant to go on their own.
9.3		Competent	The intention of the mentorship is to achieve a level of competence in specified skills required for the start-up. A means to monitor this has to be included in the agreement
9.4		Commitment	Both the mentor and the mentee need to be commitment to the relationship agreement. The mentor need to allocate enough time to achieve their expected deliverables.

9.5		Mentee level of absorption	The mentees need to have a background where they can easily comprehend the mentor's directions and also the technology and business they are developing. An example would be where ha no background in finance but are being mentored to manage it. Use of external training and or consultancy may have to be recommended.
10	Product packaging/definition		
10.1		Product definition aligned with Market	It is important that right at the start of the definition of a product, market requirements are taken into account and also continuously considered as the development process unfolds.
10.2		Product definition aligned with business model	An envisaged business model may have a large impact of the definition and development of a product and vice versa. For example, where the start-up intends to outsource a number of the sub-systems/ processes of the final product, careful modular development may be necessary.
10.3		Manufacturability of plant/product	The definition of a product should take Cognance of the availability (or ease of access) of identified components as well as proven processes required for manufacturing.
10.4		Continual investigation for new products (from the innovation)	Quite often in technological innovation developments, the developed technology/product could have several other uses not defined at the beginning. These uses may emerge as the development unfolds and hence

			a log of the needs to be kept for further development at opportune moments.
11	Risk		
11.1		General start-up business risk	The constant monitoring of both business and product risks that can affect a start-up like product budget, quality and schedule, business cash flow, key innovators unavailability, etc.
11.2		Statutory risk assessments	Risk assessment required by the country's laws like safety assessments before operating certain hazardous processes
12	Personal aspects		
12.1		Frustration with other members	Business partners, whilst all working towards a common goal, will from time to time get frustrated with each other due to such occurrences as one partner not performing as expected and the divergence of general characteristics of each individual.
12.2		Frustrations with failures and rejections	Commercialisation of technological innovations will at some point go through periods/events which could frustrate innovators, in some cases to a point of giving up altogether or even developing other complications like depression and blood pressure. Examples include failures of tests, cash flow, challenges with market acceptance of product, low investors interest, etc.

5.4 Conclusion

In this chapter, the results findings in chapter 4 were critiqued by a focus group composed of three identified experts in the field of technological commercialisation. The focus group commented on each of the themes contained in the updated template framework by considering their own experiences in relation to each one of them. Their critique was used to refine and validate the Framework (Table 4.1) that resulted from the action research in three start-up companies. The final *Framework the Commercialisation of Technological Innovations through start-ups in South Africa* (Table 5.1) expresses the actionable knowledge resulting from the thesis project.

CHAPTER 6: DISCUSSIONS

6.1 Introduction

The study's main objective was to develop a mentorship and support framework that could be used as a guideline to those aspiring to mentor and support technological innovation start-ups in South Africa. This would be achieved by considering the following two questions:

Question 1: *What support interventions are needed in the commercialisation of technological innovations by start-ups firms in South Africa?*

Question 2: *What are the implications of this analysis for mentors and other technology support agents who seek to aid the commercialisation of technological innovations within this context.*

This chapter firstly discusses the findings of the research by considering their implications for the commercialisation of technological innovations through start-ups in South Africa in section 6.2. The discussions follow the sequence of the themes recorded in the framework in table 5.1 with the exception of the certification and facilities themes as well as product packaging and marketing which are grouped together due to the close interrelationship of their discussion points. Section 6.3 of the chapter argues a response to the first research question and section 6.4 discusses the second question.

6.2 Discussion of the Commercialisation Framework (table 5.1)

6.2.1 Finance

The findings related to finance in this research could be divided into two groups: the first group is that of raising funds and the second is to do with the management of the funds. Innovators in start-up firms need to firstly understand the types of funding suitable for the different stages their firm will go through. In South Africa, the funding structure could be simplified in data reporting by diving it into venture capital, developmental capital and buy-out (KPMG and SAVCA, 2013). The venture capital

fund was further divided into seed capital and start-up and early stage. Challenges in accessing the venture capital funds were researched by Jones and Mlambo (2013). Their survey found that a number of factors greatly reduced the availability of early stage funding to start-ups and also that seed capital was only available through angel investor networks. This study found that it was easier to raise seed capital and even to some extent the early stage capital through crowd funding investment using a well networked mentor. Another avenue for raising start-up funds is through government incentives. In commenting on why some of the participants mentioned that they had not succeeded in accessing government funding, the interviews with the experts confirmed that these grants are guided by government procurement processes and so require very strict application processes and other commitments like the number of jobs to be created. It was found that alignment between the incentive imperatives and the way the proposal is packaged was crucial to accessing these government incentives. One expert in the focus group even casually mentioned that quite often the incentives are given to those who can write a fitting proposal irrespective of the viability of their innovation.

The knowledge of the requirements for each level of investment is also important for a start-up firm as it informs the preparation for the application for such. The research has shown that a well prepared business plan with an associated financial model that is neither overstated nor understated is necessary for a successful application. Success in finance for a start-up is not only limited to sourcing the funds but also to how the funds are managed. Investors will typically impose requirements on the start-up firm to minimise their risk. These requirements, in the research, included the need for periodic reporting and formal board meetings. Because the funds are normally requested for a particular stage of the firm, it is always important that the innovators adhere to the budget in the financial model so that all the critical activities of the stage are covered. The management of the funds raised and the adherence to the funder's requirements are a subject of skills development which is a part of the Human Capital section (section 6.2.4).

