

https://dspace.org/

Technological capability building in public research organisations: the case of CSIR in South Africa

Sekwele, Stella Dineo

2015
http://hdl.handle.net/10539/18630

Downloaded from a DSpace repository. https://dspace.org/



Technological Capability Building in Public Research Organisations: The Case of CSIR in South Africa.

Stella Dineo Sekwele

A research report submitted to the Wits Business School in the University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management in Innovation Studies

Johannesburg, 2015

ABSTRACT

The purpose of this study is to investigate the process that Public Research Organisations (PROs) in South Africa, such as the Council for Scientific and Industrial Research (CSIR), use in building technological capabilities. PROs in industrialising countries face a number of challenges such as limited access to resources, cut-backs in government funding, lack of relevance to industry needs and failure to transfer technology to industry as well as changing government priorities. In the specific case of the CSIR Biosciences Unit, the above mentioned challenges have had a detrimental effect on building technological capabilities, and are likely to have a compounded effect on how technological capabilities are built within the CSIR.

One approach that has been suggested in the literature reviewed in the case of industrialising countries that could assist in understanding the challenges currently faced by the CSIR Biosciences Unit is to contrast the elements of the balanced Technological Capability Building (TCB) system model with an unbalanced TCB system model. The objective of this research is therefore to understand the factors that promote or impede technological capability building in a PRO in South Africa. The study uses the TCB model as a reference to investigate how this is done in the context of the selected case study, but it goes further to explore how the TCB model is actualised/implemented in this particular PRO, investigating how a lack of technological capabilities impacts on its overall performance.

Much has been written about how best to develop technological capabilities in general. However, there is limited empirical evidence on the process through which capability building is done within public research organisations in industrialising countries. Therefore, little is known about the specifics of the process in these contexts, including considerations such as speed and decision making in the capability building process.

Public Research Organisations (PROs) in such countries use highly sophisticated technology and machinery, a majority of which is sourced internationally, in order to carry out their developmental mandate. As a result, the technology and operational expertise also emanates from outside of industrialising countries.

In this study, empirical data from the CSIR Biosciences Unit is interrogated and analysed by employing a qualitative methodology in order to gain an in-depth understanding of how this process works in a PRO based in South Africa. Most of the empirical literature that has been explored by several authors and scholars primarily deals with how organisations in industrialised countries build technological capabilities, but there is very limited literature and empirical data on how public research institutions in industrialising countries build their own technological capabilities.

In conclusion, the findings of this research project are in general agreement with the literature, which indicates that organisations that deploy a balanced and effective approach to TCB with equal attention given to internal and external processes are likely to yield positive results in terms of improved effectiveness. However, this study goes further to demonstrate that the more fundamental issues in this particular case are limited funding, ineffective and inconsistent leadership and a lack of retention of scarce skills.

DECLARATION

I, Dineo Sekwele, declare that this dissertation is my own unaided work. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in Innovation Studies at the Wits Business School in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other University.

……..

……. day of ……2015

Stella Dineo Sekwele

DEDICATION

To my four beautiful children, Reamogetswe, David Kgosietsile Junior, Gomolemo and Omphemetse Sekwele.

ACKNOWLEDGEMENTS

Firstly, I would like to thank my husband, David Sekwele for his support and understanding throughout my study. His encouragement and selflessness motivated me to finish the race. I would also like to thank my four children, Reamogetswe, David Jnr, Gomolemo and Omphemetse for enduring the pain of not seeing their mom as often as they would have liked to. It is through their endurance that I continued to face this challenging experience for them to benefit from the fruits in the future.

I would also like to thank my supervisors, Dr Diran Soumonni and Professor Gillian Marcelle for their guidance and support throughout my research journey. You have a very special way of working with students.

A huge thank you goes to the CSIR, my former employer for their financial support and encouragement to undertake my studies when I thought it was impossible do to so. Thank you for making my master's degree possible! I would like to thank my friends for their words of encouragement and for understanding the reasons for my absence in their lives during this journey. Lastly, I would like to thank my mom and siblings for their understanding and continuous love and encouragement.

Table of Contents

Abstract……..I

Declaration……III

Dedication……IV

Acknowledgement……..V

List of Abbreviations……XI

List of Tables……..XII

List of Figures……XIII

CHAPTER ONE: INTRODUCTION……..1

1.1 PURPOSE OF THE STUDY 1

1.2 CONTEXT OF THE STUDY 2

1.3 PROBLEM STATEMENT 3

1.4 SIGNIFICANCE OF THE STUDY 3

1.5 RESEARCH QUESTION 4

1.6 LIMITATIONS OF THE STUDY 5

1.7 ASSUMPTIONS 5

1.8 DEFINITION OF KEY TERMS 6

REVIEW OF THE LITERATURE……9

1.9 OUTLINE AND STRUCTURE OF THE REPORT……..10

1.10 CONCLUSION 11

CHAPTER TWO: LITERATURE REVIEW……..12

2.1 INTRODUCTION……13

2.2 TECHNOLOGICAL CAPABILITY BUILDING (TCB) FRAMEWORK 15

2.2.1 Internal Processes of TCB 17

2.2.2 External Boundary Process of TCB 19

2.3 THE ROLE OF PUBLIC RESEARCH ORGANISATIONS (PROs) 22

2.3.1 Overview of Public Research Organisations..... 22

2.3.2 The Role of Public Research Organisations within the National System of Innovation (NSI) 25

2.3.3 Challenges Faced by Public Research Organisations in Industrialising Countries ..... .26

2.4 PROCESSES OF LEARNING AND TECHNOLOGICAL CAPABILITY BUILDING IN PUBLIC RESEARCH ORGANISATIONS 29

2.4.1 Recruitment and selection of skilled talent 29
2.4.2 Succession Planning 30
2.4.3 Mentorship 31
2.4.4 Career Advancement Programme 32
2.4.5 Graduate Programmes 33
2.4.6 Organisational Exchange Programmes 33
2.4.7 Managing Transfer of Knowledge from Expatriates 34
2.4.8 Internal collaboration amongst Operating Units 35
2.5 FACTORS THAT FACILITATE AND IMPEDE TECHNOLOGICAL CAPABILITY BUILDING IN PUBLIC RESEARCH ORGANISATIONS (PROs) 36
2.6 FACTORS THAT FACILITATE TECHNOLOGICAL CAPABILITY BUILDING WITHIN PROs IN INDUSTRIALISING COUNTRIES 36
2.6.1 Organisational Culture 36
2.6.2 Organisational structure that supports learning 37
2.6.3 Communication 38
2.6.4 Human resources development (HRD) system 39
2.6.5 Knowledge Management System 39
2.6.6 Performance appraisal system 40
2.6.7 Rewards and Recognition System 41
2.7 FACTORS INHIBITING TECHNOLOGICAL CAPABILITY BUILDING WITHIN PROs IN INDUSTRIALISING COUNTRIES 41
2.7.1 Limited Funding 42
2.7.2 Lack of Infrastructure 42
2.7.3 Lack of Absorptive Capacity 43
2.7.4 Lack of trust and openness amongst colleagues within an organisation 44
2.8 SUMMARY 45
2.8.1 The role of public research organisation (PRO) in industrialising countries 45
2.8.2 Processes of learning and technological capability building in public research organisations 46
2.8.3 Factors that facilitate technological capability building within public research organisations in industrialising countries 46
2.8.4 Factors inhibiting technological capability building within public research organisations in industrialising countries 46
2.9 RESEARCH QUESTION 47
CHAPTER THREE: RESEARCH STRATEGY AND METHODOLOGY 48
3.1 INTRODUCTION 48

3.2 RESEARCH STRATEGY AND DESIGN: QUALITATIVE RESEARCH 48
3.3 SELECTION OF PARTICIPANTS..... 50
3.4 RESEARCH METHODOLOGY..... 53
3.4.1 Data Collection..... 53
3.4.2 Primary Data: semi- structured interviews 54
3.4.3 SECONDARY DATA: POLICY DOCUMENTS 56
3.5 DATA ANALYSIS 57
3.5.1 Analysis of Interview Data 58
3.5.2 Documentary Analysis..... 58
3.6 LIMITATIONS OF THE STUDY 60
3.7 ETHICAL CONSIDERATIONS 60
3.8 RELIABILITY AND VALIDITY 62
3.8.1 Triangulation 62
3.8.2 Transferability 63
3.9 SUMMARY 64
CHAPTER FOUR: PRESENTATION OF FINDINGS AND DATA.....65
4.1 CSIR OVERVIEW..... 65
4.1.2 Brief introduction of CSIR Biosciences Unit..... 68
4.1.3 Background Profile of Respondents and Process Followed 69
4.2. PRESENTATION OF FINDINGS AND DATA RESULTS..... 70
4.2.1 Processes for Learning and Building Technological Capabilities..... 70
4.2.2 Champions searching for technologies to build technological capabilities 74
4.2.3 Mechanisms for knowledge dissemination amongst staff 76
4.2.4. Selection of partners to learn and build technological capabilities 77
4.2.5 Knowledge exchange with external partners to learn and build technological capabilities..... 79
4.2.6 Benefits from external partnerships..... 81
4.3 FACTORS FACILITATING LEARNING AND TECHNOLOGICAL .....
CAPABILITY BUILDING..... 83
4.3.1 Programmes for attracting and retaining staff..... 85
4.3.2 Incentives for staff motivation and individual high performance..... 87
4.4 FACTORS INHIBITING LEARNING AND BUILDING TECHNOLOGICAL CAPABILITIES..... 90
4.5 SUMMARY OF DATA PRESENTATION..... 96
4.5.1 Processes used for learning and building technological capabilities..... 96

4.5.2 Factors facilitating learning and building technological capabilities..... 96
4.5.3 Factors Inhibiting Learning and Building Technological Capabilities..... 97
CHAPTER FIVE: ANALYSIS OF THE RESEARCH FINDINGS……..98
5.1 INTRODUCTION..... 98
5.2 BACKGROUND..... 98
5.3 MECHANISMS USED FOR LEARNING AND BUILDING TECHNOLOGICAL CAPABILITIES..... 98
5.3.1 Internal Processes..... 99
5.3.2. External Process..... 100
5.4 FACTORS FACILITATING LEARNING AND TECHNOLOGICAL CAPABILITIES.. .102
5.4.1 Recruitment of expatriates..... .102
5.4.2 Succession Planning..... .103
5.4.3 Mentorship Programme..... .104
5.4.4 Criteria for selecting partners and suppliers..... .105
5.4.5. Career Ladder System..... .106
5.4.6 Performance Rewards System..... .108
5.4.7 Graduate Programmes..... .110
5.4.8 Communication..... .111
5.4.9 Infrastructure..... .112
5.5 FACTORS INHIBITING LEARNING AND TECHNOLOGICAL CAPABILITY..... .113
5.5.1 Limited Funding..... .114
5.5.2 Leadership and management practice..... .116
5.5.3 Technical Skills..... .119
5.5.4 Collaboration with local partners..... .120
5.5.5 Knowledge Management System..... .122
5.6 SUMMARY OF THE RESULTS..... .124
CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS……...126
6.1 Introduction……126
6.2 Major findings on learning and technological capability building……127
6.3 Recommendations……...132
6.4 Limitations of the Research……..135
6.5 Suggestions for Future Research……...135
REFERENCES……...136

APPENDIXES……...144

Appendix A……145

Appendix B……....146

Appendix C……....149

LIST OF ABBREVIATIONS

CSIR – Council for Scientific and Industrial Research.

HCD – Human Capital Development

OECD – The organisation for economic co-operation and development

OU – Operating Unit

PRO - Public Research Organisations

R&D - Research and development

SET - Science, engineering and technology

(S&T) Science and Technology

LIST OF TABLES **Page Number**

Table 3.1: Participants from Biosciences Unit **51**

Table 3.2: Expert Commentators Table **53**

LIST OF FIGURES **Page Number**

Figure 4.1: Process used for learning and building technological capabilities **70**

Figure 4.2: Champions searching for technology to build capabilities **74**

Figure 4.3: Mechanisms for knowledge dissemination amongst staff **76**

Figure 4.4: Criteria for selecting partners to learn and build capabilities **78**

Figure 4.5: How knowledge is exchanged with external partners **79**

Figure 4.6: Benefits from relationships formed with external partners **81**

Figure 4.7: Factors facilitating learning and technological capability building **83**

Figure 4.8: Programmes for attracting/retaining staff **85**

Figure 4.9: Existing incentives to increase staff motivation and high performance **88**

Figure 4.10: Factors that hinder learning and technological capabilities **90**

Figure 4.11: Skills shortage as a barrier to learning and capability building **93**

Figure 4.12: How the Unit manages the risk of losing capabilities built overtime **95**

CHAPTER ONE: INTRODUCTION

1.1 PURPOSE OF THE STUDY

The purpose of this study is to closely investigate the processes that Public Research Organisations (PROs) in South Africa, such as the Council for Scientific and Industrial Research (CSIR), use in learning and building technological capabilities. Much has been written about how best to develop technological capabilities in general, but there is limited empirical evidence about the process by which capability building is done within public research organisations in upper middle income countries. Therefore, little is known about the specifics of the process in these contexts, including considerations such as the nature and speed at which organisations build technological capabilities over time, the frequency and variation in terms of the depth and continuity of the accumulation of technological capabilities, the quality of learning mechanisms over time, and decision making in the capability building process. While such public research organisations use highly sophisticated technology and machinery which is mostly sourced in high income countries, the technology and the know-how to best operate this technology and machinery inevitably lies outside the acquiring countries that are predominantly industrialised countries. It is on this basis that this research project investigates whether relevant capabilities exist at a micro-level within public research organisations, such as CSIR, the key focus of this study and how these capabilities are built.

In this study, empirical data from the CSIR Biosciences Unit will be investigated in an effort to better understand how this particular entity within an industrialising country learns and builds its technological capabilities. This will highlight potential challenges, if any, that exist in learning and capability building within the public research organisation, the CSIR Biosciences Unit, thus laying a foundation for a more detailed study to be done in the future.

1.2 CONTEXT OF THE STUDY

This research was carried out at the CSIR, a Public Research Organisation in South Africa, within the Biosciences Unit. Public Research Organisations are relatively large and well established entities that are owned by the state and mandated to perform activities that address social needs to benefit the society it serves (Menendez & Cruz-Castro, 2003). The mandate of the CSIR Biosciences Unit is to offer new innovations to the industry it serves through translation of research outputs into market ready products that have an impact on society (CSIR, 2011). This indicates that the Unit should have the technological capabilities to translate research ideas into market ready products that can be commercialised. Menendez and Cruz-Castro (2003) suggest that for a public research organisation to be well positioned to address social needs, interaction with other actors/partners and participation in international cooperation is necessary to improve on building capabilities for research and technology. This means that the Unit should interact more with other stakeholders such as universities, potential users, suppliers, clients, technological organisations, PROs and other firms to build technological capabilities in order to address the relevant outcomes identified in their strategy. The availability of funds is key to enabling investment in developing and strengthening the competencies required to support the organisation in carrying out its mandate.

Of the Unit's total operating budget of R154 million, 36% of it is received via parliamentary grant from the South African government, and the balance is generated from research and development (R&D) activities that the Unit provides to external partners (CSIR, 2011). The overall CSIR Biosciences parliamentary grant received from the main funders, Technology Innovation Agency (TIA) and Department of Science and Technology (DST) was relatively low starting from 2012 in comparison to the previous years (CSIR, 2011). The reduction of funding was as a result of changes in funding approach from the main funders, as well as the CSIR's shift from funding early stage research projects to late stage research projects (CSIR, 2011). This was exacerbated by the global economic downturn in the last three years which affected capital markets and subsequently had a negative impact on research intensive industries such as the CSIR Biosciences Unit (CSIR, 2011). The reduction of the parliamentary grant greatly weakened the Biosciences Unit's

financial position, and as a consequence impacted negatively on investing in learning and technological capabilities.

1.3 PROBLEM STATEMENT

The peer-reviewed literature generally acknowledges the importance of building and strengthening technological capabilities in PROs. However, public research organisations in upper middle income countries have historically faced many challenges such as limited access to resources, cut-backs in government funding, lack of relevance to industry needs and failure to transfer technology to industry as well as shifting government priorities (Rush *et al*., 1995). There is little or no evidence in the literature that this situation has changed. In the specific case of CSIR Biosciences, these challenges have had a detrimental effect in building technological capabilities and are likely to have a compounded effect on how technological capabilities are built within the Biosciences Unit. One approach that has been suggested in the literature and that helps to understand these challenges at the CSIR Biosciences Unit is to contrast the elements of the balanced Technological Capability Building (TCB) system model with an unbalanced TCB system model. The objective of the exercise will then be to understand the dynamics that promote or impede the deployment of an integrated TCB approach or similar strategy, without which organisations are likely to underperform.

1.4 SIGNIFICANCE OF THE STUDY

The study has been chosen based on the notion that learning and technological capability building is critical and necessary in public research organisations in upper middle income countries, and this subject has been largely left unexplored by many scholars and authors in the field of innovation studies. The study thus fills a gap in the existing research.

The suggested processes in learning and building technological capability in public research organisations may provide a framework or guidance for building

technological capabilities to other public research organisations in industrialising countries. Furthermore, the study documents the successes and hindrances that were experienced by a public research organisation in an upper middle income country, in this case, South Africa, which could be used as a guide to help overcome the pitfalls and challenges that similar organisations may face. Despite South Africa being an upper middle country which is based on its per capita GDP, this does not reflect its weak social indicators such as high unemployment, high poverty rate and high inequality.

While studies in innovation typically focus on innovation policy or management, in either case, the element of human resources management and factors motivating/influencing staff to innovate is left unexplored by many scholars and authors. According to the studies conducted by Arundel *et al*., (2007) across 15 European countries in private sectors, organisations that put considerable effort in understanding how people interact and learn at the workplace tend to have employees who are more active in innovation and solving complex problems than those who interact less with their employees. The study further highlights that organisations where learning and complex problem solving is constrained have proved to innovate less and are highly dependent on absorption of innovation developed elsewhere.

The current empirical study makes a contribution to improving understanding on how organisations responsible for promoting science in upper middle income countries should invest in building technological capabilities to achieve continuous success and better results. Thus, the study raises important issues/challenges affecting public research organisations in industrialising countries, and how these issues are likely to affect their performance if not managed effectively. The study therefore adds to the body of knowledge in an attempt to fill the current gap.

1.5 RESEARCH QUESTION

The key questions that need to be answered are the following:

- How does CSIR Biosciences Unit go about building technological capabilities?

The sub-questions are:

- What factors influence technological capability building in a public research organisation such as the CSIR?
- What barriers exist to hamper the technological capability building at the CSIR?

1.6 LIMITATIONS OF THE STUDY

- The research was limited to the case company, the CSIR, a public research organisation in South Africa.
- The study was limited to the opinions/views of CSIR Biosciences staff only. Their views may be perceived differently by other CSIR Operating Units staff members.
- The research was limited to investigating technological capability processes, barriers and factors influencing technological capability building within CSIR Biosciences only.
- The research did not intend to study the CSIR in its entirety but was limited to learning and technological capability building processes within the CSIR Biosciences Unit.
- The research was conducted after the restructuring process that took place in 2011. The responses provided by the respondents may have been negatively influenced by the number of organisational restructuring processes that took place in the Unit and the various challenges that the Unit faces.

1.7 ASSUMPTIONS

- The research will be based on inputs from interviews held with Biosciences managers and leaders responsible for building technological capabilities of their subordinates, as well as expert commentators' views and analysis of relevant CSIR Biosciences documents.

- It is assumed that the participants will be honest and open about the information they convey.
- The reluctance of some of the participants to open-up and be truthful in their responses could impact on the findings of the study.
- The views of the participants will be used as a valid source of data and will collectively form the findings for this study.
- All participants have an in-depth knowledge and experience in building the technological capabilities of staff members.
- Availability of the participants and adherence to the projected time frame for interviews will have an impact on the timeous submission of the final report.

1.8 DEFINITION OF KEY TERMS

1. **Human Resources Management** – The process of hiring and developing employees so that they become more valuable to the organisation (Business dictionary.com, No date).

2. **Innovation –** encompasses the introduction of new or adapted products, produced with new or adapted equipment and in new or adapted forms of organisation, and utilises new or adapted organisational procedures (Cozzens & Kaplinsky, 2009, p. 58).

3. **Innovation management -** is a process of managing innovation to allow the organisation to respond to external or internal opportunities, by using its creative efforts to introduce new ideas, processes or products (Tidd & Bessant, 2009).

4. **Learning –** A deliberate process whereby individuals acquire knowledge, technical skills, and attitudes through experience, reflection, study or instruction (Brookes, 1995, p. 62).

5. **Learning Organisation** – An organisation that facilitates the learning of its members to see the whole together and continuously transforms itself to create the results they desire (Senge, 1990).

6. **National System of Innovation (NSI) –** comprises of a set of actors such as firms, public research organisations, universities and supporting institutions, such as financial institutions and government regulatory agencies that jointly or individually contribute to the development and diffusion of new technologies, and which provides the framework around which government forms and implements policies to influence the innovation process (Metcalfe, 1995).