6.2.2 Networks

Throughout all the three projects, the crucial roles networks played was constantly felt. The roles that the networks played were varied but mostly centred on introductions to potential clients, funders, facilities, technical expertise, business partners and relevant conferences and other training opportunities. I was the major source of the networks largely because of my businesses and involvement in a number of associations and forums (voluntary, elected or appointed). Some of the participants also did bring limited networks to their start-ups. Some new networks that also proved to be very valuable were created during the study through conferences, workshops and course attendances. Literature has acknowledged networking as one of the crucial enablers of commercialisation. Choo (2007), for instance, argued that networking is necessary for commercialisation because of the multi-disciplinary teams required which includes intellectual property, marketing, contracting, etc. An innovating company would have to have a wide reaching network from which to source knowledge and services in all these disciplines.

Access to most of the framework themes in this study which include finance, collaboration, facilities and other services not covered by the study like intellectual property protection, or even regulatory and institutional assistance could be sourced through networks (Meijer, et al., 2019). Higher education and research institutions are not spared of this need for networks. Purchase, Kum and Olaru (2017) noted that the CEOs of the commercialisation arms of these institutions should be recruited not only for their business experience but also for their business connections.

Government Innovation Policies have also been identified as crucial in the innovativeness and commercialisation success of small companies (Pustovrh, et al., 2017). In the above study in Slovenia, a small, open, post-transition economy with a dominant SME sector, the authors set out to test a variance-based structural equation model (SEM) for selected antecedents and determinants of commercialisation enablers on a sample of 105 SMEs. Their conclusion pointed to, amongst other things, the need for governments to support the SME innovativeness through providing linkages (networks) that enable the SMEs to collaborate with other innovators as well as with large research institutions. Creating networks is one thing and utilising them is

another. In this study, I noted that the utilisation of networks greatly improved the speed of the commercialisation process. I also noted that it facilitated in the optimisation of the products being developed.

6.2.3 Collaboration

In the study, two types of collaborators were identified. The first of these was the business collaborator. The decision taken by project 1 to partner/collaborate with a soil specialist company that was already credible in the industry and had already established clients led to the early development of an appropriate product package and engagement with strong potential clients. Had it not been for delays in developing the required automated system by software developers, the project would have gone to market quite early in the commercialisation period.

The second type of collaborators are the suppliers. The role of suppliers in all the three projects was very crucial for the achievement of the project goals. Two of the start-ups required the assistance of the subcontractors to develop their reactors. The innovators' preliminary drawings required a lot of modifications especially with regards to the types of material used and all this was re-designed by the suppliers. The one start-up depended so much on a subcontractor software developer that in the end they had no choice but to offer the developer a stake in the start-up.

There is not much mention of the importance of suppliers or indeed the whole subject of supply chain in innovation literature for South Africa. Perhaps it is because there is a general feeling that innovators usually improvise components during the development phase. The nature of the three of the projects in this study was that products (mechanical and software) had to be developed and manufactured for continued commercialisation. Outside South Africa, there are some authors who acknowledged the existence of suppliers during the commercialisation phase like Datta, Reed and Jessup (2013) who recommended involving them in order to help minimize new product cost as well as to enhance quality and scheduling.

The importance of partnerships was also identified by Meijer, et al. (2019) through at least four of their identified drivers of SME commercialisation in the Dutch energy sector. The first of these, staff, was expanded as the shortage of qualified and experienced technical staff being experienced by the SMEs. In the study, both projects 1 and 3 experienced this phenomenon where expertise was difficult to come by. The teams quickly went into partnership with the identified resource/s like in the case of the remote sensing software development specialist. Another type of collaboration that could be included here is that of collaboration with universities and other research institutions. Booyens (2011) in her study found that although this collaboration was particularly critical for knowledge spill-over to small firms, it was not prominent in South Africa. In this paper this collaboration is covered through discussions on Facilities and Certification (section 6.2.6) and Networks (section 6.2.2).

6.2.4 Human capital

The discussions on human capital skills development have been divided into three main groups namely leadership and general management, technical management and entrepreneurial practices. The interventions discussed are meant to cover the entire resources in a start-up. However, in this research, all three project did not recruit any staff for greater part of the study mostly due to lack of funds but perhaps also due to other reasons not studied. There were also at least two incidents of difficulty in acquiring critical resources which could possibly point to a general skills shortage in the country. The study, however, did not investigate this possibility.

Markham (2002) in literature kick-started the discussion on human capital with the argument that a champion is needed to drive any commercialisation project. In this study, although it seemed that participants were equally involved, there was always one who was the driver. All the leadership positions emerging on their own without any intervention like appointed or election. Perhaps the absence of this driver could have affected the progress of the project or perhaps the other one could as well taken over the leadership. There was no evidence from the study that the most technically qualified partner in the start-up would be the leader.

Markham (2002) also went on to argue that the skills required on one side of the valley of death differ from those required on the other side. This would seem to suit projects in corporates as typically they already have both of these skills sets. Considering that none of the participants in the study had previous business experience, a lot of learning had to happen. Some of the skills alluded to in the paper were those of general business administrations which include planning, executing and monitoring of such areas like human resources, financial management. It also includes preparing and presenting proposals, concluding contracts and identifying and managing subcontractors. Although some of the participants were demonstrating knowledge with some of these, I did notice a lack of discipline in the implementation and hence I think it is important to instil a very strict disciplined culture from the beginning. The lack of general business skills was identified as one of the main factors negatively impacting early stage venture capital in South Africa (Jones and Mlambo, 2013). The survey results in their research revealed that most inventors in the country do not have the relevant business skills in order to take their start-ups forward and would need to bring in appropriately trained and experienced managers. Unfortunately, according to the survey, these relevant managers are not often available to the start-ups. Of concern in South Africa was some of the findings recorded in Rogerson's (2008) study which indicated that in spite of the lack of general business management skills being one of the main causes of small business failures, there was little willingness by the entrepreneurs to access the relevant skills training programs.

The second area requiring skills development in technological innovation start-ups is of course technical management. The specific skills identified for this were project management, product development and quality assurance/control. An interview with key World Bank officials on innovation in Africa (African Business, 2013) supported the idea of providing targeted technical assistance to early stage enterprises, a grouping to which the participants in this thesis belong. The officials strongly recommended the use of incubation systems which would include this targeted assistance. However, because incubations are not part of the subject start-up innovators, I had to include the assistance in their mentorship and support program.