7. **Technology –** is defined as significant knowledge retained by people and organisations as a result of knowledge and experience accumulated in projects, production and process development and improvement (Pavitt, 1987).

8. **Technological Capability -** (TC) is defined as a firm-specific collection of equipment, skills, knowledge, aptitudes and attitudes, which confers the ability to operate, understand, change and create production processes and products (Marcelle, 2004, p. 3).

9. **Technological Capability Building (TCB)** - A process of assembling or accumulating technological capability, and is regarded as an investment activity undertaken by firms (Marcelle, 2004, p. 4)

Industrialising countries – This term is used in this report to describe countries whose economies are not predominately characterised by a reliance on modern technological advances. It roughly (but not precisely) corresponds to the low, lower middle and upper middle categorisation of the World Bank. It is not as value-laden or as prejudicial as the more popularly used term in “developing countries”.

The World Bank each year on July 1 revises the analytical classification of the world's economies based on estimates of Gross National Income (GNI) per capita for the previous year (World Bank, 2015). Below is the Gross National Income (GNI) per capita calculated using the World Bank Atlas method. For the purpose of this study, the definitions below will be used throughout the report where necessary**.**

- Low-income-country – Are defined as countries with a GNI per capita of $1,045 or less in 2013.
- Middle-income-country – Are defined as countries with a GNI per capita of more than $1,045 but less than $12,746.
- Lower-middle-income and upper-middle-income countries – Are separated at a GNI per capita of $4,125.
- High-income-country - are countries with a GNI per capita of $12,746 or more.

Review of the Literature

The main areas of the literature that will be reviewed are:

1. **The role of Public Research Organisations in upper middle income countries.**

   This section will discuss public research organisations in industrialising countries, their mandate and role within the national system of innovation. The intention is to establish how they build technological capabilities within the value chain and within the organisation.

2. **Technological Capability Building processes as applied to public research organisations in upper middle income countries**.
   The intention is to understand the processes which public research organisations use in building technological capabilities**.**

3. **Factors that facilitate learning and technological capability building in public research organisations.**

   The intention is to identify factors that facilitate learning and capability building in public research organisations, as well as how these factors influence the way that learning and technological capability take place.

4. **Factors that impede technological capability building in public research organisations.**

   Public research organisations in upper middle income countries are faced with many challenges as opposed to other firms. This section explores the factors that influence learning and technological capability building in public research organisations. The intention is to determine barriers towards learning and technological capability building in a public research organisation.

1.9 OUTLINE AND STRUCTURE OF THE REPORT

The study comprises of six chapters. This section provides a brief description of the chapters that have been covered in this report.

Chapter 1: Introduction

This chapter comprises of an introduction, background and context of the study. It also outlines the key research questions, research problem and purpose, as well as the alignment of relevant studies.

Chapter 2: Literature Review

This chapter presents a review of the literature on topics related to the research question. The literature review will focus on the learning and technological capability building approach and the literature relevant to Technological Capability Building (TCB). It also focuses on the main themes of the research which attempts to answer the key research questions. The themes identified are:

- The role of public research organisations in industrialising countries
- Processes for learning and building technological capabilities
- Factors that facilitate learning and technological capabilities
- Factors that impede learning and technological capabilities

Chapter 3: Research Methodology

This chapter presents and discusses the research methodology used and how it assists the researcher in understanding the processes undertaken by the CSIR Biosciences to learn and build technological capabilities.

Chapter 4: Presentation of Results

This chapter presents the summary of the data collected from the interviews held with the participants at CSIR Biosciences Unit, expert commentators as well as CSIR documentary analysis.

Chapter 5: Analysis of Results

This chapter presents details of the research findings from the interviews contrasting with literature and the insights from the researcher.

Chapter 6: Conclusions and Recommendations

This chapter draws conclusions from the key research findings and provides implications for learning and technological capability building at the CSIR Biosciences Unit, and outlines future research directions. Conclusions are then drawn and potential opportunities for future research identified.

1.10 CONCLUSION

The researcher's main purpose for carrying out the study is to investigate the processes that the CSIR Biosciences Unit utilises to learn and build technological capabilities. This was done by looking at the various processes, programmes/initiatives that are in place to influence technological capability building as well as the challenges that hinder learning and building technological capabilities within the Unit. The methodology used by the researcher enabled her to answer the key research question of this study, which is "how does the CSIR Biosciences Unit go about building technological capabilities?'' The research focuses specifically on four key areas:

- The role of public research organisations in upper middle income countries.
- Processes for learning and building technological capabilities in public research organisations.
- Factors that facilitate learning and technological capability building in public research organisations.
- Factors that impede technological capability building in public research organisations.

CHAPTER TWO: LITERATURE REVIEW

This chapter critically engages the peer-reviewed literature on learning and technological capability building (TCB) in general, as well as in upper middle income countries, using the Council for Scientific and Industrial Research (CSIR) in South Africa as a specific case study. The literature begins by introducing and defining technological capability building as an investment process in which organisations learn to accumulate technological capabilities under conditions of uncertainty (Marcelle, 2004). In the studies conducted by Marcelle (2004) on TCB, the resulting outcome was the framework which she believes shows that when firms in "developing country" implement TCB systems that are aligned to the following five key elements: financing, management and co-ordination, culture and leadership, managing relationships with suppliers and with innovation systems, there will be an increase in the effectiveness of TCB and learning. The TCB Framework will be discussed at length in this study, with the aim of providing some theoretical background to (TCB) as an ideal "system" for organisations in upper middle income countries. Four core themes emerged from the literature review, and resonate throughout the study. These themes are:

- *the role of public research organisations in upper middle income countries,*

- *processes for learning and building technological capabilities in public research organisations – this focuses on various internal processes key to organisational development in countries that are engaged in learning and building their technological capabilities,*

- *factors that facilitate learning and technological capability building in public research organisations – the focus here is on factors that facilitate technological capability building within PROs in upper middle income countries, and*

- *factors that inhibit learning and technological capability building in public research organisations – key emphasis here is on factors that are central in*

encouraging/facilitating TCB to take place within upper middle income countries.

2.1 INTRODUCTION

A scholarly observation of firms that invest considerably in learning and technological capability development has shown that firms that deploy organisational mechanisms that are integrated across the entire organisation are likely to achieve consistency and cohesiveness, and thereby make substantial progress in building technological capabilities (Marcelle, 2004). These mechanisms include allocating financial resources for learning and capability building, appropriate organisational culture and specific management practices as well as to manage the relationships between firms and their equipment and service suppliers and their innovation system (Marcelle, 2004). A similar view as that expressed above is shared by Fagerberg *et al*., (2010), who argue that organisations that do not put considerable effort into learning and developing technological capabilities will not prosper. Therefore, the way in which organisations organise their learning processes and mechanisms is critical to realising the benefits of capability building. This means that when TCB is properly understood and implemented it has the added advantage of positioning an organisation ahead of its competitors.

Earlier work by Figueiredo (2002a) had also argued that investment in learning and capability building is an essential foundation for mapping organisational success and for building and sustaining innovative capabilities to ensure sustained competitiveness with technological frontier companies. Effectively, what this means is that the ability to learn and acquire knowledge and translate that learning into action rapidly is the ultimate competitive advantage. Organisations that do not put a concerted effort into learning and developing technological capabilities will continue to lag behind (Fagerberg *et al*., 2010). Bryan and Farrel (2008) assert that the winners will be organisations that make well informed choices when building technological capabilities notwithstanding the uncertainties that need to be taken into consideration. Therefore, the scope, investment and time necessary to develop TCB is another important consideration for successful implementation.

Marcelle (2005) also argues that building technological capability is a process, not a single event, and it needs to be managed by firms effectively in order to yield significant benefits. Bearing in mind that the building of TCB is an on-going process, putting into consideration technological advancement and constant changes in the market, the need to keep abreast of the changes and stay in the forefront of TCB and implementation then becomes key to an organisation's success or its demise (Marcelle, 2005). In this regard, Figueiredo (2002a) emphasises the importance of learning for organisations as a way of building and sustaining their innovative technological capabilities in order to build competitive advantage relative to their competitors in world markets.

Figueiredo (2002a) asserts that to become competitive and catch up with technological frontier organisations, organisations in industrialising countries must first acquire the knowledge to build up and accumulate their own technological capabilities. These capabilities will enable organisations in industrialising countries to create, assimilate, use and develop relevant products and processes in response to their changing economic environment (Kim, 2000). The process may be through technology transfer, technology acquisition and imported technologies from foreign firms and through networking (Chipika & Wilson, 2006). This means, for organisations in industrialising countries to compete with the best the world has to offer, considerable effort needs to be made to build relevant and sufficient internal capabilities to increase the existing knowledge base. Kim (2000) suggests that concerted effort be made to expose organisations in industrialising countries to relevant external knowledge to increase their existing knowledge base.

This chapter presents the literature reviewed, and begins with a conceptual explanation of the TCB framework, followed by a discussion around the four main themes that have been identified which include:

- Conceptual Framework of Technological Capability Building.
- The role of Public Research Organisations in upper middle income countries.
- Processes for learning and technological capability building in public research organisations in upper middle income countries.
- Factors that facilitate technological capability building within public research organisations in upper middle income countries.

- Factors that inhibit technological capability building within public research organisations in upper middle income countries.

2.2 TECHNOLOGICAL CAPABILITY BUILDING (TCB) FRAMEWORK

This section will briefly provide some theoretical background to technological capability building (TCB), referencing from the empirical study that was undertaken by Marcelle (2005) from firms in industrialising countries. The study will highlight how the CSIR Biosciences Unit in South Africa, an upper middle income country, learns and builds technological capabilities. Findings from studies conducted by Marcelle (2005) will be applied in this research study.

The work cited above is largely focused on a study done on 26 telecommunications firms in "developing (African) countries" that included amongst others Uganda, Ghana, Tanzania and South Africa. From her findings, Marcelle (2004, p. 25) states that the TCB system consists of five elements: (i) allocation of financial resources; (ii) management practices, systems and decision making rules; (iii) practices to establish and maintain facilitating leadership and organisational culture; (iv) accessing external technology capability resources from suppliers and (v) accessing technology capability resources from the innovation system (local and "global"). The framework focuses on the processes rather than on the outcomes of learning (Marcelle, 2004).

The TCB approach as developed by Marcelle (2004), considers capability building from the perspective of a firm attempting to achieve its strategic objectives, and defines Technological Capability Building as an investment process in which organisations learn to accumulate technological capabilities under conditions of uncertainty (Marcelle, 2004, p.28). Figueiredo (2002a, p. 74) shares a similar view in that he defines technological capabilities as the resources needed to generate and manage improvements in processes and organisation of production, products, equipment and engineering projects. The definition given by Archibugi and Coco (2005, p. 177) is also in line with that of Marcelle (2004). The authors assert that technological capabilities are associated with embodied elements such as capital goods, equipment, infrastructures, and non-embodied elements such as human skills and scientific and technical expertise. The argument offered by Marcelle (2004) is

that to derive any benefits, both embodied and non-embodied capabilities must be tightly integrated across the entire organisation.

According to Lammarino *et al*., (2009), technological capabilities involve learning and accumulation of new knowledge on the part of the firm, and also the integration of behavioural, social and economic factors into a specific set of outcomes. Organisations develop this process through experience with a particular technology and through learning by doing (Geffen & Judd, 2004). This process requires organisations that support open learning and align such learning with the overall business strategy. Integrated learning across the whole firm with conscious efforts towards building technological capabilities is key to success (Marcelle, 2005).

The above discussion indicates that capabilities are the results of learning processes which have been adapted and highly localised within an organisation over time. Figueiredo (2002a) emphasises the importance of learning for organisations as a way of building and sustaining their innovative technological capabilities in order to build a globally competitive advantage. Marcelle (2004) found that "developing country firms" accumulate technological capabilities through a systematic investment process that involves learning, transforming capabilities, uncertainty, trial and error, multiple motivations and diverse practices.

Wood and Weigel (2011), indicate that technological capabilities are acquired through different ways within the organisation. These include: formal relationships with well-defined contracts, licensing technology from foreign firms, hiring technical consultants, buying and selling to more advanced organisations (i.e. commercial relationships), imitation, reverse engineering, observation, journals and meetings. Thus, firms and other organisations are advised to learn from the success of leading actors using innovative technology (Wood & Weigel, 2011). Grieve (2004), argues that organisations in industrialising countries need to first have a firm grasp of advances in modern technology, learn from it, and in so doing are able to support innovation and building their technological capabilities. The TCB system approach argues that to be effective, firms in industrialising countries must be able to organise their learning and capability accumulation efforts in a systematic, organised process involving the following five key elements: allocating financial resources, fostering management practices, developing an organisational culture that supports

technological learning, accessing external technological capabilities from suppliers and accessing the local and global innovation system (Marcelle, 2004).

2.2.1 Internal Processes of TCB

There are three internal mechanisms of TCB namely allocating financial resources, fostering management practices and developing an organisational culture that supports technological learning. These mechanisms are discussed in detail below.

2.2.1.1 Allocating financial resources

This element involves mechanisms that identify financial resources to the TCB investment effort as well as establishing rules and practices to undertake TCB expenditure (Marcelle, 2004). Oni (1999) asserts that funding and concerted effort is needed to invest in capacity building in order for the organisation to be well positioned and competitive in the global market. This view is supported by Marcelle (2004) who argues that financial investment and a knowledgeable and experienced leadership is required to ensure that investments such as the purchase of technological hardware, employment of technical personnel, delivery of training and development and other learning routines are allocated towards building relevant technological capabilities required by the organisation.

Kim (2000), asserts that governments in industrialising countries can use policy instruments to influence the process of building the level of a firm's technological capabilities. For instance, in 1999, the South African government introduced Skills Development Levies to encourage organisations to undertake training and development of human resources (South Africa, 1999). The primary objective of this Act is to encourage organisations to increase the levels of financial investment towards training and development in order to build competencies and enhance their stock of knowledge.

2.2.1.2 Fostering management practices

This is a process of setting rules and establishing decision making systems for undertaking TCB. This process includes establishing coordination mechanisms and systems for aligning TCB with a firm's overall objectives (Marcelle, 2004). Oni (1999, p. 37) asserts that organisational success and effectiveness is often attributed to the leadership and management of the organisation. The TCB framework determines the effectiveness of the organisation as a task that belongs to leadership and management of that organisation as they are the ones who prescribe the organisational strategies and goals (Marcelle, 2004). According to Cimoli and Pocile (2009), leadership and management is strongly influenced by internal factors such as an organisational system that supports and diffuses learning and technological capabilities, and an enabling environment which promotes the culture of learning to achieve technological progress.

2.2.1.3 Developing an organisational culture that support technological learning

According to Marcelle (2004), organisational culture involves cultural practices that are not seen as the preserve of senior management but that are inclusive of staff at all levels of the firm. The success and effectiveness of the organisation is influenced by the leadership behaviour and management of the organisation (Oni, 1999, p.37).

Deshpande and Webster (1989), assert that organisational culture can also be defined as a set of shared assumptions and understanding about organisational functioning. In addition, Carnall (1995) defines organisational culture as encompassing how people in an organisation are likely to act, given internal and external factors that impact on the organisation.

Jaruzeleski *et al*., (2011), state that for an organisation to instil culture, its management should implement various systems and processes that will encourage and support the desired organisational culture that is most likely to support their innovation efforts. Features of this culture include appropriate senior management leadership and involvement, clear assignment of responsibility and careful design of learning programmes to ensure that opportunities are widely available to each

individual to expedite learning (Jaruzeleski *et al*., 2011). Thus, if this process is deliberately and effectively manipulated over time they could produce positive implications for the accumulation of technological capability and the rate of performance improvement is likely to increase. Marcelle (2004) suggests that another method of establishing a culture of learning and building technological capabilities could be through establishing champions that understand technological trends in industry by disseminating and spreading knowledge gained throughout the organisation. According to Hipkin (2004, p. 247) failure to understand culture and other practices can lead to misguided assumptions, under-performance and non-alignment within the work environment.

2.2.2 External Boundary Process of TCB

There are two external mechanisms of TCB, which are accessing external technological capabilities from suppliers, and accessing the local and global innovation system. These are discussed below in more detail.

2.2.2.1 Accessing external technological capabilities from suppliers

According to Marcelle (2004), this process includes the selection of suppliers, procuring equipment and services from external suppliers under suitable terms and conditions and integrating this supply process with other aspects of technological capability building. The process involves research partnership formed by an organisation with suppliers to exploit opportunities of common interest (Baskaran, 2001). The exploitation of these opportunities requires strategies such as establishment of technical licensing agreements with foreign suppliers, formal transfer of technology for both explicit and implicit knowledge (i.e. assimilation of imported technologies and generating new knowledge through knowledge conversion and research), high commitment to investment in education and human resource development, poaching experienced managerial and technical people from existing organisations, recruitment of high calibre scientists and engineers from other

countries and recruitment of well-trained scientists from universities to increase the level of organisational knowledge base (Kim, 2000).

The literature confirms that the importation of technological inputs is a major source of technological capability building within firms in industrialising countries (Marcelle, 2004). This suggests that technological capability in firms within industrialising countries to a large extent depends on the acquisition of skills from more industrially advanced countries. The challenge often involves some owners being reluctant to share/give away their intellectual property (IP) in order to preserve their technological advantage over the acquirer, thereby perpetuating dependency on the part of the weaker party (Hipkin, 2004). This means that this process will require some willingness and the ability of external suppliers to play a role in developing capabilities for organisations in industrialising countries.

2.2.2.2 Accessing knowledge from national innovation system actors and international sources

Arnold and Thuriaux (1997) indicate that accessing knowledge from various sources requires managing relationships between the firm and its external resource bases. According to Marcelle (2004, p. 58) such relationships refer to the processes through which firms interact within the innovation system. Metcalfe (1995) notes that the National System of Innovation (NSI) comprises a set of actors such as firms, public research organisations, universities and supporting institutions, such as financial institutions and government regulatory agencies which jointly or individually contribute to the development and diffusion of new technologies, and which provide the framework around which government forms and implements policies to influence the innovation process. Marcelle (2004) notes that these actors within the national innovation system (i.e. universities, commercial suppliers, technological communities of practice, industry associations) are considered to be important sources of technological inputs, such as codified knowledge, tacit knowledge, improved understanding of technological trends and patterns through regular interaction. This type of relationship stresses the importance of the connections between different types of collective actors (Arocena & Sutz, 2000).

In the study conducted by Arocena and Sutz (2000), between different countries in the North and South, it was found that the NSI in the South was not generally paying attention to the importance of the connections between different types of actors. The study showed that innovation that takes into account user-producer interactions is more effective in the promotion of innovation than one that does not pay attention to these. For example, in Latin America the connections between different actors was not effective, therefore it was difficult to foster national innovation identities due to the low relational nature of their NSI concept. Furthermore, the lack of a cohesive national connectedness resulted in limited scientific and technological shared knowledge, industrial innovation, and the ability to apply knowledge best suited to their local conditions. This situation resulted in Latin America developing technological capabilities from the North that were least suited to their national needs. These practices overtime undermined potential growth prospects of their national economy as they lacked resonance with a large proportion of their local needs. These countries from the South did not have the technical knowledge required to adapt imported technologies to their local conditions over a sustained period. The study highlighted factors such as low spending on innovation, very little in-house R&D performed by firms, highly informal industrial innovation, low reliance on local knowledge institutions, high reliance on foreign embodied science and technology and low levels of complexity as some of the reasons why there is a wide distance between the countries of the North and the South in relation to technological and economic advancement (Arocena & Sutz, 2000).

Kumar *et al*., (1999) assert that strong linkages within the national system of innovation enhance the technological capabilities of local firms from simple information sharing to strategic partnering or even joint ventures. The same view is supported by Lamin and Dunlap (2011), who indicate that by viewing the firm as embedded within a system, the performance of a firm, and specifically its technological capabilities, will be influenced by the on-going pattern of relationships maintained with the actors. However, since most organisations in industrialising countries face the challenge of a fragmented local innovation system (Marcelle, 2004), leveraging technological knowledge from this type of system remains a challenge. Hence organisations rely on imported technological inputs. Lamin and Dunlap (2011, p. 212) indicate that increasing interactions with these external actors

will result in greater opportunities for absorbing the knowledge necessary for the creation of more complex technological capabilities.

Wang and Zhou (2012) argue that firms located near knowledge sources, such as universities, research organisations, and other important suppliers and users, can accelerate the rate of building technological capabilities and introduce innovation. This means the National System of Innovation (NSI) would need to involve a wider range of institutions and tools in order to provide improved support for technological development by the organisation. The involvement of other actors within the NSI and global linkages with advanced countries provide local organisations with access to knowledge and cutting edge technologies that close the skills gap, accelerating the ability of local organisations to grow their knowledge as well as their technological capabilities (Wang & Zhou, 2012). Therefore, participation and collaboration means that firms can leverage technical expertise and information from a larger pool within the NSI (Kumar *et al*., 1999).