Quality assurance was brought in the study because it advocates the identification of the different business processes and ensuring the documentation of such. Throughout the study, I found that all participants were very weak with regards to using generally accepted processes like those for design reviews or product testing. In addition to conducting in-house training on this, I had to also get some of the participants to attend external ISO 9001 (Quality Management System) courses.

The third area requiring human capital development interventions in an innovation start-up is entrepreneurial skills. Just because one has invented a technology and is desirous to take it to the market does not qualify them as an entrepreneur. The repeated failures of start-up studied by Cosenz and Noto (2018) were attributed to the lack of entrepreneur skills and proposed the embracing of the role of learning in business evolution. In this study, the main areas that were identified as requiring special attention were in the packaging of the product offering (discussed in section 6.2.7), commercialisation skills, which is the subject of this research, and taking the product to the market. Slávik (2019) noted that start-ups had a simplified and narrow focus on business that excluded important aspects like reaching the market and shaping partnerships.

Because the study was terminated before full business operations were commenced, most of the business processes were only visible for a short time and hence may have not been fully investigated. It is however believed that their discovery and implementation, though for short periods only, was sufficient enough for them to be considered in this thesis.

6.2.5 Commitment

The levels of commitment by the participants differed from one project to the other. The participants of one of the firms were involved full time on their project and they even committed some of their personal resources on it. As a mentor, I was encouraged to spend more time with them which helped amongst other things to utilise the introduced networks and collaborators effectively, formulate and test ideas speedily and resolve challenges effectively. I found that it was easier to raise crowd funding

for them because they were always available to engage with the funders and demonstrate their progress to them.

The participants of the other two start-ups in contrast, kept their day jobs and worked on their start-ups in their spare times. Even amongst the two start-ups, I could observe that the levels of effort were different. In the one project, the participants worked almost all entire weekends and evenings and they met regularly. The differences in progress were observed to be in line with the amount of effort put into the start-up. As a mentor, I was frustrated with these two start-ups. I felt that if I spent more time on them, I would end up being the one doing the work and hence violating the contract as well as spirit of mentorship. I often felt discouraged to introduce them to some of my networks because I would not be confident that they would engage them.

6.2.6 Facilities and Certification

Technological products by their nature are typically acquired by technical experts. In the case of the three projects, the clients were all corporates and large scale farmers who are not easily persuaded through advertising. Hence Independent testing of the products was compulsory for all the projects. Clients required innovators to conduct full tests based on their specific requirements.

The testing requirements demonstrated the need to include certification/integrity testing of products and processes in the overall planning of a start-up technological innovation project. Issues like the existence of acceptable standards and availability of appropriate facilities and test skills would have to be considered. The focus group confirmed this need for testing whilst noting that in South Africa, innovators always face a challenge of locating the testing facilities they require as there is no national database of all test facilities. “There is a lot of different test equipment at universities and research centres in the country which would benefit innovators but they remain underutilised as they are not marketed to industry”. Commented one expert and continued on to say. “I have come across professors who are so proud of their test equipment that they would not let anyone else use them and yet at the end of their specific research or when they leave the institution, the equipment remain un-serviced

and unused". The need for access to laboratory facilities was also pointed out by Gachie and Govender (2017) in their paper on higher education commercialisation in South Africa. The paper specifically identified high tech laboratory test equipment as being one of the key investment activities for commercialisation.

The need for access to facilities is not only limited to start-ups in South Africa. Even large research institutions in other developing nations do require the sharing of facilities. Amongst the main recommendations made by The Committee on Utilisation of Technologies Developed at Russian Research and Education Institutions was that the huge investments in research infrastructure and facilities in the country should be shared with independent research institutions and the private sector (National Research Council, 1998). This was expected to realise increased success in technology commercialisation. In China, a research on the performance of Technology Based Incubators (TBIs in 90 cities across China (Xiao and North, 2017) pointed out the importance of facilities in these TBIs. Through their research, it become very clear that the availability of laboratory facilities and other support services were crucial for the provision of venture capital networks in emerging economies for technology based start-ups. Several other researchers also argued for the importance of testing infrastructure during commercialisation. D'Amico, O'Brien, and Larkin (2013) identified the lack of infrastructure which included laboratories for testing innovations as one of the main challenges of crossing the 'gulf'. Christensen, Ojomo and Bever (2017) pointed out that from an African context; infrastructure for testing innovations was a major challenge. Mankins (1995) on the hand, in his Technology readiness level framework covered testing infrastructure as both laboratory and relevant environment validation. The laboratory facilities term was also used by Kirkpatrick (2015) in the identification of certification/integrity testing. Yet again, Cho, et al.'s (2013) covered this same theme in their paper on support for businesses.

Both the products of project 2 and 3 required a number of tests in order to characterise and optimise them and hence match them to industry defined specifications. The tests had to be done by appropriately accredited facilities as the results were critical in convincing the clients of quality and standards of the products. Some of the test

facilities required, like in the case of the nano tubes, could only be found in specific research centres as they were not normally utilised in commercial testing. Thus, the innovators access to research centres including universities was deemed critical. The access reduced the need for capital drastically and also helped with the speed of product development. The cost of hiring the facilities from the academic and research centres was found to be lower than that in commercial laboratories. The challenge with the facilities was always in how to identify who had them. There is no database of the available facilities in the country and so we had to rely on networks of researchers to locate them. In some cases, even the institutions themselves did not know of the existence of some facilities within them because they could have been procured for a specific function by a researcher who no longer was at the institution.