2.3 THE ROLE OF PUBLIC RESEARCH ORGANISATIONS (PROs) IN UPPER MIDDLE INCOME COUNTRIES.

The aim of this section is to explore the role of Public Research Organisations (PROs) in upper middle income countries. The intention is to explore the activities that PROs engage in and how they function as key organisations supporting a given government's goals within the development of any country.

2.3.1 Overview of Public Research Organisations

Public research organisations originated in technologically advanced countries in response to the incremental technological needs of their various industries (Rush *et al*., 1995). They are relatively large and well established organisations which are publicly owned by the state to perform activities that are proper in their industrial context to address social needs and benefit the society (Menendez & Cruz-Castro, 2003). They obtain their mandates which are diverse from the state which makes

them differ from each other in the processes through which they build their technological capabilities (Menendez & Cruz-Castro, 2003). PROs play a fundamental role in supporting the growth and development of economies mainly through technological innovations and the development of appropriate human resources for research, among other things (Mazzoleni & Nelson, 2007). In essence, PROs have been established to serve the domestic market, both the national industry as well as the economy in general (Forsten, 2000).

In practice, in most parliamentary democracies, PROs are accountable to specific ministries of the government depending on the nature of their business and are directly given a parliamentary grant, also known as 'government core funding' from their ministry to perform R&D (Menendez & Cruz-Castro, 2003). The parliamentary grant is in principle a 'lever' that helps decide what tasks an organisation performs (Menendez & Cruz-Castro, 2003). This grant is usually divided into direct government grants and research/programme administration contracts for which PROs bid (Menendez & Cruz-Castro, 2003). Direct grants are used for activities which do not appear to be heavily directed by government, and public contract research is usually the result of government decision to fund R&D into particular areas of technology (Rush *et al*., 1995). According to CSIR (2014), CSIR is one of the public research institutions established by the government of South Africa for the purpose of research and development to support the country's national priorities. The CSIR is also funded through ring fenced grants called parliamentary grants from the Department of Science and Technology (DST), and earns contract research and development income from both public and private sectors; locally and internationally The parliamentary grant is used to support and address national strategic priorities, and also supports investments in research programmes and infrastructure as well as R&D skills development (CSIR, 2014).

Geffen and Judd (2004), assert that the responsibility of PROs is to advance fundamental research that addresses major national challenges through research and technological innovation. The authors further indicate that this responsibility resulted in public research organisations looking for new technologies with the capability of translating research ideas and commercialising them in the market place. This view is shared by Arnold *et al*., (2000), indicating that a recent requirement placed on a number of public research organisations is that they engage

in commercialisation activities. In contrast, while most PROs generate innovations for transfer to industry, few carry out pioneering or cutting edge industrial research on their own (Rush *et al*., 1995). In the benchmarking exercise conducted on PROs by Rush *et al*., (1995) it was found that most successful PROs carried out highly specialised technical tasks and services that enhanced innovative activities within the industry in a variety of ways. In order for the public research organisation to be well positioned to address social needs, interaction with universities and participation in international cooperation is necessary to improve on building capabilities for research and technology (Menendez & Cruz-Castro, 2003).

In the benchmarking exercise conducted by Rush *et al*., (1995), it was found that most countries have independent public research organisations which are funded by government, the private sector, or both to provide scientific and technological support for industrial development and modernisation.

According to Arnold *et al*., (2000), Public Research Organisations are funded by government to perform some of the following activities:

- Develop and refresh their competencies, establish new capabilities and technological platforms;
- Extend pre-competitive work with industry through working with groups of companies by further developing knowledge in partnership with more technically sophisticated company research partners. Hence, public research organisations try to have large customer portfolios since industry needs for support from institutes are generally shorter and more volatile; and
- Providing less sophisticated services to companies with lower levels of technological capability as technology matures.

Their activities give them an indication to judge where they stand out internationally (Forsten, 2000). However, all these activities require the availability of funds from government in order for R&D to exist and thrive (Menendez & Cruz-Castro, 2003).

PROs act as a focal point for collecting and disseminating the latest knowledge by establishing bilateral agreements with firms providing development, applications engineering, consultancy or other services internationally (Arnold *et al*., 2000). Technologies developed by public research organisations are transferred to the

private firms for commercial exploitation, leading to the creation of wealth, jobs and other social benefits (Mazzoleni & Nelson, 2007). It is apparent, then, that PROs are the most important elements of the structures supporting economic development as stated by Mazzoleni and Nelson above.

2.3.2 The Role of Public Research Organisations within the National System of Innovation (NSI)

The aim of this section is to explore the role of Public Research Organisations (PROs) in industrialising countries within their respective National Systems of Innovation (NSI), as well as the challenges they face and how these challenges can be overcome.

Arnold *et al*., (2000), highlights that Public Research Organisations are assigned by government within the country in which they operate to play a more significant role in the National System of Innovation. PROs comprises of a set of actors including firms, public research organisations, universities and supporting institutions, such as financial institutions and government regulatory agencies that jointly or individually contribute to the development and diffusion of new technologies that provide the framework within which government forms and implements policies to influence the innovation process (Metcalfe, 1995). Relationships formed between public research organisations and other actors within the National System of Innovation are regarded as one of the mechanisms through which to acquire, exchange and develop new knowledge towards increasing knowledge and building technological capabilities within Public Research Organisations (Morrison *et al*., 2006). Most PROs strengthen relationships through networking, marketing and building their profile to influence industry, government, universities and other important stakeholders in the Science and Technology (S&T) system (Rush *et al*., 1995).

They support strong established industries as well as smaller and newer firms by reducing the risk of innovation, as well as providing a useful bridge between the work performed by the universities and industry needs (Arnold *et al*., 2000). They also work constructively with leading university groups by establishing regional offices on campuses to exploit potential synergies with the university (Rush *et al*., 1995). This

method is used to forge close links with university systems, as a source of advice and intelligence and most importantly as a method of identifying the best graduates (Rush *et al*., 1995). In performing their core roles in risk reduction with industry, they are already functioning as commercialisation machines, through transforming the early stage research of the pipeline projects and results at the second and third stages of the pipeline that are useful in existing industry (Arnold *et al*., 2000). Menendez and Cruz-Castro (2003) note that they support themselves through the exchange of resources with actors within the NSI where there is a relative abundance of resources to upgrade and deepen their capabilities. They are also in the main dependent on the knowledge produced by others, as well as economic resources such as funding in order to progress. Relationships formed by public research organisations with other actors within the national system of innovation is regarded as one of the mechanisms they utilise to acquire, exchange and develop new knowledge and other resources and these in turn contribute towards building of learning and technological capabilities within public research organisations (Morrison *et al*., 2006). This view is supported by Lamin and Dunlap (2011) who affirm that the performance of organisations, specifically the complexity of their technological capabilities, is influenced by the on-going pattern of relationships maintained with other actors and clients. Therefore, resources from a number of actors within the NSI are what PROs depend on to develop their activities and deepen their technological capabilities. Furthermore, in order for the PROs to build and strengthen their technological capabilities they need to allow for a flow of knowledge within the NSI.

2.3.3 Challenges Faced by Public Research Organisations in Industrialising Countries

According to Rush *et al*., (1995) when Public Research Organisations in industrialising countries emerged, their research activities were according to the needs of industrial R&D, and firms were absorbing their specialist outputs. Foreign assistance which played a large part in establishing PROs led many of them to be modelled on the most advanced PROs in the world instead of responding to industrial needs. As a result many of the PROs in industrialising countries remained

disconnected from industrial activities, and even to the needs of the society they are located in (Rush *et al*., 1995). In the benchmarking exercise conducted by Rush *et al*., (1995) the authors highlight the following challenges faced by PROs in industrialising countries:

- *Lack of relevance to industry needs and failure to transfer technology to industry:* Most PROs lack focus on industrially relevant work and lack knowledge in best practice and how to search for new technological opportunities. This has led to many PROs constantly reinventing the wheel and not keeping their organisations up-to-date and identifying new opportunities. Hence, there are financial cut-backs on many PROs by government.

- *Fragmentation within the Innovation System in industrialising countries* are built on an institutional framework that tends to be much less formalised, with less enforceable rules and very low incentives that determine and enforce the behaviour of actors within the innovation system (Altenburg, 2009). Morrison *et al*., (2006) indicate that fragmentation within the NSI makes the relationship with other actors exceptionally difficult. That means knowledge may not be absorbed even where it would be efficient to do so. Thus, the speed, direction and path of technological capabilities within an organisation can be adversely affected if actors within the NSI do not make concerted efforts towards building their technological capabilities.

- *Limited access to resources* – these are in terms of manpower, know-how as well as necessary funding to successfully pursue projects and bring them to fruition (OECD, 2010). According to Figueiredo (2010) firms in industrialising countries are characterised as having little or no innovation capabilities. This is because highly skilled individuals within these organisations are constantly sought after and lured to developed countries by promises of bigger and better rewards compared to their countries of origin, as well as the search for better living conditions (OECD, 2010). Figueiredo (2002a) suggests that organisations in industrialising countries must first acquire knowledge to build

up and accumulate their own technological capabilities in order to bridge the gap and become competitive.

- *Cut-backs in government funding* - According to Rush *et al*., (1995), most PROs are facing cut-backs in government funding. It is inevitable that the reduction of research funding from the central government and lack of other external funding sources will have negative effects on PROs (Menendez & Cruz-Castro, 2003). That means if PROs are incapable of raising alternative funding this will create the problem of balancing national public goals and short term commercial interests. Resolving this problem usually involves convincing government policy makers to supply sufficient resources to meet national goals (Rush *et al*., 1995). Successful PROs gradually reduce uncertainty by creating new funding sources, building connections and strategic partnerships with industry and by promoting their image (Rush *et al*., 1995). However, the more government core funding an organisation has, the better equipped it is to tackle market failures and to develop new capabilities that cannot be created with private sector players (Arnold *et al*., 2007).

Government funding for PROs thus creates opportunities for them to network among themselves within and outside of their respective regions towards the development of technological innovations that will enable them to address social challenges such as health, water, energy and the environment (Menendez & Cruz-Castro, 2003). In this manner, public research organisations become relevant, competitive and take on increasingly challenging projects. According to Altenburg (2009), low income/funding to cover organisational operations results in low average productivity which reflects limited capacity to develop new technologies or adopt and improve upon existing ones.

The literature indicates that organisations that participate and interact with other actors within the NSI are able to upgrade their technology by producing better products in a more efficient way (Morrison *et. al*., 2006). However, high levels of uncertainty, leakages, lack of concerted effort and alignment with other organisations will make the relationship exceptionally difficult (Morrison *et. al*., 2006). That means knowledge may not be absorbed even where it would be efficient to do so. Thus, the speed, direction and the ability to build technological capabilities within an

organisation will be adversely affected if actors within the NSI do not make a concerted effort in this regard.

In conclusion, public research organisations play a fundamental role in supporting the State to address social problems. In order for public research organisations to operate effectively, they need to form relationships with other actors within their national system of innovation and other external partners internationally to build the required technological capabilities and to manage their research and innovation effectively. In this way, public research organisations will become relevant in their countries and more equipped to address areas of common interest.

2.4 PROCESSES OF LEARNING AND TECHNOLOGICAL CAPABILITY BUILDING IN PUBLIC RESEARCH ORGANISATIONS

This section looks at various internal processes mostly used by organisations in industrialising countries to learn and build technological capabilities. Figueiredo (2002b) points out that the performance of an organisation is an indicator of the way and the rate at which technological capabilities are built and accumulated within the organisation. According to Marcelle (2004), firms that put effort into building technological capabilities have established internal processes for learning and developing technological capabilities as well as the implementation of this accumulated knowledge.

The following are internal processes that are considered important and relevant for organisations in industrialising countries in terms of learning and building their technological capabilities:

2.4.1 Recruitment and selection of skilled talent

According to Mumford (2000), recruitment and selection of talented people play a key role in creating the conditions needed for innovation. Mumford (2000) asserts that development of knowledge within the organisation is accomplished through designing recruitment assignments that are intended to build core skills and

encourage the acquisition and enhancement of new skills. The same view is shared by Collins *et al*., (2001) who indicate that organisations that have acquired higher levels of employee education and experience have utilised extensive recruiting and selective staffing practices as a means of improving their human capital. For example, after the Meiji restoration in 1868, absorbing Western scientific and technological knowledge became a key component of Japan's industrial development strategy. Foreign professionals were recruited as consultants and specialised technical personnel for many industrial development projects as one of the mechanisms for learning and building technological capabilities (Mazzoleni & Nelson, 2007). Kishimoto (2004) indicates that technological and managerial assistance provided by multinational companies through the expertise of their employees is another mechanism of upgrading skills and product quality.

Mumford (2000) shares the same view that when an organisation brings in highly skilled scientists or engineers who share their diverse and/or related background, they tend to generate more ideas through their broad range of experience which ultimately strengthens technological capabilities and enhances innovation within an organisation. This analysis suggests that recruiting qualified professionals and bringing foreign nationals increases the development of technological learning and capability building within an organisation. Successful recruitment processes means that the organisation is able to pay salaries similar to industrial ones, and able to recruit and keep highly qualified staff. This means local organisations should acquire access to advanced knowledge and skills in the relevant fields of science and engineering to build technological capabilities. Human resources departments should also develop initiatives that seek to select and hire individuals with the right qualifications and experience that can bring a specific type of expertise, which the organisation lacks and needs to acquire, as innovation depends on the quality of people the organisation attracts.

2.4.2 Succession Planning

This is the process through which a pool of candidates possessing critical competencies are selected to fill higher-level management positions in an

organisation (Huang, 1999). Typically, through set criteria, an organisation identifies for future reference a small pool of potential successors for key roles that are critical, especially for top level positions, and place them on a specific management training and development programme to build competencies and skills required to achieve its organisational strategy (Holbeche, 2002). However, Hirsh (2000) as cited by Armstrong (2006) cautions that giving employees unrealistic expectations of career advancements and promotions presents challenges as it is difficult to talk about the future in a volatile business environment.

Ibarra (2005) asserts that this programme is an essential tool for managing continuity of talent by ensuring that replacements have been prepared to fill key vacancies at short notice as they would have been internally groomed by the organisation to assume the responsibility. In essence, it is a process of learning and building the core competencies required within organisations by identifying employees with high potential who have the prerequisite skills, experience and competency to implement organisational strategy and objectives.

2.4.3 Mentorship

This is defined by Roberts (2000) as a formalised process where an experienced person (mentor) is overseeing, supporting and encouraging a less experienced and knowledgeable person (mentee) with the aim of facilitating career and personal development. The implementation of a mentoring programme involves the mentor/mentee professional relationship where there is an interactive and open dialogue to address specific needs, exchange ideas and share experiences, learn together to collaborate on projects, share knowledge and gain expertise (Roberts, 2000). This relationship tends to be managed by an organisation to ensure that skills transfer from experienced staff takes place to increase competencies and strengthen relevant capabilities within the organisation (Ehrich & Hansford 1999). This means Human Resources personnel and line management should encourage the involvement of experienced and knowledgeable employees in the programme through a transfer of knowledge and inculcating the culture, norms and processes of the organisation in junior staff for the benefit of the organisation. Holbeche (2002)

suggests that organisations that invest in growing the expertise of their junior employees by focusing on existing talent within the organisation are more likely to benefit from increased employee commitment.

The successful implementation of this programme tends to result in increased retention rate, internal promotions, high job satisfaction and self-esteem, greater organisational commitment, increased promotional opportunities, more tenured individuals and less work stress as well as the development of skills and knowledge required by the organisation (Underhill 2006, p. 294). Organisations that undertake and support mentorship programmes tend to have increased performance and productivity levels as well as employees who are prepared to handle their roles and perform their tasks competently (Ehrich & Hansford, 1999). Therefore, it is essential for PROs, particularly, in industrialising countries to develop and implement a mentorship programme to influence skills transfer to take place within an organisation in an effort to build and increase the technological capabilities required within the organisation.

2.4.4 Career Advancement Programme

Human resources departments should establish policies and processes of career development through programmes that show people how to develop their careers strategically. A career development programme is a programme that seeks to assist employees with their personal growth and maturity within the organisation (Mumford, 2000). The programme seeks to establish a gradual improvement in the employees' work life by functioning in harmony with employee's needs so that personal working values are satisfied (Tanke, 2000). Therefore, human resources departments need to create a climate that fosters career development and challenging jobs that provide job satisfaction. This approach is more likely to prove effective if it is targeted at performance enhancement and innovation (Mumford, 2000). A career advancement programme can act as one of the interventions that human resources departments utilise effectively to motivate and retain employees, to perform at a high level and to increase a critical mass of skilled employees.

2.4.5 Graduate Programmes

The graduate programme is one of the methods utilised for learning and building organisational capabilities and expertise. Organisations do this by assigning young graduates to mentors who are experienced in the company's approach and involving them in organisational based projects to gain organisational experience (Holbeche, 2002). This indicates that by doing this, students are already applying learning acquired from universities on PRO projects and are exposed to the organisation's structure, functions and culture. These graduates then form part of the organisational pipeline through which skills and experience are acquired during the programme. Organisations that participate in this programme make it clear in their job advertisement how they envisage the employment relationship between themselves and employees (Holbeche, 2002). This means organisations that use this programme will effectively have increased their required stock of knowledge and competencies in the long term.

2.4.6 Organisational Exchange Programmes

Through exchange programmes and external expertise provided by employees from multinational companies, local employees can improve on their learning and technological capabilities both in the form of skills upgrades and upgrading product quality (Kishimoto, 2004). According to Mazzoleni and Nelson (2007), more recently organisations have put in place a system for occasionally releasing labour to go abroad to learn from developed countries and bring back knowledge they have acquired and apply it within their organisations. This process is seen as providing access to fast changing knowledge which assists in fast tracking learning, increasing competencies and providing market opportunities through established long distance partnerships (Fontes, 2007). However, Bangens and Laage-Hellman (2002) contest this noting that the process is slow due to its cumulative nature, but can be speeded up by a number of factors such as, organisational systems that support learning and capability building. Thus, organisations in industrialising countries should have

increased access to international networks to absorb and add to their stock of knowledge (Figueiredo, 2010).

Cimoli and Porcile (2009) affirm that it is critical to create an enabling environment which promotes a culture of learning, collaboration and networking to achieve technological progress through exchange programmes. If these processes are well developed and managed properly, they will support organisational learning and capability building, and provide information for reaching outside the firm's boundaries for external sources of knowledge (Marcelle, 2005). Organisations that rely extensively on sending their people abroad to learn and return to their country of origin have increased knowledge and have greatly contributed to the internal development of their technological capabilities (Mazzoleni & Nelson, 2007). Mazzoleni and Nelson further indicate that the success of accumulation of technological capabilities have relied strongly on cross-border flows of people.

The DST (2013) suggests that organisations within South Africa should partner with local and international industries to support experiential human capital development with the aim of building technological capabilities through exchange programmes. Therefore, it is essential for organisations such as CSIR in South Africa, to utilise the exchange programme effectively in order to learn from technologically advanced organisations and increase their technological capabilities. The above literature confirms that in doing so, the organisation will be exposed to advances in knowledge and technology from developed countries.

2.4.7 Managing Transfer of Knowledge from Expatriates

An important aspect of managing the transfer of knowledge is through managing highly skilled expatriates such as skilled migrants, students, scientists or technological entrepreneurs (who are regarded as knowledge assets) to build knowledge locally from the advanced countries where they originally worked or studied (Fontes, 2007). This view is shared by UNIDO (2005), where they assert that tapping into the global pool of knowledge is one of the mechanisms utilised in building technological capabilities. The same view is shared by (Fontes, 2007)

where he affirms that these experienced individuals due to their mobility and access to diverse streams of information can act as channels that retain connections to their home country through knowledge transfer and inter-personal networks. They are therefore, seen as contributing to the development of technological capabilities through the flow of knowledge between different geographical locations (Fontes, 2007). Thus, an organisation such as CSIR Biosciences Unit may need to manage this process contractually by setting key deliverables and timelines to ensure that skills/knowledge transfer from expatriates takes place within the organisation.

2.4.8 Internal collaboration amongst Operating Units

Internal collaboration is the process which requires the full engagement of the organisation across business Units (Slowinski & Sagal, 2010). It focuses on knowledge perspectives such as knowledge sharing, exchanging and integrating knowledge to overcome barriers to achieve the research goals of the organisation (Numprasertchai & Igel, 2005). Lamin and Dunlap (2011) assert that within an organisation, learning involves transfer of knowledge between the various organisational Units.

Collaboration has become increasingly popular and generates a positive effect on the innovation performance of firms through knowledge spill overs (Wang & Zhou, 2012). For an organisation in an industrialising country to build technological capabilities, they may have to build internal collaborations within the organisation (Baskaran, 2001). This is because the degree of specialisation within public research organisations is diverse and requires the use of other competencies and learning from others. Lamin and Dunlap (2011) note that when different business Units within an organisation possess vastly differing knowledge systems, one Unit will not have the capacity to readily identify and transfer the other Unit's relevant knowledge.

The exchange of information through collaborative efforts within an organisation is known to increase learning and facilitate job rotation, giving employees the opportunity to move horizontally across a range of jobs gaining exposure through interacting with a variety of employees and work Units (Collins *et al*., 2001). Thus,

the combination of knowledge sharing and ideas is positively related to learning and technological capability building within an organisation.