In addition to the above, the hi-tech nature of the projects required access to specific knowledge sources including researchers and research material sources like libraries. One of the initial challenges experienced with access to research material was the unaffordability of journals on the online market and also the exclusion of use of research libraries (mostly online) at universities and research centres as none of the three companies were initially affiliated to the organisations. Project 2's office location inside a research centre campus gave them some access to research resources. Project 1 depended mostly on free research material developed for the space applications sector within international organisations like the African Union, NASA, The European Space Agency, and other non-governmental organisations .Project 3. On the other hand depended on any available free literature on the internet as well as its relationship with several university based researchers.

6.2.7 Product packaging and Marketing

Across all three projects, it was discovered that product packaging had to be informed by the introduction of the 'potential client' at the beginning of the projects as well as throughout the entire projects' execution. As the products (of all the three projects) were not for mass markets, market research tended to be a one on one with targeted potential clients. The study showed that the engagement with the targeted clients had to be kept strong throughout the commercialisation phase. In some cases, the product

packaging had to be adjusted to accommodate the evolvement of the needs of the targeted clients. For example, in the biomass project (project 3), The initial packaging was in a way that the bio oil would be for the power generation market but it was later discovered that this oil was mostly composed of wood vinegar where the market demand was in oil and gas fracking as well as chemicals production.

Product packaging/definition in this study is considered as the process of identifying the format in which the product will be offered to the market. The product packaging also includes specific details of the use of the product. In their framework, Datta, Reed & Jessup (2013) placed product packaging in the first process of layer 1, the first four components of layer 2 which include source of innovation, type of innovation, market entry and IP protection. This was also in line with Stan Sadin's TRLs 1 to 4 (Banke, 2010). In all the three projects in this study, the initial packaging/definition had already been done by the start of the study. However, it was discovered, as the projects progressed that it was necessary to revisit the decisions made in this regard.

Product packaging is about the definition of the intended use of the product itself, the timing of the launch of the product as well as the technology used. The selection of the technology would most probably be a skill that the innovator brings to the table in the hi-tech innovation environment which was the case in all the three projects considered in this research. A case can be made from this that whereas market input is required during the product definition phase, the same case would be made where product packaging is required during the marketing phase where product definition must still be active and willing to re-design. Some of the literature that had some elements of the product packaging theme includes Zadeh, et al, (2017) who identified lack of alignment between the technology selection and the market as one of the challenges in the commercialisation of projects in Iran (theme 11, 12 and 34 of 43).Slater and Mohr (2006) dedicated a large portion of their paper on this link between marketing and product design.

The need for an alignment between an invention and the market clearly directs the innovator to engage with the market in the early stages of the innovation so as to access the need and hence the right packaging of the eventual product. The early

stage introduction of a potential client or early adopter was also emphasized by Choo (2007) who went on to recommend that where the potential clients could not be identified early on in the project, the innovator should strongly consider re packaging their product for a different client profile. Although this could be considered as being harsh, the study's focus group of experts alluded to the same recommendation by insisting that there had to be a potential launch customer for a commercialisation project to have a good success chance.

This recommendation was shared by Datta, Reed and Jessup (2013) who advocated for a concurrent engineering approach where research and development, manufacturing and marketing happen at the same time. This, they found was essential for optimizing costs, market entry timing and product/market fit. Whilst these researchers argued for ensuring that the product is aligned to the market, other out-rightly said that an invention need to be informed by the needs of society. For example, the success of the 'pull economy' type of business innovation in Nigeria described by Christensen, Ojomo and Bever (2017) illustrated the importance of ensuring that innovations, including both the product and the associated technology are appropriate to the intended community.

Whereas innovating in large firms has the advantage of having or contracting market research teams, the start-up innovator has to use his/her own skill to market product. Rose and Winter (2015), on South African water sector entrepreneurship challenges, also weighed in on this issue by calling for government to include in its entrepreneur policies support for market analysis and industrial design. A good market analysis will inform the design of suitably packaged products/services by innovators.

The development of marketing skills has been identified as one of the crucial success factors for commercialisation in literature. The marketing skills in this case should run across the project life cycle, from the product development phase to the deployment and distribution of goods as demonstrated in the Integrated Framework by Datta, Reed and Jessup (2013). Unfortunately, not enough resources are put in Africa to provide training that help innovators to fully understand the market and devise means of approaching it according to the World Bank officials on African Business (2013). In this

study, the participant's marketing skills were developed through their engagements with potential clients with my guidance.

The African market itself was also blamed for some of the failures of innovation start-ups by both Christensen, Ojomo and Bever (2017) and Berry, et al. (2002) because of its low market base. This, the authors, argued that it contributed to the low venture capital participation and envisaged business sustainability. This was true to some extent in two of the start-ups of the study but was not an issue at all for one of them (project 3) whose products had a very large market base within Africa. Further to this, the products of all the three start-ups could also have strong markets in both the USA and Europe. In this study, the practice of continuous market engagement proved its worth in the continuous product definition and alterations through the consultations with the potential clients at all times.

6.2.8 Risks

One issue that required close attention throughout the projects was the need to constantly identify risk, devise mitigating plans and monitor the results. Risk as a theme for support and mentoring start-up firms in the commercialisation of technological innovations is missing in literature theory. This theme emerged during the course of the study in the projects and was identified through both the daily observations and the participants' interviews. Several areas of risk were identified in the projects and some of them had the potential of crippling project.

From the Human Capital theme, a risk associated with availability of skills was identified. It was established that certain critical skills were not readily available in the country. This risk negatively affected the schedules and also perhaps the quality of the concerned start-up. Another risk was experienced within the collaboration theme. There was a persistent challenge with identifying an appropriate contractors for the manufacture of the different reactors for the two start-ups that required this as their production platform. Again here, schedules and quality in addition to cost were negatively affected. A third risk identified was related to the marketing theme. In some instances, the desired early engagement with potential clients resulted in some

participants over committing to delivery schedules. Yet another risk identified was closely related to the product packaging theme. This was to do with the choice of the technologies to be used for the production.