2.5 FACTORS THAT FACILITATE AND IMPEDE TECHNOLOGICAL CAPABILITY BUILDING IN PUBLIC RESEARCH ORGANISATIONS (PROs)

Public Research Organisations (PROs) in industrialising countries are faced with many challenges which could potentially have a negative effect on technological capability building within an organisation. This section explores factors that might impact on the ability to implement learning strategies and building technological capabilities in an organisation. The intention is to determine factors that may facilitate learning and technological capability building and, factors that may impede technological learning within a public research organisation in industrialising countries.

2.6 FACTORS THAT FACILITATE TECHNOLOGICAL CAPABILITY BUILDING WITHIN PROs IN INDUSTRIALISING COUNTRIES

Seven factors have been identified as central in building technological capability within public research organisations in industrialising countries. These are discussed below.

2.6.1 Organisational Culture

Tidd and Bessant (2009) define organisational culture as a pattern of shared values, beliefs and agreed norms which shape behaviour and how things are done in an organisation. In his article, Organizational Culture and Leadership, Schein (1985), suggests that the essence of culture lies in the set of ‘underlying assumptions’. Organizational culture is further defined by Deshpande and Webster (1989) as a set of shared assumptions and understanding about organisational functioning. It therefore is no surprise as Schein contends that the theoretical argument about

culture is that it is a complex system of norms and values that is shaped over time. Ke and Wei (2008), in their article, organizational culture and leadership in ERP implementation, concluded that organisational culture is generally understood as the social glue that holds organisational members together and expresses the values, social ideals and beliefs that members share.

Organisational culture provides employees with a common frame of reference for changes in an organization. Lau and Woodman (1995) in their paper titled *Understanding Organizational Change: a schematic perspective*, state that when an organisation has different cultures, people have different perceptions and interpretations of organisational changes, which affect the way employees embrace change. This in essence suggests that the success of projects within the organisation is closely identified with the culture which exists within the said company. It is therefore not farfetched based on these findings to draw the conclusion that successful capability building within an organisation is the output of sound and functional culture within the organisation. Ke and Wei (2008) draw the conclusion that without a match between the culture of an organisation and the cultural assumptions embedded within the organisation, costly mistakes are likely to result. An example as cited by Cooper in his paper *the inertia impact of culture on IT implementation*, which highlights the fact that when IT conflicts with an organisation's culture, the implementation will be resisted in one of two ways, either the system will be rejected or it will be modified so that it matches the existing culture (Cooper, 1994).

2.6.2 Organisational structure that supports learning

According to Luthans (2011), organisations that support learning have designed horizontal structures and set up cross-functional teams that encourage employees to assume authority and make decisions directly related to their activities. Typically these organisations have structures that have a flat hierarchy so as to allow a free flow of information as opposed to a top to down flow. Similar views are shared by Sine *et al*., (2006), who suggest that innovative organisations are those that have horizontal structures as opposed to vertical structures with bureaucratic layers.

They have established processes which tend to encourage risk taking behaviour, resource sharing, and internal debate to promote forward thinking, a culture of knowledge sharing, open communications, team work and innovativeness throughout the organisation (Luthans, 2011). Marcelle (2004) expressed the same view that organisations that allow risk taking and experimentation tend to promote open communications, support on-going challenges to existing ways of thinking and doing business, promote 'learning how to learn' and encourage personal achievement, are more likely to support capability development. Tidd and Bessant (2009) argue that there is no single best structure but that successful organisations tend to be those that develop the most suitable "fit"' between structure and operating contingencies. Therefore, companies may succeed at or impede their efforts at learning and capability building because of the way the functioning of their processes are organised.

2.6.3 Communication

The TCB literature acknowledges the importance of relational aspects but does not emphasise the role of communication yet communication plays a vital role in building trust and commitment within an organisation (Holbeche, 2002). Armstrong (2006) asserts that two-way communication is required to ensure that management keeps employees regularly informed regarding the policies and plans that affect them. Holbeche (2002) suggests that this mechanism encourages an upward flow of information and top-down information. However, the success of effective communication is influenced by how the organisation's systems are designed to stimulate and facilitate the flow of information throughout the organisation (Twiss, 1992). This point indicates that the way organisational structure and processes are designed have an effect on the flow, the speed and the effectiveness of communication within the Unit, which ultimately has an impact on how the organisation learns and builds its technological capabilities. Effective communication motivates employees to contribute, commit and cooperate by facilitating knowledge and jointly solving problems (Tidd & Bessant, 2009). This means effective communication has a direct impact on learning and capability building. The manner

in which the organisational efforts are communicated within the organisation can either increase buy-in from staff or create resistance.

2.6.4 Human resources development (HRD) system

Is a process of improving an organisation's performance through the capabilities of its staff members (Weinberger, 2006). Similarly, Swanson (1995; 2001) has considered HRD as a process of developing human expertise through training and development for the purpose of improving performance and achieving greater effectiveness. A study by Marcelle (2004) found that organisations that establish extensive human resources development programmes and practices have seen increased individual motivation and performance. These organisations tend to have established individual development programmes that enable employees to progress through the career ladder (Tanke, 2000).

2.6.5 Knowledge Management System

According to Anand (2011), Knowledge Management (KM) is the explicit and systematic management of vital knowledge and its associated processes of creating, gathering, organizing, diffusion, use and exploitation. KM is about harnessing the knowledge and experience that people have, and creating a culture where senior people think that knowledge sharing is worth investing in (Holbeche, 2002). Marcelle (2004), indicates that organisations that build knowledge management systems to capture, organise and disseminate knowledge across the firm are likely to have acquired technological capabilities. These organisations tend to store knowledge in a repository and increase access in knowledge sharing within the organisation which tends to increase knowledge collaboration and building capabilities (Anand, 2011). The same sentiment is shared by Armstrong (2006) who posits that organisations that capture organisational expertise and distribute it within are likely to achieve the biggest payoff.

Thus, organisations that have KM systems in place have a greater chance of building and developing technological capabilities through knowledge that originates

within from individuals and/or teams. Furthermore, it gives these organisations competitive advantage as the culture of knowledge sharing, trust, and openness are embedded within the organisation.

2.6.6 Performance appraisal system

Performance appraisal is a process used to determine how well each of the organisations' employees is doing towards achieving the criteria considered essential for success in the employees' job position (Tanke, 2000). In essence, performance appraisal enables the employer to know how well the employee is doing their jobs and what steps should be taken if performance improvement is needed. Mumford and Licuanan (2004) suggest that attention should be given to understanding how the performance strategies selected by the leaders shape the nature of the innovation they are willing to support. This view suggests that organisations must give more attention to the critical behaviour and performance they are willing to support and reward. The same view is shared by Shalley and Gilson (2004) asserting that managers must make clear to employees the kind of behaviour that is acceptable and how the organisation's reward system works.

Collins *et al*., (2001) indicate that firms should use performance appraisal to identify needed knowledge, skills and abilities and implement development plans designed to improve the knowledge, skills and abilities identified. These authors believe that when an employer shows the willingness to contribute to the organisation's development, employees will show the same level of commitment to the organisation. If performance rewards are distributed in these types of ways, they should have a positive effect on employees' performance (Shalley & Gilson, 2004). Therefore, organisations should focus on how human resources practices (e.g. rewards, resources, goals and expected performance evaluation) can be used by leaders to develop a work context within which the output of their employees can enhance innovation and building capabilities (Shalley & Gilson, 2004). This analysis implies that organisations should have a culture and reward system that has significant impact on innovation and be clear on how performance will be rewarded. The management practice could be used as a strategy to promote and influence innovation and technological capability building.

2.6.7 Rewards and Recognition System

Organisations should develop management practices that direct, evaluate and reward critical behaviour and performance that influence innovation (Mumford & Licuanan, 2004). That means organisations need to develop and implement a robust system for identifying, evaluating, recognising and rewarding excellence in performance. However, Tidd and Bessant (2009) argue that many organisations have reward systems which reflect performance of repeated tasks rather than encourage the development of new ideas. These authors further indicate that these organisations measure progress based on how things are done by the book rather than challenging and changing the status quo. An example of a reward system includes the dual ladder system, which enables technologically innovative staff to progress within the organisations without needing to move across to management posts. Other examples include promotion, higher pay, and greater access to self-defined projects (Rush *et al*., 1995).

Shalley and Gilson (2004) assert that organisations should place systems in place to track innovation so as to be able to appraise and reward appropriately. Programs such as profit sharing may make employees more willing to try to be innovative and may help to increase employees' long-term commitment to the organisation. In addition, if employees feel that their jobs are relatively secure, they may be willing to exert the cognitive effort required for innovation and be more willing to take risks that could lead to innovative outcomes (Shalley & Gilson, 2004).

2.7 FACTORS INHIBITING TECHNOLOGICAL CAPABILITY BUILDING WITHIN PROs IN INDUSTRIALISING COUNTRIES

This section identifies four factors that affect technological capacity building within public research organisations in industrialising countries. These are limited funding, lack of infrastructure, lack of absorptive capacity and lack of trust and openness amongst colleagues within an organisation.

2.7.1 Limited Funding

Limited funding is a key challenge for public research organisations in industrialising countries. Public Research Organisations are some of the main institutions supporting the process of economic development in different forms across the country and economic sectors (Mazzoleni & Nelson, 2007). Most PROs particularly in South Africa are highly dependent on government funding, which has proven to be a problem given the reduction in institutional funding from government towards research and development (Menendez & Cruz-Castro, 2003). This statement is confirmed by the study conducted in South Africa by Hipkin (2004), who highlights that in 1998, CSIR had a reduction of government funding of over 25% as a result of political changes and shifts in the business climate. The reduction of funding resulted in reduced R&D output nationally. This indicates that limited funding has adverse effects on capability building initiatives. This financial pressure calls for PROs to develop strategies to diversify their sources of funding to further research and develop technological capabilities. New sources can be created by building connections and strategic partnerships with industry (Rush *et al*., 1995).

2.7.2 Lack of Infrastructure

Marcelle (2005) argues that investing in infrastructure for technological learning is important. This point is further supported by Juma and Yee-Cheong (2005, p. 78) who note that the problems hindering technological learning in industrialising countries are due to the absence of adequate infrastructure. According to these authors, adequate infrastructure is a basic requirement for enhancing the creation and application of knowledge and technological development. The authors further suggest that industrialising countries need to adopt strategies and/or policies to improve their infrastructure in ways that promote the technological development necessary for sustained economic growth (Juma & Yee-Cheong, 2005). Because infrastructure is an intermediate input into production, its costs have a direct effect on a firm's profitability and competitiveness, as well as increasing its operational performance (Juma & Yee-Cheong, 2005). Infrastructure services also allows

organisations to shift from manual to electrical machinery, transportation networks reduce workers' commuting time, and telecommunications networks facilitate the flow of information. Infrastructure may also attract firms to certain locations, which can create an agglomeration of economies and reduce transactions costs (Juma & Yee-Cheong, 2005).

2.7.3 Lack of Absorptive Capacity

Cohen and Levinthal (1990) define absorptive capacity as the ability of a firm to recognise the value of new, external information, assimilate it and apply it to commercial ends. Wood and Weigel (2010) define absorptive capacity as the organisation's ability to take in and act on new information about the technology they are learning. The absorptive capacity of an organisation tends to develop cumulatively and builds on prior related knowledge (Lamin & Dunlap, 2011). Cohen and Levinthal (1990) argue that to generate such abilities, organisations need sustained investment in technological activities. Furthermore, these organisations should have accumulated learning and capabilities to change technologically and also have the capacity to acquire technologies from external sources (Cimoli & Porcille, 2009).

Wood and Weigel (2010) emphasise the need for organisations in industrialising countries to have the capacity to acquire technologies related to capital goods and know-how from external sources, and adapt their technology to suit the needs and requirements of their organisation. The existing level of the receiving firm's absorptive capacity will determine the extent to which they can actively participate in the technology transfer process (Kumar et.al., 1999).

Fagerberg and Srholec (2008), assert that an organisation with absorptive capacity has a greater opportunity to advance by borrowing and adapting the best technological practices and becoming a highly productive organisation. The same view is shared by Lamin and Dunlap (2011), who state that a lack of absorptive capacity within an organisation can be a major barrier to internal knowledge transfer and building technological capabilities as it may cause the organisation to take time to analyse incoming information effectively, and as a result become hard to

understand and adapt. This view implies that previous knowledge and skills must be available to acquire new skills that make the technological development possible. Abramovitz (1994) contests this view, asserting that not only individual skills have the potential to exploit and adapt technology, but that the broader social and cultural factors are aspects that are particularly important in acquiring and adapting best practice as this is related to what organisations are capable of doing.

Marcelle (2005) argues that organisations should pay attention to the individual aspects of absorptive capacity if they are to succeed. This requires developing a culture in which employees are supported and encouraged to acquire technological knowledge and confidence in using technology. Another view by Kuemmerle (1997), argues that organisations need to have absorptive capacity to evaluate and exploit relevant ideas/knowledge across the globe and adapt it to meet the needs of their organisation. This requires firms to build the prerequisite capability by providing the training necessary to enable them to absorb technology and to maintain their competitiveness (Clark & Juma, 2002). This process may build technological capabilities provided that adequate resources and competences are available locally to exploit these opportunities. However, Fontes (2007) argues that structural modifications within an organisation such as policies and concerted efforts as well as communication technologies are required in order to engage in a process of absorptive capacity and to enable internalisation of the knowledge. This depends on the structure of communication between the external environment and the level at which the organisation is absorbing technology (Cimoli & Porcile, 2009) as well as the character and distribution of expertise within the organisation (Figueiredo, 2010).

2.7.4 Lack of trust and openness amongst colleagues within an organisation

An organisational environment that is missing trust tends to have people who are afraid of being exploited and robbed of their good ideas, resulting in organisations incurring high expenses due to mistakes (Tidd & Bessant, 2009). Trust helps to structure and shape the patterns of interaction and coordination within and between organisations. It motivates employees to contribute, commit and cooperate by facilitating knowledge, engendering open communication, resource sharing and joint

problem solving (Tidd & Bessant, 2009). Therefore, high levels of mistrust and lack of openness may lead to a lack of knowledge sharing, which impacts on learning and building of technological capabilities within an organisation.

2.8 SUMMARY

The literature review identifies four main themes that inform the research study and also helps in formulating and refining the research questions. Empirical literature indicates that learning and capability building are used by firms in industrialising countries as a key strategy for enhancing their innovation and business performance. The framework suggests that effective firms are able to organise their learning and capability accumulation efforts in a systematic and organised manner. This involves developing and implementing five core elements, such as allocating financial resources, fostering management practices, developing an organisational culture that supports technological learning, accessing external technological capabilities from suppliers, accessing the local and "global" innovation system. This is all in an effort to learn and accumulate technological capabilities.

2.8.1 The Role of Public Research Organisations (PROs) in industrialising countries

PROs play a fundamental role in supporting the growth and development of economies through technological innovations and the development of appropriate human resources for research. In order for public research organisations to operate effectively, they need to form relationships with various actors within their national systems of innovation as well as with external actors in order to internally build the required technological capabilities, and to manage their research and innovation effectively. Relationships formed within the innovation system are regarded as one of the mechanisms through which firms can acquire exchange and develop new knowledge towards building of learning and technological capabilities within Public Research Organisations. However, challenges such as fragmentation within the national system of innovation in industrialising countries have had a negative impact on the speed at which public research organisations in industrialising countries learn and build technological capabilities.

2.8.2 Processes of learning and technological capability building in public research organisations

A review of the literature highlighted mechanisms that firms in public research organisation use to learn and build technological capabilities. These mechanisms include recruitment and selection of skilled talent, succession planning, mentorship programmes, career advancement programmes, graduate programmes, organisational exchange programmes, managing transfer of knowledge from expatriates and internal collaboration amongst Operating Units. Organisations that use these mechanisms seem to have increased their stock of knowledge and the competencies required in the long term. Furthermore, these programmes seem to encourage and motivate employees to learn and build technological capabilities as well as creating a culture that supports learning and innovation. Consequently, these programmes if effectively implemented over time, can produce positive results in the learning and accumulation of technological capability.

2.8.3 Factors that facilitate technological capability building within public research organisations in industrialising countries

The literature reviewed indicates factors that facilitate learning and technological capability building, such as organisational culture, organisational structure, communication, human resource systems, knowledge management systems, performance management systems and rewards and recognition systems. Organisations that develop management practices and processes that are used towards directing, evaluating and rewarding the desired organisational behaviour are able to learn and build technological capabilities through these programmes.

2.8.4 Factors inhibiting technological capability building within public research organisations in industrialising countries

The reviewed literature highlights some of the challenges faced by public research organisations in industrialising countries. These factors include amongst others limited funding, lack of infrastructure, lack of absorptive capacity and lack of trust and openness. These factors have adversely affected organisations in industrialising countries particularly in terms of how they acquire the knowledge required to build up

and accumulate their own technological capabilities to enable competitiveness in the local and global markets. Additionally, the speed, direction and level of advancement in terms of technological capabilities will be negatively affected. However, organisations that have plans to mitigate and manage these factors are able to re-evaluate their approach and improve their systems in order to gain competitive advantage.

The following are the themes that have been highlighted:

- The role of public research organisations in industrialising countries.
- Processes of learning and technological capability building.
- Factors that facilitate learning and technological capability building.
- Factors that inhibit learning and technological capability building.

Following the review of the literature presented, it is useful to rearticulate the guiding questions for this study in order to set the stage for the research methodology chapter that follows.

2.9 RESEARCH QUESTION

The key question and sub-questions that this research seeks to answer is:

How does CSIR Biosciences learn and build technological capabilities?

Sub - research question 1

What are the factors that facilitate technological capability building within the CSIR Biosciences Unit?

Sub-research question 2

What are the factors that inhibit learning and technological capability building within the CSIR Biosciences Unit?

CHAPTER 3: RESEARCH STRATEGY AND METHODOLOGY

3.1 INTRODUCTION

This chapter aims at describing the research strategy and methodology that were adopted to answer the key research questions of this study. The following elements are discussed in relation to the afore-mentioned: research strategy, research methodology, limitations of the study and ethical considerations.

3.2 RESEARCH STRATEGY AND DESIGN: QUALITATIVE RESEARCH

The research methodology applied utilised a qualitative approach that focused on CSIR Biosciences Unit as a case study. The decision to use this particular approach stems from the fact that qualitative research is regarded as a form of social inquiry, with the intention of exploring a particular area, collecting data (interviews and a survey) and generating ideas from this data through a process of inductive reasoning (Ritchie & Lewis, 2003). The qualitative research methodology also helps the researcher to have an in-depth understanding of a situation (Cooper & Schindler, 2011). This approach is ideal for understanding social realities as it involves feelings, emotions, motivations, perceptions, self-described behaviour and the interactions between the social actors involved (Yin, 2003; Cooper & Schindler, 2011). The qualitative research method enabled the researcher to elicit views and perceptions from respondents that were interviewed. Unlike qualitative research, quantitative methods are limited in their ability to explore the richness of detail as well as the nuances and multi-layeredness of the information gathered during the course of this study. Silverman (2010) argues that because the qualitative approach is based on interpretation rather than measurements, it brings sensitivity to the investigation. Based on the above statement, this study employs a qualitative research method with the aim of understanding how people interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences (Merriam, 2009).

The interview protocol of the study was designed in a semi-structured manner and used when conducting the research (See Appendix A). These semi-structured interviews provided the respondents with the opportunity to openly share their views as well as their understanding of the processes that CSIR Biosciences Unit applies in learning and building technological capabilities.

For this study, the CSIR Biosciences Unit was selected as a case study. A case study is described by (Yin, 2009) as an empirical inquiry that investigates a phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. Another view by Merriam (2009) describes a case study as an intensive, holistic description and analysis of a single, bounded Unit which facilitates the understanding of complicated subjects by means of extending experience and adding strength to what is already known about certain topics through previous research (Yin, 1994). A case study can bring about the discovery of new meaning, extend the reader's experience, or confirm what is known. It can draw attention to the question of what specifically can be learned from this single case (Stevens & Dimitriadis, 2004).

Based on the above paragraph, the CSIR Biosciences Unit was chosen as a case of analysis because it would allow for the collection, investigation and analysis of data as well as offer insights from respondents' experiences, and contribute to the general understanding of the nature of this type of research. Approval was granted by the relevant authorities at the CSIR Biosciences Unit to conduct this research. It is important to note that other Operating Units within the CSIR were not included in the case study. Within this case study, a sample of participants within the CSIR Biosciences Unit were identified in advance before the data collection began. Criteria to select whom to interview, what to observe and which documents to analyse were established to guide the process. The sample consisted of a CSIR Biosciences senior management and middle management team and their views were obtained on how CSIR Biosciences learns and builds technological capabilities.

Primary and secondary data were collected to answer the research questions and to provide the researcher with a rich understanding of the phenomena under investigation. The findings from data collected were corroborated with the

triangulation technique (expert commentator interviews) to assess the validity of what has been said in an in-depth interview and further supported by various CSIR documents analysed by the researcher. This method was deemed to be appropriate in providing answers to the key research question.