In one of the start-ups, there were difficulties surfaced with the commissioning of some of the equipment. It was discovered that the technology used was not readily supported by equipment readily available. This could have led to the importing of very pricy equipment. Fortunately in this case, the challenge could be averted by the modification of the technology. The finance theme also experienced its own risk that was associated with the raising of investments. The country had experienced a lot of failures in biomass projects. This was probably due to reduced due diligence for green projects. Unfortunately, this meant that investors had become wary of putting their money in these projects. Eventually, the concerned start-up got it right by avoiding the 'green' imperative in the business plan and rather focussing on the advanced technology developed that would ensure reasonable profits with a much reduced capital input.

All these negative effects could have been anticipated and hence mitigation plans developed had there been an initial project risk assessment. In spite of my prior background having included risk, quality and health and safety management which all require assessments at the beginning of a project or new organisational strategy, I ignored to conduct assessments in the start-ups. I only realised the omission after the risks started manifesting and the participants were not prepared for them. I think it is imperative for every aspiring mentor in technological innovation commercialisation in South Africa to consider conducting early assessments of the possible risks and planning their mitigations.

6.2.9 Frustrations

In the literature reviewed, the issue of stresses and frustrations in innovation commercialisation projects did not come out strong enough to be considered a theme. The closest to this was from researchers' concerns with government policy (Rose and Winter, 2015; Booyens, 2011). In writing about mentorship in working environments in

general Char, Walz and Gardner (1992) observed mentors need to be constantly aware of the psychological condition of their mentees. They termed this mentor type, '*psychosocial*'. In this thesis, by being part of the innovators teams, I was close enough to experience some of their stresses and frustrations. In some cases, the frustrations were severe enough to threaten the existence if the start-up. One example of this was in project 1 when they could not identify a suitable specialist software developer. Another example was in project 2 when the one participant, who was the most critical partner for the technology, was not demonstrating full commitment to the project thereby causing unnecessary delays to the project and also affecting negatively the requirements of the investor.

Project 3 participants, although being worried about cash flow issues, seemed to deal with their stresses quite well. They needed much less intervention from myself as opposed to that needed by the other participants from project 1 and 2. Although I cannot claim that my interventions saved the projects, I still felt that they assisted in getting the participants to continue focusing on their tasks. A constant flow of good news related to favourable comments by clients, successes of tests, etc., also fuelled some enthusiasm in the projects. Other less felt sources of frustrations by all the participants were the failures of tests and rejection of both marketing and financial proposals.

6.2.10 Mentorship

The concept of mentorship as described by the Dawson (2014) could only be partially adopted in the study. This is due to the fact that the action research adopted in the study advocates a much tighter involvement in a project than is generally practiced in mentorship. However, because of the high content of learning requirements in all the three projects, mentorship has been singled out as one of the main enabler themes. Literature has continually made calls for mentorship to be a part of the support activities provided to innovation start-ups (African Business, 2013; Xiao and North, 2016; Ting, Feng and Qin, 2017; Choo, 2007; Lundqvist, 2017).

The inclusion of some of Dawson's 16 Mentoring Design Elements, namely, Objectives, Roles, Activities, Rewards and Policy in my contracting with the start-ups proved its worth for me in the case of one of the start-ups. Because of the diminishing progress due to the participants not being fully committed to the project, I found myself being required to take on the role of management. This was even sweetened with the offer of shares in the firm. The signed contract had to be used in order to clarify the boundaries of my involvement and we stuck to that.

As a mentor in the study, I got to learn one major lesson that I would wish to stress to aspiring mentors. I consider myself as being well qualified and experienced in both business and project management. However, I found that the participants benefitted more from colleagues, expert in their fields, who I occasionally brought in for discussion session than they did from me. This may just be a psychologically based phenomenom but I however, would recommend a further study to firstly test my finding and secondly, if it proves positive, to investigate the reasons.

This kind of training may not have been possible had I not have a good network web of experts. The networks also assisted in speeding up most of the activities of the projects as discussed in section 6.2: Networks. Thus, some of the attributes of a mentor are to be a well-qualified and experienced person who realises their shortfalls and also has a good network they can call upon to assist in training as well as in connecting to other project needs like finance and facilities.

One theme that caught me by surprise in the study is that of *personal frustrations.* I found myself, as a mentor spending a considerable time addressing participant's frustrations as discussed in section 6.11: Frustrations. All I had to depend on to assist the participants were my experiences in founding and managing other technological innovation start-ups. Perhaps counselling as a module could be included in the preparation of a mentor.

Finally, I have come to agree with Ruth Gotian's (2016, p 1) assertion "A common assumption in society is that just because people have content expertise, life experiences and match our gender or ethnicity, they can successfully mentor others.

Often, the most successful in the field, are given mentoring responsibilities, yet, there is no necessary connection between the two". I think that it is imperative that there must be a framework for preparing mentors for their roles. This study's framework is but one of the inputs for this preparation.

6.3 The support interventions needed for the commercialisation (Q1)

The call to investigate support mechanisms to small business in South Africa, particularly innovative entrepreneurial firms was made by other researchers including Booyens (2011) who wrote the following in the conclusion of her paper "*This study raises various questions for further investigation and contributes to policy debates by indicating that broad-based policy support and interventions are required to assist SMMEs in overcoming the many barriers that hamper their growth and development. Specifically, innovative entrepreneurs and micro-sized enterprises require targeted policy support"* (p77). This study has identified twelve support interventions (6.2.1 to 6.2.10) that are needed for start-ups to successfully commercialise their technological inventions in South Africa. The identification processes started with scanning literature in order to create a theoretical framework which was used as a template in line with the Template Analysis Technique chosen for the data analysis in the study. The template was then updated from the findings which were created from field notes and participants interviews. This update was further refined by a focus group composed of three experts selected for their experiences of technological commercialisation in South Africa. The focus group also served as a validation processes.

The support interventions are not necessarily independent of each other. They interact with each other. For example, through a mentor's network, the start-up could be introduced to an organisation to collaborate with for marketing or certification purposes.

The framework was shared with the particpants throughout its development and some of its aspects were tested out. This formed a test for its 'actionable knowledge' status. It may be argued that most of the interventions have been described elsewhere in literature but this study achieved in combining them in one study. The study also

teased out some soft science aspects of technological innovation commercialisation in the form of '*psychosocial*' as defined by Char, Walz and Gardner (1992). It is noted in the study that the start-ups could seek to be a part of an incubator where most of these support interventions could be provided. In this case one would have to firstly investigate if the incubator can indeed provide these services. My casual observation in the country is that most incubators in the country would not be in a position to identify and provide all these support services. Alternatively, a start-up could collaborate with an academic or research institute or a large corporation where they would be assisted with most of the services.

Other than start-ups and their associated mentors and supports, policy makers and technological innovation managers/agencies would also find this framework useful either as a template or background material. I hope that all its users will constantly update and refine it and also that other researchers will validated the updated framework in the future.

6.4 Implications for mentors and supporters (Q2)

Steven Cho (2007), observed that mentoring of entrepreneurs and technopreneurs *"focuses on providing guidance to the entrepreneurial protégé's personal and professional development in achieving a set of business goals. Also, the business mentor brings a dynamic web of resources into the relationship in terms of their broad business knowledge and personal and professional networks*" (p147). This observation lays out the foundation for this study's findings regarding the implication for mentors and technology support agents seeking to aid start-ups in the commercialisation of technological innovation in South Africa.

Firstly, the study has identified some of the major interventions that the start-ups may require during the commercialisation process. The interventions may not be limited to the ones identified and the mentor is advised to also try and identify others that may not have come up. Furthermore, the mentor may also add on to the sub-themes for each interventation depending on their experience and the context of the start-up's innovation. Because of the wide range of the needed interventions, the mentor is

advised to be able to accept their shortcomings in providing these services and consider bringing other external experts to assist with the mentoring.

Once both the mentor and the relevant start-up have familiazed themselves with the framework's interventions and any other they may have identified, the framework requires of the montor/mentee relationship to be formalised using amongst other guidelines, Dawson's sixteen mentoring design elements (2014). Through this process expections from each party can be confirmed and commitment to the relationship defined and confirmed.

The framework developed in the study answers to the call by Crisp and Cruz (2009) to ensure that the operational definition of mentorship should be specific to the population of interest and the assistance provided to them. In the case of the study, the specific population of interest are the technological innovation start-ups in South Africa and the assistance provided to them are the interventions identified in the framework. The framework also answers to a broad need for commercialisation mentors in South Africa as discovered by Gachie and Govender (2017) in their survey research of challenges for commercialisation in South Africa Higher Education Institutions.

6.5 Conclusion

This chapter has discussed the identified interventations (table 5.1) needed for the commercialisation of technological innovations through start-ups in South Africa and the implacations of these for mentors and supports seeking to aid the start-ups. The discussions have also compared the interventions against existing literature, particularly studies in South Africa. The 'actionable knowledge' aspect of the framework for different users including other innovation practitiones and policy makers was also pointed out. This was done by offering responses to the two research questions.

CHAPTER 7: CONCLUSIONS

7.1 Concluding remarks on the study

South Africa, like most other countries, has identified innovation as one of its pillars for economic development. Innovation itself comprises of three main activities namely, invention, commercialisation and market penetration and these typically take place in corporations, academic and research institutions, and start-ups. Innovations in start-ups often have more challenges than when it is undertaken by the corporation or an institutions which would have resources and other support mechanisms.

Inventors who plan to take their inventions to the market through start-ups have to cross the commercialisation activity on their own with minimal resources and other support structures. This is more so for those that are not lucky enough to be located within a technology incubator. The inventor in South Africa would also have additional challenges in navigating this commercialisation phase of innovation. The few venture capitalists that are available are themselves very risk averse and not readily willing to invest in a start-up with no performance track record. Likewise, the few angel investors who are available only invest within their close networks. Development laboratory equipment is either non-existent or existing in private laboratories at high costs or in academic and research institutions who do not publicise what they have. Furthermore, expertise in business and project management and more especially product development resides in the corporations and not readily available to the start-ups.

This qualitative action research set out to discover the support interventions needed for the commercialisation of technological innovations by these start-up firms in South Africa and the implications of this analysis for mentors and supporters seeking to aid the commercialisation process. The study was conducted in three technological innovation start-ups which were commercialising their inventions. My roles in the start-ups was that of a mentor and a supporter in addition to also being an insider action researcher. I used field notes and participant interviews methods for collecting data which was then refined and validated through a focus group comprising of three commercialisation experts in technological innovations in the country. The data was

analysed using a template analysis method, the template of which was created through the support interventions themes identified in the literature chapter. The framework template was updated with the field notes and interviews data and further refined using the focus group.

The investigation identified twelve main support areas needed by the start-ups for successful commercialisation. The identified support areas, in the form of themes are finance, networks, collaboration, human capital, commitment, facilities/infrastructure, markets, testing, product packaging, risk management and personal aspects. Each of the themes had its own sub themes which were used to further explain the main theme. These themes were used to define the support interventions needed to in the commercialisation of technological innovations through start-up firms in South Africa. Further to this the themes were also used to flush out the implications to those mentors and supports needing to aid in these commercialisation processes. The implications of the results for the aspiring mentors and supporters was that they would have to have a very strong network within the finance, business and academic and research institutions that would be introduced to the start-ups at different times. The mentorship and support intervention would also include the development of the innovators in business management, project management, product development and other related management areas like risk, quality and safety. Furthermore, the support would include the provision of personal development guidance especially in relation to motivation for stronger commitment and resolving personal conflicts and internal frustrations. The study also concluded that it is essential for the mentorship relationship to be formalised and also for the mentor to constantly reflect on their capabilities so that they can bring in outside help where necessary.