3.3 SELECTION OF PARTICIPANTS

A total of 27 participants were interviewed, 24 were from the CSIR Biosciences Unit and the other 3 were external expert commentators. All the participants interviewed were familiar with the CSIR Biosciences Unit as shown on table 3.1 below. The selection of the participants from the Biosciences Unit was based on the roles they play within CSIR Biosciences Unit. These selected participants are responsible for building employees technological capabilities within CSIR Biosciences and therefore are seen as key in contributing to the research objectives. The expert commentators were selected based on their previous interaction with the CSIR Biosciences Unit as either past employees or project partners as shown on table 3.2 below. The interviewer completed all 27 interviews, covering all the main themes in the interview protocol, which was guided by the literature review. The interview scheduling was dependent on the timing and availability of participants. No further interviews were conducted once the scheduled interviews were completed.

Below is a list of the participants that were interviewed and their level of responsibility within the CSIR Biosciences Unit.

TABLE 3.1: PARTICIPANTS FROM BIOSIENCES UNIT

Position Description	Responsibility	Number
Member of the executive leadership team	Provides vision, leadership and strategic direction and ensuring financial sustainability for CSIR Biosciences Unit.	1
Senior member of strategic research management	Leads the evaluation of current business processes, recommends, implements and improves sound business processes in line with relevant CSIR policies and procedures to fulfil the Unit strategy and operational plan and efficient functioning of the Unit.	1
Senior member of project management team	Ensures that CSIR Biosciences multiple projects are delivered according to the specific time agreed with the client, on budget and according to the clients' brief.	1
One of the Chief Scientists	Responsible for implementation of the research and development strategy of the research group and for management of the research group to achieve performance targets	1
One of the Principal Researchers	Responsible for identifying key strategic projects (both internally and externally) that are aligned to the Biosciences strategy to solve problems identified in the market.	2
One of the Project Managers	Ensures that Technology Platform projects are delivered according to the specific time agreed with the client, on budget and according to the clients' brief.	1
Senior member of commercialisation team	Ensures that CSIR Biosciences projects are commercialised according to the CSIR research translation protocol through patent	1

	application, sale, maintenance and regular review.	
One of the Technology Platform Managers	Provides the Scientific and Innovation strategy of the technology platform by ensuring that objectives of the CSIR Biosciences Unit are met.	3
One of the Business Area Leaders	Responsible for successful incubation and growth of an enterprise that could be spun-out from the CSIR to be a sustainable business contributing to the bio-economy with supporting human capital, and to develop a robust environment within which the enterprise can remain sustainable over prolonged time periods.	4
One of the Senior Researchers	Responsible for conducting fundamental research in a specified area of focus to continuously solve problems identified by the Unit.	3
Senior member of Social Impact team	Responsible for constructing major strategic Public and Social Good programmes supported by research and development with depth in capacity, of a minimum of three-year duration, involving multiple stakeholders that will support the development and creation of sustainable public and social good outcomes	1
One of the Science Innovation Leaders	Responsible for implementation of the research and development strategy of the research group and for management of the research group to achieve performance targets	4
Senior member of Human Capital Development team	Responsible for raising funding for staff development including consolidating	1

	students' activities to obtain high quality SET base.	

TABLE 3.2: EXPERT COMMENTATORS TABLE

Member of SA parliament	Responsible for issues related to research and development of SA	1
Executive Director of Research: Higher Education Institution	Responsible for leading and directing University research at Higher Education Institution in SA	1
CEO	Responsible for leading SA research laboratory owned by government	1

3.4 RESEARCH METHODOLOGY

3.4.1 Data Collection

Three sources of data were used in the collection of data: The first one was a series of 24 interviews across CSIR Biosciences Unit with selected managers who are responsible for developing employees' capabilities to gain different perspectives of the same phenomena. In this study, interviews were conducted at the respondents' office, CSIR Biosciences Unit. This was a convenient option for the respondents as they were familiar with the location, which made them feel more at ease when responding to the interviewer. After gaining the consent of the individual respondents, written notes were taken during the interviews to ensure that information is stored and properly recorded for ease of reference and to fill in any gaps. For the purpose of confidentiality and ethical reasons, the actual interview recordings will be kept strictly private and only be used strictly for research purposes.

However, these recordings can be made available via transcripts, to the interviewees on request.

The second method was interviews with three external expert commentators. The commentators were chosen on the basis of their previous interaction with the Unit and their understanding of how CSIR Biosciences Unit operates.

The third research method was based on an analysis of various CSIR Biosciences Unit documents that included strategies and goals, human capital development strategies, CSIR annual report and other relevant documents which informed the context of the case study. These documents were analysed and coded to identify emerging themes which were assessed through frequency of mentioned responses/views of the participants in order of importance. In conducting the case study, data was collected through the following two methods:

3.4.2 Primary Data: semi- structured interviews

Interviews are defined as a process by which a researcher and participants engage in a conversation focused on questions related to a research study (De Marrais, 2004, p. 55). The main purpose of conducting an in-depth interview is to obtain information based on the perceptions/perspectives of the particular respondent(s). This process will help the interviewer to gather reliable data that may answer the research question (Saunders *et al*., 2009). For the purpose of this study it was therefore necessary to conduct interviews to assess behaviour, feelings, or how people interpret the world around them (Merriam, 2009).

Semi-structured interview – According to Merriam (2009), a semi structured interview consists of questions that are flexibly-worded with a mixture of less or more structured questions. Most of the interviews were guided by a list of questions or issues to be explored. This format allowed the interviewer to respond to the situation at hand, to the emerging worldview of the respondent, and to new ideas on the topic. In this study, the primary data was collected through semi-structured interviews with questions based on themes that enabled the researcher to gain insights into the various approaches applied to learning and technological capability building at the

CSIR Biosciences Unit. The purpose of conducting in-depth semi-structured interviews was to find out the views, interpretations, understanding and motivations of respondents regarding the subject under investigation so as to elicit the necessary information to answer the research questions. The interviews conducted enabled the researcher to identify patterns of similarities and differences within the Biosciences Unit. Saunders *et al*., (2009), assert that this method is believed to yield knowledge that is high quality and more systematic than haphazard, more objective than partial, and comprehensive instead of selective, as well as standardized and methodical.

Face-to-face interviews were conducted with 27 respondents. Each interview took approximately 45 minutes and was recorded in full for later analysis. Standard interview protocols were utilised as a template or a guide for each respondent, the questions had similar wording and were asked in the same order. Furthermore, the interviewer made a concerted effort to extract as much information as possible from the interviewees so as to ensure that personal biases and preconceptions were not reflected in the interview responses.

The interview protocol was structured into two parts. The first part captured data pertaining to the interviewee's demographic profile and the second part was more on processes and factors around learning and technological capability building within the CSIR Biosciences Unit. The interview questions were categorised into relevant/specific themes to enable the interviewer to interrogate and find answers to the research questions.

The objective of the in-depth interview process was to identify and collect data and elicit the perceptions and opinions of the participants on the following issues:

- The processes used by the CSIR Biosciences Unit to learn and build technological capabilities.
- Factors influencing learning and technological capability building within the CSIR Biosciences Unit.
- The perceived barriers within the CSIR that inhibit technological capability building.

The researcher used a tape recorder during the interview process, so as to focus on managing the interview process, taking notes on issues of interest which supplement the research questions, following up on questions and probing more deeply into issues to be able to draw conclusions (Merriam, 2009). All interviews were conducted by the researcher in person and permission was granted by all participants for discussions to be recorded.

3.4.3 SECONDARY DATA: POLICY DOCUMENTS

According to Saunders *et al*., (2009), secondary data includes both qualitative and quantitative data and they are used principally in both descriptive and explanatory research. In this study, the following CSIR Biosciences documents were utilised as secondary data, these documents are available on the CSIR intranet;

- CSIR Biomentor4U (2012)
- CSIR Human Capital Development Strategy (2006)
- CSIR Biosciences Strategy (2011)
- CSIR Annual Report (2014)
- CSIR Remuneration policy (2010)

The interviewer primarily used the qualitative research method. However, in order to provide the reader with a sense of the proportion of the respondents who articulated certain recollections or views, a basic quantitative representation of the qualitative data has been given in this study.

According to Merriam (2009) documents are a ready-made source of data that existed prior to the research at hand and are accessible and resourceful to the investigator. This includes a broad range of materials available to the researcher such as written materials, notices, correspondence (including emails), minutes of meetings, diaries, reports of shareholders, transcripts of speeches and administrative and public records (Saunders *et al*., 2009).

Saunders *et al*., (2009), assert that secondary data collection can be used to help the researcher to triangulate findings based on other data, such as written

documents and primary data collected through observation, interviews or questionnaires. This method supported the interviewer in evaluating what already existed and was collected to address the research question. Documentary analysis was used to improve the rigour of the study.

The participants in this study were selected based on the following criteria:

- The individual should be a manager or a leader of individuals or a group within the Biosciences Unit.
- The individual should have the potential to comprehend the intention of the study and be able to provide the required level of detail.
- The individual should have knowledge and understanding of the phenomenon under study.
- The individual should be accountable and responsible for building technological capabilities as well as providing strategic direction to the implementation of building technological capabilities within the Biosciences Unit.

A key factor in the selection of these respondents was their role in building of technological capabilities of researchers and scientists within the CSIR Biosciences Unit.

3.5 DATA ANALYSIS

This section discusses the techniques and approach that were used to analyse data.

In the course of the study data was examined and the responses coded through the use of selective coding as prescribed by Cooper and Schindler (2011). The process involved the selection of various categories and sub-categories, which were captured using Microsoft Excel Spreadsheet as a database. The spreadsheet made it possible to capture key insights and themes from each interview. The notes that were captured during the interviews were entered into the database.

3.5.1 Analysis of Interview Data

All interviews were recorded using an audiotape and details of each interview transcribed by the researcher. This was in addition to the notes that were taken during the interview itself. The real-time notes also served as back-up in case the audio recordings failed for any reason. Data extracted from interviews was analysed to determine patterns based on the number of times specific issues were mentioned from acquired data.

The interview protocol was analysed for trends to provide an understanding and explanation of the interview questionnaire. Themes were analysed to identify commonalities and the relationships between them. Individual responses were analysed for similarities and differences to develop an understanding and explanation of data.

Furthermore, content analysis was conducted by analysing relevant documents such as the CSIR Biosciences Strategy, Human Capital Development (HCD) strategy, and other related strategies as mentioned above. This process highlighted common themes and key factors were identified from the data. The process enabled me, as the researcher, to interpret the results and to develop an understanding of the issues raised. Throughout the process, I analysed the results continually referencing the literature review. Through following this procedure, key themes emerged from the data that was gathered from the interviews and was integrated into one document.

3.5.2 Documentary Analysis

Secondary data was obtained from the Biosciences Unit by analysing documents such as reports, strategies, policies, processes and operational plans. The purpose of analysing these documents was to learn more about the CSIR as an entity and the Biosciences Unit in relation to the broader organisation. Furthermore, these documents were used for comparative analysis to search for common patterns

across them in an attempt to present aggregate findings that have a wider appeal (Miles & Huberman, 1994; Yin, 2003).

Merriam (2009), states that documents are a good source of data for numerous reasons. They may provide the best source of data on a particular subject as opposed to observations or interviews in particular instances. The advantage of using documentary material is that it is an existing organisations' document which could provide a holistic picture of organisational plans, strategies policies, processes etc. However, one of the limitations cited is that there is the possibility that sometimes documents produced may be fragmentary and may not fit the conceptual framework of the research (Merriam, 2009). The researcher determined the authenticity and accuracy of documents during the research process by looking at the following:

- The history of the documents.
- Was the document complete as originally constructed?
- Has it been tampered with or edited?
- The circumstances under which the document was produced.
- The purpose for which the document was produced.
- For whom was the document intended?
- Other documents that exist that might shed additional light on the same programme, project or event.

Based on the above, data found in documents was used to verify data collected from in-depth interviews and thereby generate an understanding of, as well as providing explanations beyond the individual contexts. This method assisted in tracking down leads, being open to new insights and being sensitive to the data during documentary analyses. All data was treated as confidential and handled according to the CSIR confidentiality policy/procedures and according to the best practice.

3.6 LIMITATIONS OF THE STUDY

The present study has a number of limitations that are associated with the researcher's previous position at the CSIR Biosciences Unit and involvement in the CSIR Biosciences' strategic planning, which could have negatively or positively influenced interactions with participants in the study. These include:

- In this study, only views of the staff of the Biosciences Unit were considered. Those of other Operating Units within the CSIR were excluded.
- CSIR Biosciences Unit had just completed a fourth organisational restructuring and therefore, information given included all four restructuring processes.
- Since the implementation of the CSIR Biosciences restructuring process which resulted in some individuals being demoted, retrenched, appointed in new jobs, and rotated in some jobs and some jobs being expanded, the participants were limited to those who remained after the restructuring process. It is possible that some may not have been as forthright in their responses for fear of possible retribution. However, as the interviewer, I reiterated that their identities would remain strictly confidential. Furthermore, the interview protocol was designed to encourage interviewees to speak openly and express their views as freely as possible.

3.7 ETHICAL CONSIDERATIONS

Research ethics refers to the appropriateness of the researchers' behaviour in relation to the rights of those who become the subject of a research project or who are affected by it (Saunders *et al*., 2009). Therefore, the reliability and validity of the study will to a large extent, depend upon the ethics of the investigator (Merriam, 2009). The researcher in this study maintained ethical standards as per the Wits Business School code of ethics and was approved by the Wits Ethics Committee before commencing with the interview process.

Participants were notified and requested to participate in the study prior to conducting interviews. Refusal to participate in the study at any stage was accepted during the course of the research.

The right to privacy, the notion of informed consent, and the issue of deception was considered ahead of time and were resolved as they cropped up once the researcher was in the field (Merriam, 2009). A high level of rigor, integrity, sensitivity, and confidentiality of information was maintained throughout the study. This is in keeping with Merriam (2009) statement that the researcher should ensure that careful attention is paid to the way in which data is collected, analysed and interpreted, and the way in which the findings are presented.

As the researcher, I adhered to the research procedures faithfully to ensure that reliable and valid findings are presented. Merriam (2009) notes that the researcher should ensure a careful design of the study and apply standards well developed and accepted by the scientific community.

As the researcher, I got written permission from the Biosciences Executive Director to conduct interviews with some of his staff members as well as to access the relevant reports for this study. Permission to conduct and record the interviews was granted to me by the participants in the study. Data analysed was not manipulated as this constitutes unethical behaviour. The research findings were only discussed with the research supervisor.

3.7.1 Reflections on the Role of the Researcher at CSIR Biosciences: Pre Existing Relationships

A key advantage for me as the interviewer was that I was employed by the CSIR from 2002 and worked in the Biosciences Unit in 2009, where I worked until I left the employ of the organisation, which gave me some insight. However, this was long before undertaking this research project. As such, I was well known by all the participants and was intimately familiar with the culture and experiences of CSIR Biosciences Unit. The pre-existing relationships between the participants and me could have influenced the interviewees' responses in providing honest and open responses. On the other hand, interview time was efficiently utilised as I did not

need additional help to understand most of the terminologies, culture and history of the CSIR in general and the Biosciences Unit in particular.

3.8 RELIABILITY AND VALIDITY

Merriam (2009) posits that the quality and the ability of the research to stand up to outside scrutiny and the extent to which the research can be relied upon is largely dependent on the reliability and validity of the research.

Reliability refers to the extent to which data collection techniques yield the consistent findings made by other researchers (Saunders *et al*., 2009). The same view is shared by Merriam (2009), who asserts that reliability is the extent to which research findings can be replicated. That means if the same study were to be repeated by a different researcher conducting the same research, the research should yield the same results or very similar ones. Therefore, the connection between reliability and internal validity rests on the assumption that a study is more valid if repeated observations in the same study produce the same results (Merriam, 2009). In such a study, Merriam (2009) further states that a researcher can use triangulation to ensure consistency and dependability or reliability of data.

To ensure acceptable levels of reliability during the research process, as the researcher, I conducted all the interviews in person. I sought to maintain consistency by generating a standard interview protocol and asking the same interview questions across the board. To enhance internal validity and ensure that the findings of the research are congruent with reality, I applied the concept of triangulation which will be discussed in more detail in the following section.

3.8.1 Triangulation

Triangulation is defined as the use of different data collection techniques within one study in order to help ensure that the data is telling you what you think it should be telling you (Saunders *et al*., 2009). The main rationale for using multiple sources of data is to achieve data triangulation (Yin, 1994). This is because any findings or

conclusions in a case study are likely to be more convincing and accurate if it is based on several different sources of data, following a corroborating method (Yin, 1994). The same view is shared by Saunders *et al*., (2009), who assert that the triangulation technique provides the researcher with an opportunity to observe and analyse a phenomenon that few individuals have considered before.

In this study, three expert commentators were interviewed as part of the triangulation exercise and they included a CEO of one of the government funded laboratories in South Africa, the Executive Director of Research at one of the Higher Education Institutions in South Africa as well as one Member of the South African Parliament who is the chairperson for Science and Technology Committee in parliament. These commentators have previously worked for or have been exposed to the CSIR and thus understand the processes and systems that CSIR Biosciences has in place for learning and building technological capabilities. The interview process involved a total number of 27 participants. Expert commentators were also used to comment on the emerging findings of the research as well as to gather data that would provide varied perspectives on the organisation under investigation.

The research also sought to validate and cross-check data collected through interviews conducted within the Biosciences Unit as well as secondary data such as Biosciences reports and strategies as well as expert commentators' interviews in order to assist and support the study in reaching a credible conclusion. This technique allowed for the validation and the interpretation of responses from interviewees, as well as improved clarity and judgement about my assumptions. This technique was used as a strategy to increase the credibility of the study's findings. Therefore, qualitative data collected using semi-structured interviews and secondary data was a valuable way of triangulating qualitative data collected.

3.8.2 Transferability

According to Mouton (2003), transferability refers to the possibility of generalising the results of the study to other situations or contexts. It is clear from the research conducted that the respondents who were interviewed were from one Operating Unit,

CSIR Biosciences within the overall CSIR. This clearly indicates that the results collected from semi-structured interviews with views and opinions of the participants, expert commentators' and documentary analysis represent the actual state of the CSIR Biosciences Unit's learning and technological capability-building processes. Therefore, findings cannot be generalised and applied to other Operating Units within the CSIR as they are limited to the particular experiences of the Biosciences Unit.

3.9 SUMMARY

This chapter has focused on the research methodology that was employed in the study. It further explains in detail the research methodology that was applied and the reasons for selecting the qualitative research method. The CSIR Biosciences Unit was used as a case study. The main aim of selecting this research method was to try and gain insights into the respondents' perspectives and interpretations of learning and technological capability building process within the CSIR Biosciences Unit. The research method provided evidence and rich contextual detail around how CSIR Biosciences learns and builds technological capabilities in order to extricate a number of conclusions relating to various factors within the Unit. The next chapter provides a detailed presentation of how data was captured and analysed to enable the interviewer to derive recommendations and conclusions from the study.

CHAPTER FOUR: PRESENTATION OF FINDINGS AND DATA

This chapter presents the research data gathered through in-depth semi structured interviews with CSIR Biosciences staff, expert commentators and presentation of CSIR secondary data. The focus was on processes that are currently in place to learn and build technological capabilities as well as factors that facilitate and inhibit learning and technological capability building within the Biosciences Unit. For each research question, a description of the relevant findings is presented followed by an illustration with a bar chart.

4.1 CSIR OVERVIEW

The Council for Scientific and Industrial Research (CSIR) is a Public Research Organisation which was established on 5 October 1945 through an Act of parliament *(Act No. 33 of 1945)*. The CSIR reports to the Department of Science and Technology (DST), which is responsible for developing scientific systems and technological innovation to develop a prosperous society.

The CSIR's mandate is, as stipulated in the Scientific Research Council Act (Act 46 of 1988, as amended by Act 71 of 1990), Section 3: which indicates that;

"the objects of CSIR are, through directed and particularly multi-disciplinary research and technological innovation, to foster, in the national interest and in fields which in its opinion should receive preference, industrial and scientific development, either by itself or in co-operation with principals from the private or public sectors, and thereby to contribute to the improvement of the quality of life of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act." (Act No. 33 of 1945)

The CSIR mandate implies that the role that the CSIR plays fosters the building of extensive relationships with universities, public researchers, the private sector and with communities. The multi-disciplinary approach utilised by the CSIR encourages

employees within the organisation to work in diverse teams and thereby discourages a silo mentality.

A large proportion of its financial budget comes from the DST to perform the following functions:

- undertake research in connection with the better utilisation of the resources of the Republic, and the improvement of the productive capacity of its population;
- the improvement of technical processes and methods to improve industrial production, and the promotion and the expansion of existing industries, and the establishment of new industries;
- standardisation in industry and commerce;
- utilise the technological expertise in its possession or make it available to any person;
- foster the training of its manpower;
- publish information concerning its objects and functions, and establish facilities for the collection and dissemination of information in connection with research;
- establish and control facilities in those fields of research which the Board may from time to time approve;
- co-operate with State departments, societies, institutions and other persons that are nationally or internationally involved in research.

CSIR employs a total of about 2 300 employees consisting of science, engineering and technology (SET) specialists, of these 50% are at Masters' level and higher. CSIR invests in the training and development of its students and staff through undergraduate and postgraduate bursaries. The aim of this programme is to foster and support the development of young talent as well as the development of expertise amongst its staff members (CSIR, 2006).

The CSIR is comprised of the following core Operating Units (OUs) focusing on performing scientific research:

1. **Biosciences:** This Operating Unit focuses on doing research related to Biotechnology.

2. **Manufacturing and Science Materials (MSM):** This Operating Unit focuses on doing research in the field of materials science and manufacturing.
3. **Defence Peace Safety and Security (DPSS):** This Operating Unit focuses on research and development for the defence and security industry in South Africa. They provide technology, knowledge, advice and solutions on matters around national security.
4. **Natural Research and Environment (NRE):** This Operating Unit focuses on research and development for the natural environment. They provide integrated sustainable solutions for the growth and development challenges in the natural environment in South Africa.
5. **Built environment:** This Operating Unit focuses on promoting sustainability in the built environment. They achieve sustainability in the built environment industry in South Africa by providing advanced methods of managing infrastructure and the built environment system.

These core Operating Units are supported by centres such as Meraka which focuses on information communication and technology research, the National Laser Centre and Modelling, as well as the Digital Science Unit that provides technology-based services. They also have different ways of building technological capabilities as required by the (CSIR, 2012).

The CSIR through its Operating Units plays an important role in supporting well established private and public firms as well as emerging firms within the South African Innovation System. For instance, CSIR has several signed memoranda of agreement concluded with a number of government entities for the purpose of building technological capabilities. Eight areas were identified and project plans were developed (CSIR, 2011).

The CSIR also operates in the “global innovation system” by forming different partnerships/collaborations with private firms in industrialising countries and industrialised countries. The intention is to enhance the CSIR’s capacity to better understand global industrial developments and requirements and to be able to strengthen its capabilities to develop technology. The partnerships formed by the CSIR with other actors within the national system of innovation can be regarded as one of the mechanisms that the organisation uses to acquire, exchange and develop

new knowledge and other resources that contribute to the building of learning and technological capabilities (CSIR, 2011).

4.1.2 Brief introduction of CSIR Biosciences Unit

CSIR Biosciences emerged when two Operating Units were amalgamated in the year 2000, namely Foodtek and BioChemtek. The Unit mainly serviced the Food, Chemical and Biotechnology industries using innovation to translate research outputs (e.g. publications and patents) into market ready products (CSIR, 2011). It employed a total of 200 employees consisting of 140 full time staff members and 60 students. Of the total number of staff members, 165 had science backgrounds. On average the Unit employs 52 doctorate and 33 Master's degree holders per annum, which constitutes between 41% to 45% of its total staff members. It also engages with industry, both locally and internationally (CSIR, 2011).

The Unit remains a key player in the South African biotechnology landscape and supports the 10-year innovation plan of the Department of Science and Technology (CSIR, 2011). Over the last five years the Unit has faced numerous challenges around its financial sustainability, and this was compounded by the local financial crisis and the consolidation of previously five funders into one in 2011 (CSIR, 2011). As a result, a conscious decision was made by the management of the CSIR Biosciences to reposition the Unit to closely align to the DST's newly developed Biotechnology Strategy at that time. This required an in-depth look at its strategy and stakeholder perceptions towards proposing a new strategy that was more inclusive of all national stakeholders to enable it meet national needs (CSIR, 2011). This process facilitated the restructuring of the Unit and ensured alignment with the DST's newly developed Biotechnology Strategy and Ten-Year Innovation Plan, so as to enable the Unit to drive a national agenda without any constraints (CSIR, 2011). In spite of this restructuring, the CSIR Biosciences Unit continued facing financial challenges, recording a five-year deficit and continuing to lose key staff with core competencies (CSIR, 2011).

4.1.3 Background Profile of Respondents and Process Followed

This section presents the background profile of the respondents who were selected for the study

The interviews conducted were face-to-face and semi-structured with respondents involved in building the technological capabilities of their research group. Respondents were given an opportunity to provide information on their general profile such as number of years in the position, number of subordinates, dedicated budget for building technological capabilities and knowledge available in the group.

A total of twenty-four face-to-face interviews were conducted with Technology Platform Managers, Commercialisation Managers, Science Innovation Leaders, Business Area Leaders, Social Impact Manager, Senior Researchers, Chief Researchers, Biosciences Executive Director, Strategic Research Manager and Project Managers. These interviewees are managers and senior leaders of CSIR Biosciences. Therefore, the insights and opinions that they shared were relevant to this topic.

In addition there were three interviews conducted with external expert commentators. The expert commentators consisted of a CEO of one of the government funded laboratories in South Africa, the Executive Director of Research at one of the Higher Education Institutions in South Africa as well as one Member of Parliament in South Africa. These commentators had previously worked for or have been exposed to the CSIR and thus understand the processes and systems that the CSIR Biosciences Unit had in place for learning and building technological capabilities. The interviews involved a total number of 27 participants.

Prior to conducting the interviews, respondents confirmed their willingness for the interview to be recorded as well as their preference regarding anonymity. All interviews were recorded except those of the expert commentators.

4.2. PRESENTATION OF FINDINGS AND DATA RESULTS

This section presents the results of face-to-face qualitative interviews conducted with select staff members of CSIR Biosciences, analysis of CSIR Biosciences documents as well as the external interviews with expert commentators. For each research question, a description of the findings is presented followed by an illustration with a bar chart.

4.2.1 Processes for Learning and Building Technological Capabilities

This section presents data in relation to processes used for learning and building technological capabilities internally and externally. The figure below shows the responses on the number of processes that are widely used for learning and building technological capabilities within the Biosciences Unit. The identified processes in order of decreasing frequency are depicted in Figure 4.1 below.

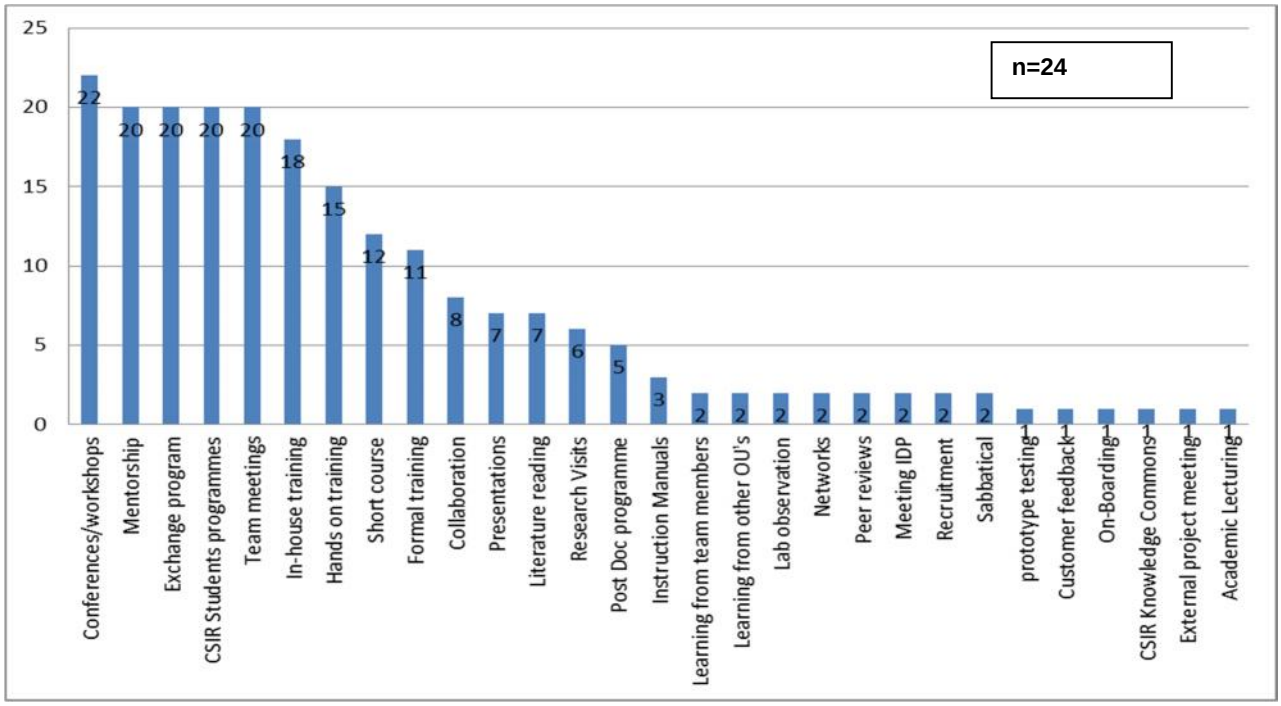


Figure 4.1: Processes used for learning and building technological capabilities.

Most interviewees reported that the Biosciences Unit has a number of processes for learning and building technological capabilities although they expressed concerns

about these processes not being fully utilised. They further reported that the processes used are not funded internally but via government subsidies due to the Unit's financial constraints. The majority of the respondents were of the opinion that the Biosciences Unit has lost its focus on learning and development of staff due to financial constraints. For example, one interviewee stated:

> *"CSIR in general has very good learning and development processes in place, however, Biosciences processes are not fully integrated and therefore, the implementation of learning and capability building suffers. This is where the problem lies".*

A majority of respondents were in agreement that mentorship within the Unit is encouraged and highly utilised to build and increase the required skills. Furthermore, respondents concurred that CSIR has well-established student programmes in place to build a pipeline to sustain the future needs of the Unit. A majority were in agreement that student programmes were effectively utilised to build the capabilities needed for the Unit.

Some respondents indicated that the lack of usage of these processes was as a result of a number of organisational restructurings within the Unit, as well as the constant change in leadership within the Biosciences Unit. The interviewees were all in agreement that the Biosciences Unit did not have integrated systems processes and a consistent way of doing things, but rather, each leader was focused on his/her own interests without clear direction from the top and without aligning to the new Biosciences strategy. Echoing the general sentiment above, is the statement bellow made by an interviewee:

"CSIR Biosciences model for learning and building technological capabilities is not balanced as it underutilises both internal and external learning processes currently in place to their benefit. Therefore, the Unit must make a conscious decision to focus its efforts on building competencies that are required for the refocused Biosciences to ensure delivery on its new strategy".

Two different interviewees also articulated the same sentiment as follows:

> *"CSIR Biosciences leadership does not put concerted effort into training and development of its staff. For example, training and development should be*

seen as an integral part of organisational development and sustainability. Currently, training and development is not prioritised as an important aspect of growth and sustainability. All you hear is the Unit's financial constraints"

"The CSIR Knowledge Commons as a learning and sharing knowledge platform was not fully utilised by CSIR Biosciences and this platform could be used to leverage knowledge from internal and external networks as well as exchanging and strengthening knowledge".

An important element highlighted from the respondents' feedback as noted above is that the Knowledge Commons, which was established primarily for the purpose of learning from each other through information sharing was not mentioned at all amongst respondents except for the one respondent. The CSIR (2006) indicates that the concept of Knowledge Commons was established as one of the core parts of the internal communications infrastructure to facilitate learning and encourage interaction amongst the CSIR Units to learn and share knowledge throughout the organisation. The intention of the infrastructure was to disseminate knowledge throughout the organisation and to increase knowledge sharing.

The CSIR (2011) notes that a key component of the new strategic direction of the Biosciences Unit is to ensure that training takes place in the form of professional and vocational training that ensures that the right skills are available to internal and external stakeholders within the Bio economy. Furthermore, the strategy indicates that mentoring and short courses will be utilised to re-skill certain employees to ensure alignment with the new focus.

CSIR (2011) further indicates that Biosciences plans to collaborate with other Operating Units within the CSIR as well as tap into already existing programmes that contribute to skills development. An important observation from the results in Figure 4.1 above indicates that cross-learning as a process for learning and building technological capabilities from other CSIR operating Units is not highly utilised by the Biosciences Unit.

One expert commentator construed this limited cross learning as an example of the silo mentality that is predominant within the CSIR Biosciences Unit, which has been

detrimental to the Operating Unit's success and has had the negative effect of compounding its failures.

In agreement with the quote above, another expert commentator stated that:

> *"CSIR Biosciences should focus less on developing students and focus more on bringing in post-doctoral researchers as they bring in new ideas and require minimum supervision, and can produce more publications, patents or results for clients on a contract/collaboration basis than students. Furthermore students' development is not part of the CSIR Biosciences strategy but a University mandate. CSIR is currently seen as competitors by the Higher Education and Training (HEIs) instead of being seen as a collaborator"*

The non-utilisation of the knowledge commons was further alluded to by an expert commentator who observes as follows:

> *"Knowledge commons is viewed as a foreign concept to the CSIR culture. This in my opinion was as a result of the knowledge concept not widely publicised and not sold to staff to receive buy-in, hence the low uptake of the platform".*

As shown in Figure 4.1 above, the results highlight the processes that were widely used within the Unit. However, this does not suggest that the less frequently used processes are less important. For example, a post-doctoral researcher may have acquired skills that can be easily utilised to produce publications or patents, as well as formed part of a team to deliver on a client's need with less supervision. Thus, while the findings in the figure reflect the perceptions of the respondents regarding the types and frequency of the processes used for learning, high frequencies for a process do not necessarily correspond to an equivalent impact or effectiveness of that process over others.

4.2.2 Champions searching for technologies to build technological capabilities

The respondents were asked to list all the role players who in their opinion are champions for searching out new technology to build technological knowledge within the Unit. The responses in order of decreasing frequency are depicted in Figure 4.2 below.

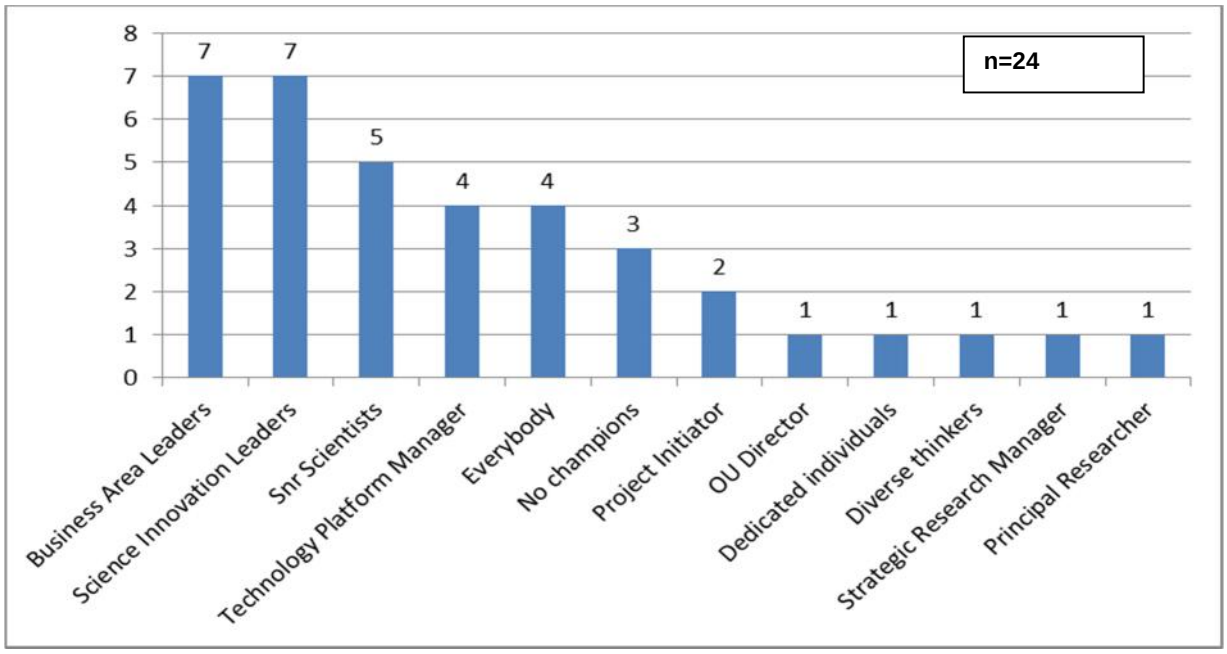


Figure 4.2: Champions searching for technology to build capabilities.

The interviewees reported that the CSIR Biosciences Unit's strategy required champions to scout for technology throughout the world to keep abreast with the latest technology and trends required to learn and build technologies within the Unit. They also stated that the Unit had identified Business Area Leaders, Science Innovation Leaders and Senior Scientists to scan, search and select systems and technologies all over the world as sources of transferring knowledge and building technological capabilities within the Unit. A majority of the respondents said that this was a good strategy but due to financial constraints searching out advancement in technology around the globe requires considerable investment in travel costs. This strategy was therefore, not implemented effectively and as a result, it failed to bear the intended results.

Some respondents were of the view that searching for technology all over the world is a good strategy for an organisation such as CSIR Biosciences as the organisation needs to keep itself abreast of the latest technology in their field. However, it was noted that even though the implementation of this strategy is minimal, the Unit does not have systems in place to capture and retain knowledge acquired externally.

Some respondents indicated a high dissatisfaction with the minimal role that the Technology Platform Managers play in scouting for technology. For example, one respondent reflected this sentiment as stated below:

> *"Technology platform managers should be proactive in managing, driving and championing innovation and technology. Currently, Business area leaders and science innovation leaders are driving and championing technology, yet the power and authority to develop technology resides with the Technology platform managers"*

The respondent further argued that the minimal role that Technology platform managers play in scouting for technology is a clear indication of poor leadership, which frustrates all innovation efforts in the Unit.

In support of the above sentiments, some respondents indicated that the minimal role that Technology Platform Managers are playing was a result of a poor implementation of the Biosciences Unit's strategy and lack of clarity around roles.

An expert commentator construed scouting for technology to build technological capabilities as a limitation which could be costly to Biosciences if not examined thoroughly. The commentator stated:

> *"CSIR Biosciences had a tendency of thinking that scouting for new technologies required international travelling. Scouting can be done through a desktop search and scanning, and travelling should only be done if there is something substantive to show. The method that CSIR Biosciences uses for scouting for technology is an "old method" and could only be afforded by organisations in developed countries".*

The above indicate that Business Area Leaders and Science Innovation Leaders seem to be the ones who are primarily given the responsibility for scouting for technologies to build technological advancement within the Unit.

4.2.3 Mechanisms for knowledge dissemination amongst staff

Figure 4.3 below shows the mechanisms that are mostly utilised within Biosciences Unit for disseminating knowledge. The 24 interviewees stated that the Unit had various ways of disseminating knowledge within the Unit as shown in the figure below. The most significant and frequently used mechanisms mentioned by all respondents were group meetings followed by conferences and presentations. The responses in order of decreasing frequency are depicted in Figure 4.3 below.

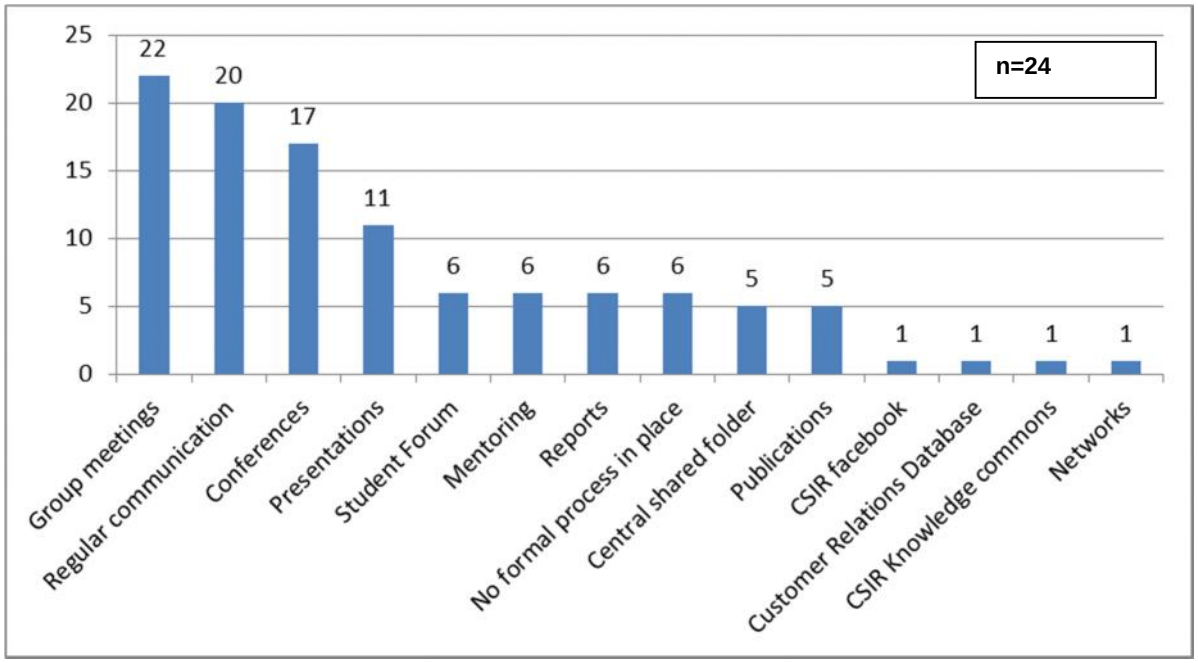


Figure 4.3: Mechanisms for knowledge dissemination amongst staff

The majority of the respondents concur that group meetings are one of the most utilised mechanisms for disseminating knowledge. Most participants stated that they hold weekly, monthly and quarterly meetings to disseminate information and knowledge within the group and this mechanism seems to be effective in increasing knowledge within the group/Unit.