The resulting *framework for the commercialisation of technological innovations through start-up firms in South Africa* (Table 5.1) is intended to guide aspiring mentors in this field in the quest for a successful innovation. The framework may also be used by innovators and commercialisation agents in their innovation projects.. Policy makers in the country could use it as an input to their process of formulating or reviewing of the System of Innovation. These management implications for practitioners are elaborated in the following section.

7.2 Recommendations from the study

One of the most effective ways for innovators in South Africa to follow in addressing the support challenges in the framework is to seek the help of experienced and qualified mentors. Traditionally, anyone with some experience in particular field and willing to help has been considered a mentor. This research argues that aspiring mentors, in particular for commercialisation, need to be equipped with knowledge of the potential challenges that they may encounter. It also supports the notion of formalising the mentor/mentee relationship at the beginning of the engagement so as to ensure commitment and expectation boundaries by both parties .In addition, it will also clear out some contentious expectation such as reward expectations. The mentor would also have to be aware that because of some of the resource constraints in the country, they may also be expected to provide other support service beyond those contained in the classical mentorship definition to ensure the success of the start-up.

The second major recommendation from the study is related to facilities for product development and testing which generally tend to be very expensive. South Africa is fortunate in that most of the required facilities and equipment are available at the different academic and research institutions as well as at private laboratories. However, the unfortunate part is that there is no public awareness of the existence of most of these. At times, even other colleagues from an institution do not know of some of the equipment within their own institution. This lack of awareness could result in start-ups trying to raise the already constrained funds to procure their own facilities or equipment or even forgo some of critical testing for their products. This challenge could be alleviated by a government policy that establishes a national database of all available facilities at the different institutions as well as at private laboratories in the country.

The other major recommendation relates to human capital development. The scope of this research did not cover the development of skills in academic institutions although it is considered as a critical component in the development of inventors and their associated supply chains (Carayannis, Samara and Bakouros, 2015; African business, 2013; The World Bank, 2017). The study focussed on the development of

different management skills within the commercialisation process through on the job training facilitated by the mentor or through external training. The study found that the innovators lacked such management skills as financial management, project management, product development management and quality and configuration management. Unfortunately these were found to be crucial to the success of the start-up as a technology business. It was identified as one of the areas the mentor has to be aware of and ensure that appropriate training and support is provided to the innovators. Other human capital development related areas to be considered by a mentor, although identified as separate themes include marketing management, risk management and attention to the innovators personal aspects such as frustrations and in-fighting. In addition, their level of commitment by each innovator would need to be addressed at the onset and monitored occasionally as it could affect the pace of the development as well as the internal relationships of the innovators.

A fourth recommendation from the study is to do with the packaging of a product which is crucial to its success in raising funding as well as the getting acceptance in the market. Innovators should conduct extensive market studies at the onset of the innovation, not merely predict sales but mostly to find out how their innovation should be presented to the market. For example,the same product could be presented from the sustainability point of view or from a fourth industrial revolution point or even from that of a health living one. Each of these views could attract different funders and early market adapters. Again, it is recommended that the mentor and supporter pay particular attention to this in their service provision.

It is acknowledged that a mentor may not be able to provide all the above services. Thus, the final recommendation is that one ought to develop a wide range of networks from which they can tap the various assistance, maybe even for free. Although I have already discussed the recommendation for the creation of a national database for all available facilities, the innovators or mentor and supporters may have to use their networks to identify these facilities whilst the database in being developed.

7.3 Limitations of the study

This study had one main limitation that need to be considered in using the developed commercialisation framework. The limitation is that the study did not cover the full commercialisation process of the three start-up firms due to time constraints. At the time of obtaining ethical approval, all three projects had already commenced and I joined them along the product definition phase. At the other end, the study ended before full industrialisation of each of the projects although some sales had taken place. Hence, the projects' operations performance were not be monitored.

7.4 Further research

This research covered a lot of themes in the technological innovation commercialisation through start-up firms in South Africa and as such it could not go into detail of each of the themes. The following further research is thus suggested:

7.4.1 Testing of the framework

It is recommended that further action research be undertaken on other innovation start-up projects in order to further refine and validate the developed framework. The validation could be for South Africa or could also include other developing countries. The mentorship model in this study was infused with support to an extent that I as a researcher/mentor was also considered as a support provider. Further research study can consider other forms of mentorship, such as pure mentorship without hands on support.

7.4.2 Research on country specific studies

Although it could be argued that there is a lot of literature on most of the literature derived themes, it appeared that there were very few such studies conducted in the South African environment. Country specific studies on these themes would be recommended.

7.4.3 Further research on the emerging themes and major sub-themes

Several themes and sub-themes emerged during the study, namely risk, personal effect, and commitment. It is recommended that further studies be conducted in the country to determine their actual effect on innovators in a commercialisation based start-up. These can focus more on the human aspect of the process as opposed to the technological processes aspects of the start-up. Perhaps these studies can be combined with those of entrepreneurship which do have several human aspects in them already.

7.5 Personal Reflection

Often I would sit with my colleagues after a game of golf lamenting about the challenges of starting a business in our country, South Africa. Sometimes the discussion would be specific to game changing technological innovation start-ups. We would marvel at our country men, Eon Musk and Dr. Soon-Shiong, who have made it big in the USA and across the globe. Most often than not we would attribute this to favourable innovation environment in the USA as compared to that in our country.

I would also engage in similar discussions with my two sons who have both visited Silicon Valley and are also both corporate bankers. Like typical bankers, they would often attribute the success in the USA to the availability of funds to risk. “There is abundant venture capital that failure is not feared” they would say. Whilst I would be agreeing with them, I would caution that there perhaps could be other fundamentals at work .Their young sister who was still at school then and is now studying sciences because she ‘hates’ BComs degrees would rally behind me and stress “Money isn’t everything”.