Two different interviewees articulated similar views as follows:

> *"In my research platform employees are encouraged to attend conferences and disseminate knowledge in the group. This mechanism seems to increase knowledge and information sharing and increased participation amongst team members".*
>
> *"Knowledge dissemination keeps our internal and external stakeholders well informed about our strategy, planning and implementation. The basis for knowledge dissemination within our Unit is to empower people with knowledge and to increase partnership with our stakeholders"*

According to CSIR (2011), participation in conferences plays an important role in improving the Biosciences Unit brand and engaging with stakeholders. The strategy further indicates that knowledge dissemination is critical to strengthening the Biosciences Unit brand and increasing effective communication with stakeholders.

As highlighted in the CSIR (2006), attending conferences and workshops is important in terms of providing informal learning in the long term from communities of practice.

4.2.4. Selection of partners to learn and build technological capabilities

Figure 4.4 below depicts the results derived from the interview process which indicates that the CSIR Biosciences Unit's criteria for selecting suppliers and partners for learning and building technological capabilities are mainly informal. The responses in order of decreasing frequency are depicted in Figure 4.4 below.

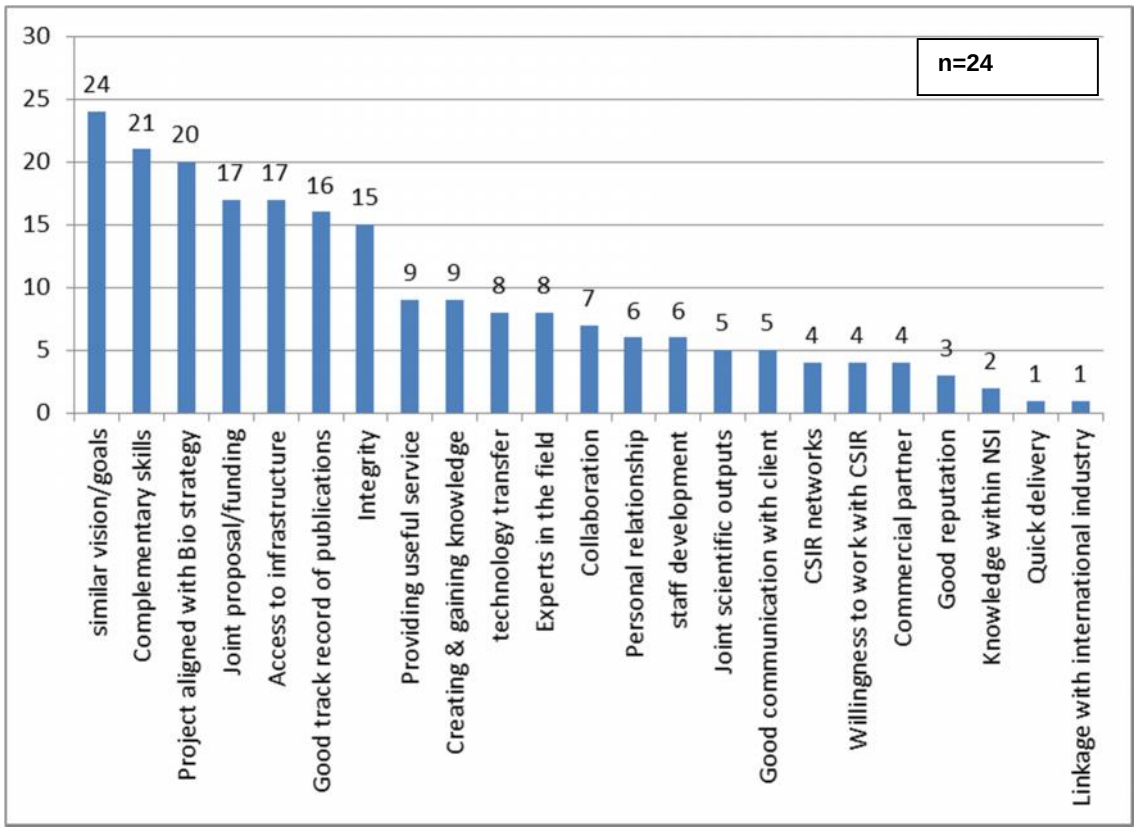


Figure 4.4: Criteria for selecting partners to learn and build capabilities.

Interviewees reported that in most cases these partnerships such as tertiary education institutions, government departments and private industries involved local and international partnerships that had no connection to the CSIR. As indicated in Figure 4.4 above, a majority of respondents concurred that although the selection of partners was informal, these partnerships facilitated the provision of complementary skills, opening up opportunities for joint proposals and funding. It also provided access to infrastructure and enabled the generation of a good number of important publications for the Unit. However, some of the respondents were concerned about the non-formalisation of this process without following the same criteria. In view of the above, two different interviewees stated the following:

> *"Sometimes we select partners that do not understand Biosciences landscape which ultimately impact negatively on our deliverables".*

> *"The selection of these partners is not formalised, it is predominantly based on the integrity of the organisation you want to partner with and your past relationship with the partner".*

The respondent further argued that the absence of a formalised criteria has created inconsistencies in the selection process due to the lack of an established structure or process. The respondent suggested that the Unit needed to establish standardised criteria for selecting partners to ensure consistency and to enable the Unit to measure the effectiveness and success of the partners they collaborate with.

4.2.5 Knowledge exchange with external partners to learn and build technological capabilities

Figure 4.5 below depicts the different methods used to exchange knowledge with external partners. The interviewees reported that exchanging knowledge with external partners is one of the mechanisms utilised by the Unit for learning and building technological capabilities. The responses in order of decreasing frequency are depicted in Figure 4.5 below.

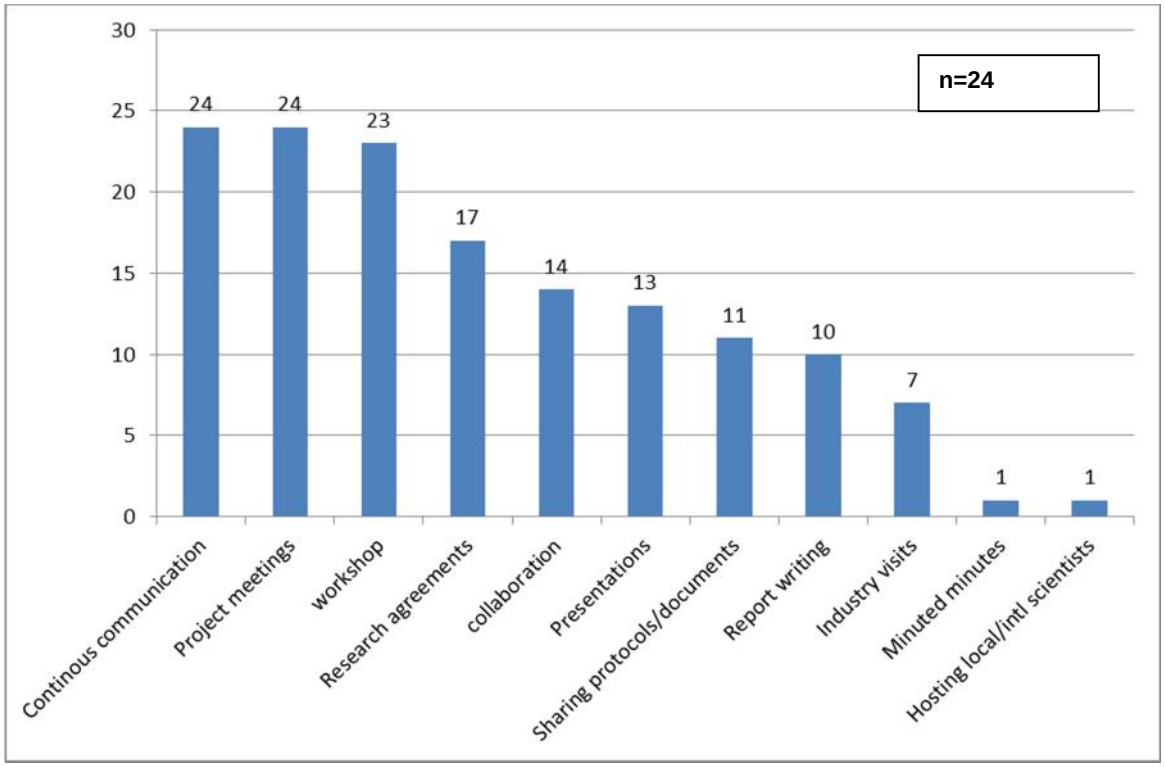


Figure 4.5: How knowledge is exchanged with external partners.

Respondents generally agreed that the CSIR Biosciences Unit had a well-established "Exchange Programme" that encouraged students and staff to participate in the programme, and use the opportunity provided to learn from

organisations that are innovative and doing world class research such as internationally based universities, major industry players, and research councils. Most of the respondents stated that the scope of the project dictated the choice of mechanism that was used. For example, one respondent stated that:

> *"Hosting local and international scientists is an effective mechanism of exchanging knowledge".* The respondent further stated that *"this mechanism was also quite effective in the sharing of ideas, as well as for show casing Biosciences Unit and establishing the organisational reputation".*

Some respondents reported that exchanging ideas and learning from external partners assisted the Unit in attracting funding through joint projects and providing solutions where the Unit required help. This was confirmed by one of the respondents who stated that:

> *"Joint project meetings with external partners as well as workshops provided an opportunity for the Unit to learn and exchange knowledge. My staff members have learned incredibly by visiting other research institutions and industry from many countries as well as attending international conferences. Interaction with external partners and continuous communication has a positive impact on building and increasing capabilities within the Unit. If the Unit does not financially support staff interaction with external partners no learning will take place and the Unit will be doomed"*

According to CSIR (2011), engaging with industry partners, both locally and internationally provides access to co-investment and collaborations on projects of strategic importance for the purpose of creating a sustainable South African Bio-economy. Furthermore, the strategy states that the Unit's stakeholders should be well informed through continuous communication about its strategy, planning and implementation.

One expert commentator stated that the CSIR Biosciences Unit has an extensive network of partners, both locally and internationally with recognised and established knowledge exchange programmes that provide access to cutting edge technology,

equipment and skills. The same commentator further indicated that the Biosciences Unit should be tapping into these networks as the Unit's success would be greatly facilitated through utilisation of these existing networks.

Contrary to the previous commentator, another commentator stated that:

> *"CSIR Biosciences does not utilise the existing/established CSIR networks extensively to learn and build capabilities. The reason could be that the pressure to deliver and survive greatly impacts on the amount of time required to review and leverage on existing networks for learning and building capabilities".*
>
> The commentator further averred that CSIR Biosciences should strengthen their database of networks that could be used to learn and build capabilities.

4.2.6 Benefits from external partnerships

The figure below depicts how the Unit benefits from relationships formed with external partners. A majority of interviewees mentioned that the Unit has done well in a number of relationships formed with external partners. The responses in order of decreasing frequency are depicted in Figure 4.6 below.

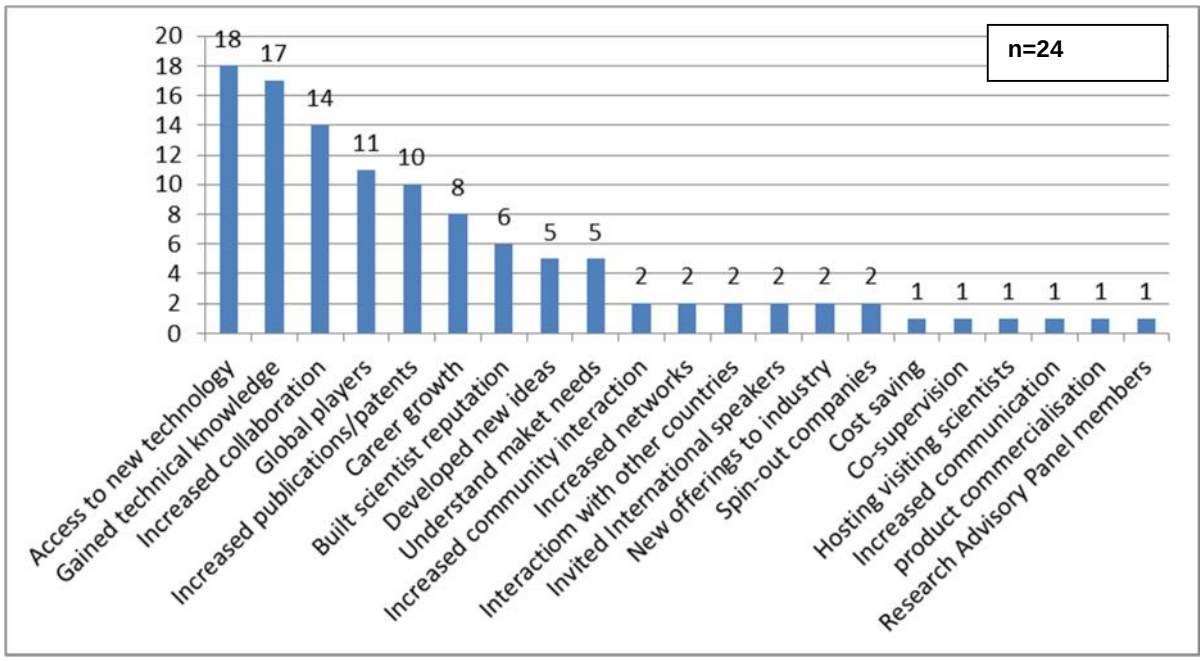


Figure 4.6: Benefits from relationships formed with external partners.

The interviewees highlighted that interaction and relationships formed with external partners provided an opportunity for the Unit to gain access to cutting edge technology, technical knowledge and increased collaborations as illustrated in Figure 4.6 above. Interviewees praised the Unit for the effective utilisation of external partners and for the benefits realised by the Unit. One interviewee reported that interacting with external partners has provided the Unit with the opportunity to participate globally and increase their networks. Another interviewee articulated the same view in the following statement:

> *"In my technology platform, 70% of my staff members have been collaborating with highly recognised institutions internationally, and the interaction and exposure has increased knowledge and capabilities required as well as future collaboration. I will continue encouraging my staff to interact with these institutions as the benefits are great".*

According to the CSIR Biosciences Strategy (2011), the premise of partnering and collaborating with external partners is vital to generating innovation and problem solving within a multidisciplinary environment. Furthermore, this type of strategy encourages the forging of strong relationships with partners, which results in ongoing sustainable R&D collaboration between the parties, including influx of industrially relevant knowledge to the Unit.

The CSIR (2006) highlights that CSIR encourages its staff to maintain close ties with relevant partners, locally and internationally, with the intention of providing access to complementary expertise and infrastructure that enables them to address key issues. One expert commentator reported that the CSIR Biosciences Unit had recently been involved in cutting edge technologies which had increased knowledge within the Unit as well as collaborations with external partners.

Another commentator indicated that the establishment of bi-lateral agreements between CSIR and other institutions/partners are used intensively to learn and build technological capabilities. The commentator indicated that this mechanism requires employees to spend time in the laboratory with another institution/partner to learn and transfer skills to the CSIR Biosciences Unit. The expert commentators believe that this mechanism provides the Unit with access to technology and technical knowledge.

4.3 FACTORS FACILITATING LEARNING AND TECHNOLOGICAL CAPABILITY BUILDING

This section looks at the factors that facilitate learning and technological capability building within the CSIR Biosciences Unit. Interviewees were asked to identify factors that encourage learning and building technological capabilities to take place within the Unit. The figure below shows a number of factors that facilitate learning and building technological capabilities within the Unit. The responses in order of decreasing frequency are depicted in Figure 4.7 below.

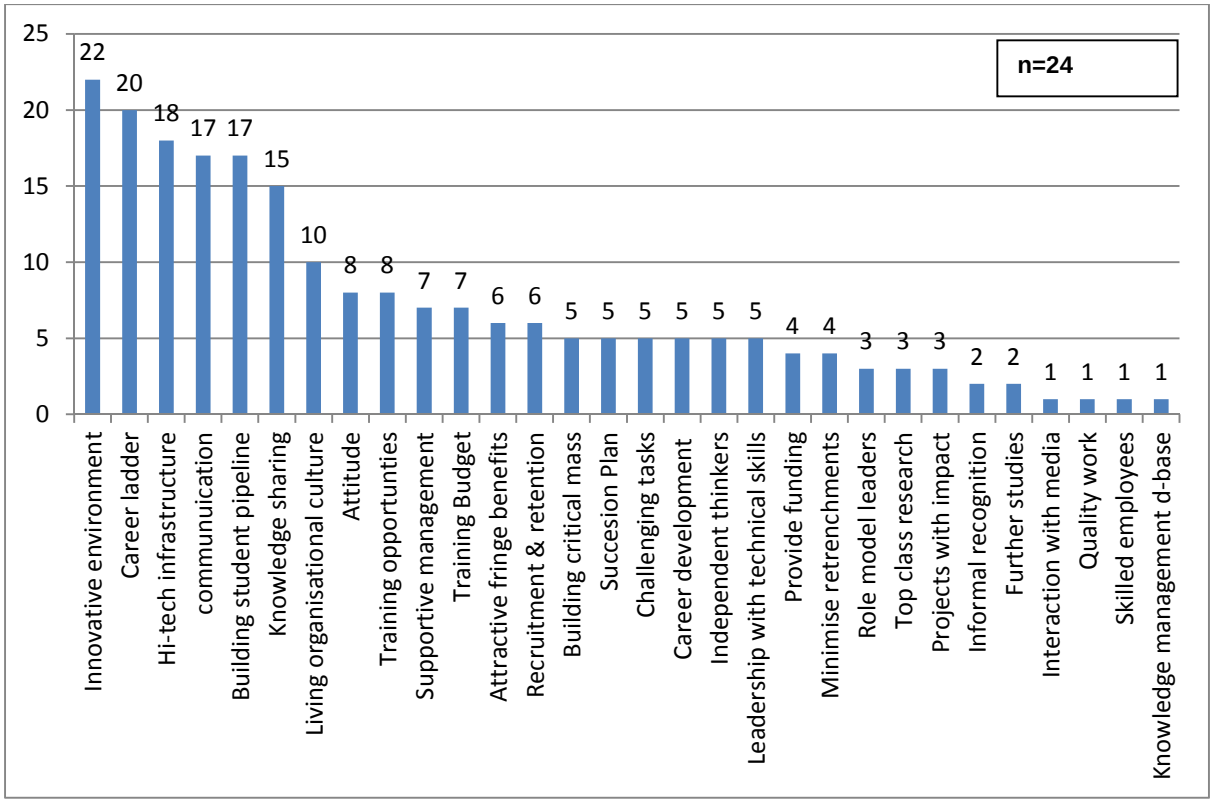


Figure 4.7 Factors facilitating learning and technological capability building.

The interviewees reported that the Biosciences Unit has been successful in establishing an environment of innovativeness that focuses its efforts on creating market-ready products and technologies. A majority of respondents interviewed agreed that the Unit has the right culture for continuous and sustained innovation. Most interviewees were confident that the newly refocused Biosciences Unit encourages an environment of innovativeness and knowledge sharing thereby

enabling the occurrence of innovation and problem solving. However, respondents felt that for the Biosciences Unit to derive further benefits from innovation, training should be prioritised and funding allocated towards training and development of staff.

A majority of the respondents praised the Unit for doing well in facilitating learning and development under the existent financial constraints (see figure 4.7 below). One interviewee stated that:

> *"The refocused Biosciences Unit focuses on the need for innovation. I am pleased to be in an environment like this as the "old Biosciences" was more focused on fundamental research like the research done at University laboratories".*

In response to the above, another interviewee suggested that:

> "*Although it is great to be in an innovative environment like the one provided within the Biosciences Unit, it is critical that the culture changes to reflect innovation. This is due to the fact that a culture driven by innovation encourages knowledge sharing and continuous learning as well as development of staff. Currently those factors are there, but there is more work to be done to ensure alignment with the refocused Biosciences*".

The results further show that a majority of respondents concur that the Biosciences Unit has established infrastructure which the Unit prides itself on. One interviewee stated that:

> *"Biosciences has highly sophisticated machinery and equipment which the Unit invested into over the years.* He further stated: *some "developing countries" do not have access to such an infrastructure and, our infrastructure has attracted many international scientists all over the world to visit Biosciences Unit laboratories to learn how to utilise the infrastructure and to gain access".*

The CSIR (2006) indicates that the CSIR is a knowledge-centred organisation that ensures on-going and sustained learning opportunities for its scientists as well as support staff to enable CSIR to fulfil its mandate. The strategy further mentioned the

strong culture of learning and sharing as fundamental to human resources development and the drive towards transformation. One of the intentions of CSIR Human Capital Development Strategy (2006) is the creation of a stimulating environment where researchers and supporting staff can grow and mentor others with the intention of developing future generations of researchers, who will ensure that the continued advancement of the CSIR as an organisation is key to the development of its professionals.