Then there was also the little matter of “Uncle William”. Every now and then, young innovators would approach me to assist them with their start-ups. Perhaps this was because I had demonstrated some level of success in technology based businesses as a black person in the immediate post-apartheid era of South Africa. The words

“please Uncle William, can you assist us with the direction of our start-up” still ring in my ears. I guess the ‘Uncle William’ would be used so that I should not consider charging for my services. I would mentor them, in a hap hazard way, I must add. Sometimes they would be successful and sometimes fail.

It is against this background that I started my journey of investigating the challenges in technological innovation start-ups in South Africa. My thesis had to have the key words of mentoring, commercialisation, empowerment and start-up. Considering the amount of times I had to folk out some funds to assist some of them and also where I had to take them to my networks for other support services like test facilities, I decided to add to the key words ‘support’. I felt that the definitions of mentorship did not stretch far enough to include these other support services I was providing. The discovery of action research methodology in the DBA program completed the equation as I could be a part of the innovators team without fearing it would be unethical as it often is in other research methods.

The intentions of my thesis journey was to assist my colleagues, my children and any other people who believe in taking technological invention into community markets to become better equipped “Uncle Williams”. Throughout the journey, I continued encouraging the business discussions with my colleagues and my children so that I could be testing if what I was discovering was making sense to them. The result of these tests were an overwhelming “yes, we need to study the reasons for our poor performance rather than just coming up with assumptions over a drink on the 19th hole or around our kitchen table”. As for my personal reflection, I look back at the famous “Uncle William” at the start of the journey and cannot but marvel at the much better enlightened ‘Uncle William’ of today. I believe that the discoveries have made me more aware of areas to focus on in my mentoring and support activities. But they have also brought to the fore other shortcoming that I think still need to be explored in the quest for an improved Uncle. Most importantly to me, my children, especially my baby daughter still at university have come to respect and embrace the concepts of innovative creations and commercialisations.

The journey has also taught me that whilst one is mentoring and supporting innovators, you get to learn a lot more from them as well. It was action learning at its best for me. The learning of new things, like bio-chemistry stuff that I never studied, the proximity to those energetic young innovators and the joy of seeing a plan come together to form a marketable product has convinced me to embrace mentoring and support in technological innovation commercialisation as my passion in my current after sixty life.

I think that the study has also made me get closer to my desire to living life after sixty as a mentor and writer in the fields of innovation and commercialisation more specifically. I have discovered through literature as well as through discussions with different people from government and academic and research institutions about my research that innovation has definitely to be one of the key drivers in the growth of our economy. However, the subject is not well understood by most of them and avenues where the subject can be taught at a practical level are almost non-existent. I plan to partially fill this gap by mentoring technological innovation start-ups where I can, participating in innovation related forums including seminars, as well as publishing short articles related to specific areas within the field in local magazines and periodicals. Regarding journal publications, I don't feel comfortable to see myself as an accomplished researcher yet. The phrases "this is not good academic language" and "develop the argument" still rings in me and after self-reflection, I do think that I need to work on these aspects a little more before I can appear in a major journal on innovation in Africa. I think I will have to rely on collaboration with seasoned researchers in order to get there.

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Appendix 1

	QUESTIONAIRE 1	For innovation participants
1.	**Challenges**	
1.1	Identify three major challenges you encountered during this phase of the project.	
1.2	Explain how these challenges manifested in the project during the phase	
1.3	Rank these challenges in order of severity	
1.4	Explain how these were addressed in the project	
1.5	Would you have addressed them differently in hindsight?	
1.6	Explain the role of mentorship in addressing these challenges	
2.	**Learning**	
2.1.	Identify three major lessons you think you have learned in during this phase.	
2.3	Did you anticipate learning about these at the start of the phase? Explain	
2.4	Explain how the lessons enfolded.	
2.5	Explain the role of mentorship in the lessons.	
3.0	**Support (equipment)**	
3.1	Was 'equipment support' identified in any of the above questions? If it was not identified proceed to questions 3.2 to 3.5.	
3.2	Identify any support you may have required during the phase (equipment)	
3.3	Explain why this support was critical for your project during this phase	
3.4	Explain how you managed to address this requirement	
3.5	Explain the role of mentorship in addressing this requirement	
4.0	**Support (networks and politics)**	
4.1	Were networks and political challenges identified in questions 1 and 2 above? If not, proceed to questions 4.2 to 4.6 below.	
4.2	Identify any challenges you may have had related to external networks and corporate politics during this phase.	
4.3	Explain how these challenges manifested	

4.4	Explain how the challenges were address (if they were)
4.5	If they had not been addressed, what impact did/would they have/have had on the project?
4.6	Explain the role of mentorship in identifying and addressing these challenges.
5.0	**Support (psychological)**
5.1	Was psychological support identified in questions 1 and 2? If it was not, proceed to questions 5.2 to 5.5.
5.2	Identify, if any, any psychological challenges you may have experienced during this phase
5.3	Explain how these challenges manifested during the phase
5.4	Explain, if any, action was taken and the result of this action
5.5	Explain the role of mentorship if any in addressing these challenges
6.0	**Support (financial)**
6.1	Was financial support identified in questions 1 and 2? If it was not, proceed to questions 6.2 to 6.5.
6.2	Explain the kind of financial support you may have required during this phase.
6.3	If these challenges were addressed during this phase, explain how they were
6.4	If they were not addressed, explain what impact they had on the project.
6.5	Did you anticipate any of these challenges at the beginning of the phase?
6.6	Explain the role of mentorship in identifying and addressing these challenges

Project No:		Table description		Expert No.:	
Project		Innovation participant No.		Date:	

	Comments
1	Comment on mentoring observations (compare the data with your experiences)
2	Comment of support observations (compare the data with your experiences)
3	Comment on participant interview (compare the data with your experiences)