4.3.1 Programmes for attracting and retaining staff

Figure 4.8 below indicates the number of programmes that are mostly utilised within the Unit for attracting and retaining staff members. In general, the interviewees reported that the Unit has been successful in attracting the kind of scientists it requires to join the Unit. The responses in order of decreasing frequency are depicted in Figure 4.8 below.

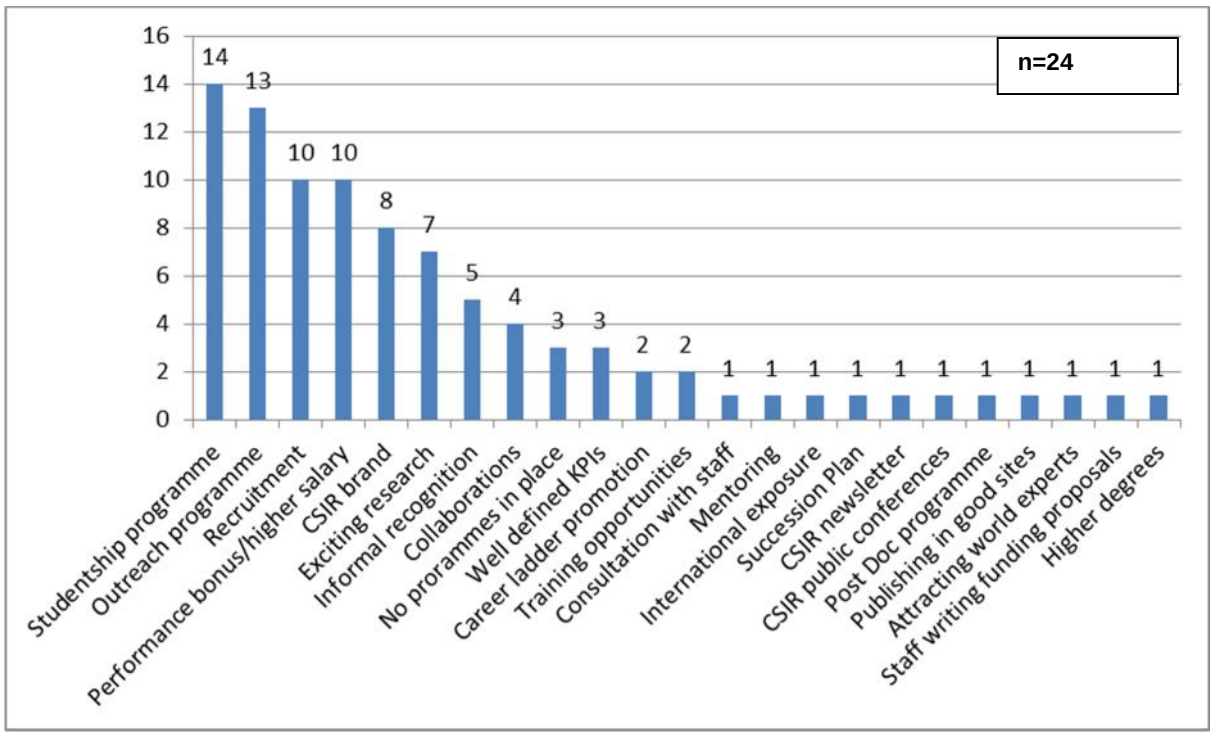


Figure 4.8: Programmes for attracting/retraining staff.

Some interviewees reported that the Biosciences Unit has been successful in attracting a high calibre of scientists and engineers to CSIR Biosciences through a number of programmes and strategies such as studentship programme for Masters,

PHDs, post-doctoral programme and targeted and effective recruitment strategies. The interviewees believe that the CSIR students' programme that is run within the Biosciences Unit is a high performer and measures well amongst its peers. For example, one interviewee, stated:

> *"CSIR Biosciences Unit in collaboration with selected Universities have trained a number of Masters and PhDs students which have largely contributed to the national system of innovation and growth of the economy".*

The respondent further stated that these students have largely been absorbed by science, engineering and technology industries as well as Universities as a result of their academic achievement and support through the CSIR Biosciences students' programmes.

Based on the above, two different interviewees shared the same view as follows:

> *"A large number of University students both locally and internationally apply to us on a yearly basis for our students programme. This on its own indicates that CSIR is regarded as one of the prestigious organisations that people would like to be associated with. Furthermore, the Biosciences Unit is recognised within the CSIR for producing a high number of Masters and PhD students through its highly successful student programme".*

> *"CSIR has a strong organisational brand and participated in exciting research that attracted recruitment of many good scientists from all over the world. Therefore, attracting world experts to CSIR Biosciences was not a challenge; instead the Unit has a lot of bright minds. Furthermore, the CSIR recruitment strategy seems to be very effective in attracting the right calibre of scientists and engineers to the organisation due to its good reputation all over the world".*

A majority of the interviewees concur that CSIR recruitment strategy is effective in that it attracts the bright minds and provides them with opportunities to conduct exciting research. One expert commentator indicated that CSIR remunerates its staff higher than their counterparts; the commentator suggested that this message

should be communicated well to staff to increase staff motivation and retention of key talent.

According to the CSIR Human Capital Development Strategy (2006), the CSIR has a structured approach to human capital development, particularly with regards to its student programmes. It also attracts and recruits from a significant pool of SET professionals, world-class researchers who fulfil the desired SET human resources profile required by the organisation.

The CSIR (2011) indicates that Biosciences Unit supports studentships, interns and bursaries at or well above the CSIR benchmarks. There are currently 70 students in the Unit's total staff complement of 200, i.e. a third of total staff. As a result 31% of the Unit's staff members of 200 are qualified at Masters and PhD level and some were placed at HEIs to create a value chain of relevant skills.

4.3.2 Incentives for staff motivation and individual high performance

Figure 4.9 below shows the existing incentives programmes that are in place to motivate staff and to encourage them to perform at a high level. In response to the question regarding incentive programmes that incentivise employees to stay motivated within the Unit and perform at a high level, the interviewees generally agreed that the Unit had programmes that reward and encourage employees to stay committed and perform. The responses in order of decreasing frequency are depicted in Figure 4.9 below.

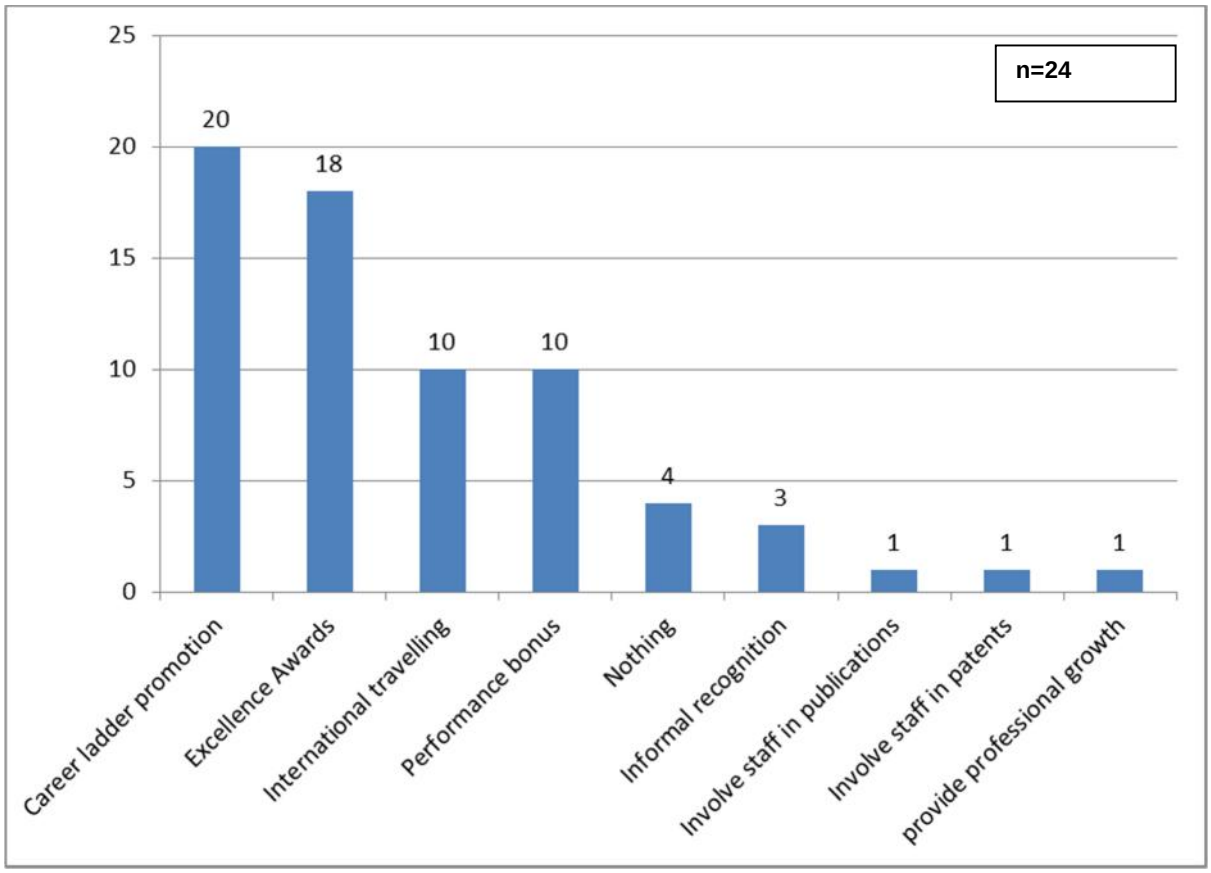


Figure 4.9: Existing incentives to increase staff motivation and high performance.

The results above indicate that employees were aware of incentives, internally and externally aimed at encouraging staff to perform at a high level and stay motivated. However, some respondents reported that the current situation shows that it has become quite challenging to incentivise employees due to financial constraints. For example, one interviewee argued that:

> *"Programmes such as performance bonuses, international travelling and excellence awards were used in the recent past, but due to financial constraints some of these programmes have not been fully implemented or utilised within the Unit".*

Notwithstanding the views expressed above by some interviewees, another group held a different view, in that they believed that CSIR Biosciences had good incentives to motivate staff to perform highly. These respondents made reference to the CSIR career ladder as an example, they noted that it was assessed on a yearly basis to promote high performing individuals who produce scientific outputs that are

recognised all over the world. They also referred to the CSIR "prestigious excellence awards" as an example of an incentive or reward system that is unique to the CSIR.

In terms of the Informal Recognition programme, another interviewee, stated:

> *"Informal recognition programmes were established to motivate staff to stay committed and perform to increase high staff morale and keep low staff turnover."*

The respondent suggested that the Informal Recognition programme increases staff morale and motivation to perform at a higher level as reflected in the following statement:

> *".....for example, in my platform if an employee has done exceptionally well consistently for a month, I announce it publicly in team meetings and offer the employee a gift voucher or a paid leave day to show recognition of good performance. The programme seems to work well and many employees appreciate the recognition they receive, however, not every technology platform within the Unit implements this programme".*

The results further show that the CSIR career ladder was one of the mechanisms used to incentivise staff to perform at a high level. The CSIR (2006), places a lot of emphasis on utilising this mechanism for creating promotional opportunities for staff who achieve Scientific, Engineering and Technology (SET) outputs such as patents, publications, technology demonstrators/prototypes and technology packages. According to the CSIR (2007:10), a performance bonus is provided annually as a short-term incentive based on the annual financial performance of the CSIR as well as on individual performance.

CSIR (2006), highlights that the CSIR needs to ensure that ongoing, sustained learning opportunities are made available to its scientists, as well as support, for example, in the form of time and incentives, for its workforce to take advantage of those opportunities.

In this vein, one expert commentator stated:

"I believe that the CSIR had good incentive programmes in place to encourage staff to perform at a higher level, for example, CSIR career ladder is regarded highly as a measure of best practice for scientific outputs and impact in the economy".

4.4 FACTORS INHIBITING LEARNING AND BUILDING TECHNOLOGICAL CAPABILITIES

This section looks at factors that inhibit learning and technological capabilities within the Biosciences Unit. The interview analysis is based on both responses from the interviewees and the expectations set in the national policy strategies. The responses in order of decreasing frequency are depicted in figure 4.10 below.

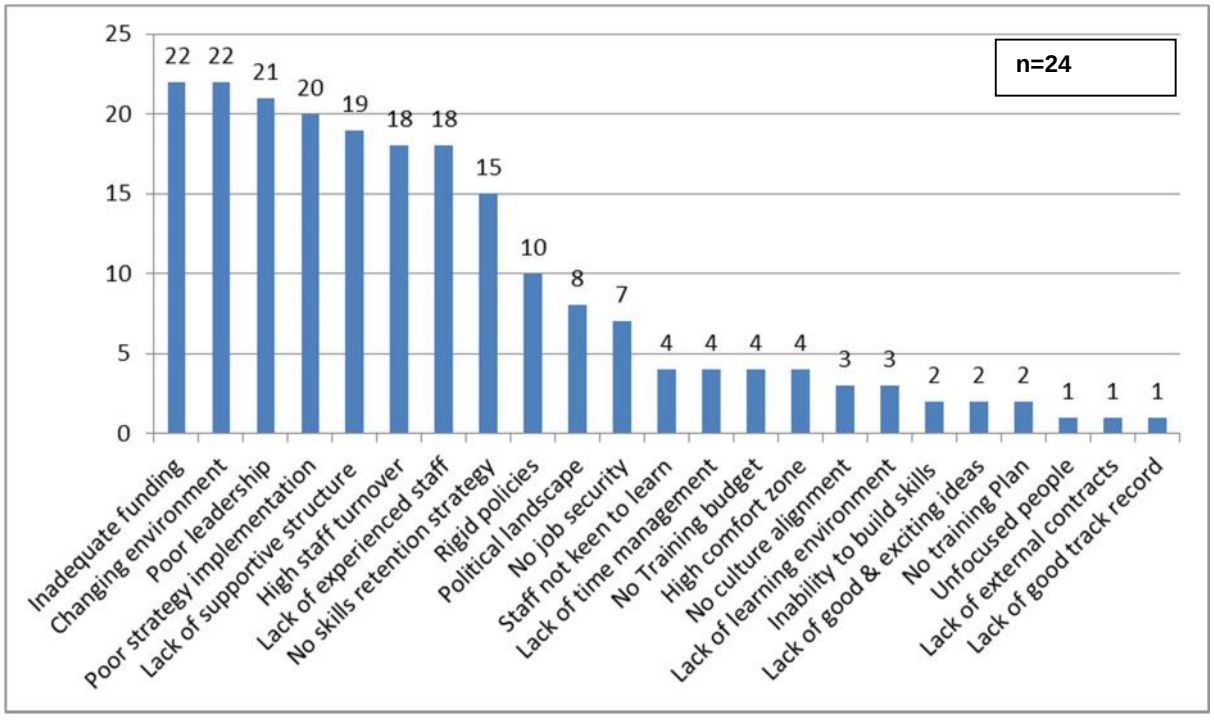


Figure 4.10: factors that hinder learning and technological capabilities.

A majority of the respondents concurred that Biosciences has had several phases of organisational restructuring, changes in leadership and a high staff turnover occurring over the last five years. Respondents believed that these changes have impacted negatively on the performance of the CSIR Biosciences Unit, and this is

reflected in its financial performance over a five year period. For example, one interviewee stated:

> *"Without funding, the Unit will always experience high staff turnover and inability to attract funding and build capabilities required within the Unit".*

The respondents further expressed the view that the Unit should encourage stable and sustained leadership, and manage change effectively as this affects staff morale an impacts on their career growth.

Most of the respondents were in agreement that the restructuring that occurred over the past five years within the Unit, is a key contributing factor to the detrimental effect on building the capabilities required within the Unit. They stated that over the period of restructuring a large number of experienced and competent staff members resigned from the Unit leaving a vacuum that has since not been filled. They reported that the high staff turnover was as a result of the new refocused Biosciences strategy which moved from basic/fundamental research to more applied science to produce market ready products. As a result, a majority of the foundational research team were retrenched and some resigned. These factors have been recorded as a considerable impediment to learning and building technological capabilities within the Unit.

In response to the above statement, another respondent stated that:

> *"The inability to replace staff members who left the organisation with competent staff members was a huge mistake which affected the Unit's performance negatively. It is known that when employees leave the organisation, they need to be replaced with competent and experienced staff member to enable skills transfer to take place and increase knowledge within the Unit. However, Biosciences replaced the lost staff members with inexperienced staff from the internal pool. I think this is the reason why the Unit is unable to build and increase the stock of knowledge and capabilities needed within the Unit."*

Another interviewee, stated:

> *"Innovation cannot happen where there is no funding for training and development. Biosciences has been in a financial deficit over the past five years with limited funds allocated towards human capital development."*

The respondent suggested that the Unit should allocate funds towards human capital development in order to learn and build technological capabilities and to conduct top class research and innovation and stop making funding an issue for not developing staff.

Another interviewee, stated

> *"The Unit is not fully implementing the mechanisms due to financial constraints and continuous change in leadership. This has led to the Unit not investing in training and development of its staff and thereby, lagging behind with the latest technologies and developments in the field of Biosciences technologies. This is where the problem lies".*

According to the CSIR Human Capital Development Strategy (2006), funding for human capital development is 16% of the parliamentary grant (PG) allocated to each Unit and is aligned with the Unit's strategy and its needs. Furthermore, the strategy mentions that the development of professional staff and providing funding for learning are some of the factors that demonstrate that the CSIR Biosciences Unit continues to support learning and building capabilities.

4.4.1 Skills shortage as a barrier to learning and capability building

This section looks at the types of skills shortage within the Unit that may be a barrier to innovation within the Biosciences Unit. Most interviewees agreed that there is a serious shortage of technically skilled and non-technical staff in the Unit. The responses in order of decreasing frequency are depicted in Figure 4.11 below.

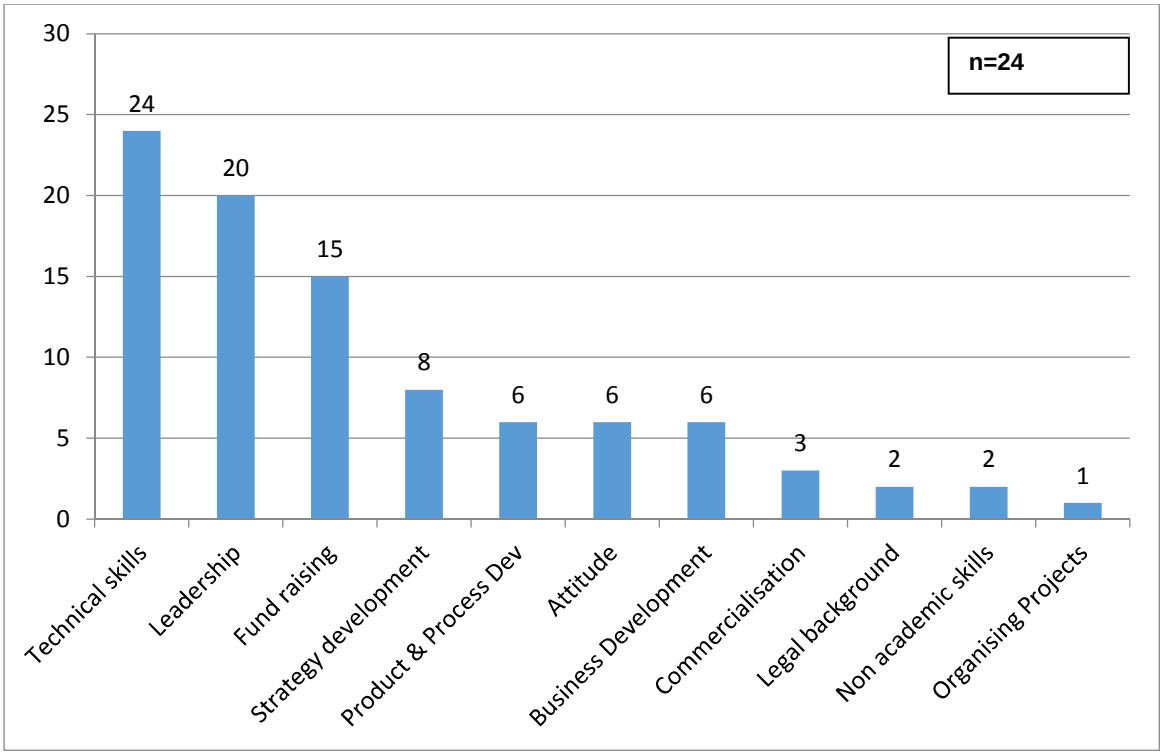


Figure 4.11: Skills shortage as a barrier to learning and capability building.

Interviewees alluded to the fact that a lack of technical skills constituted a major barrier to raising funds. The quotes below from two interviewees are reflective of the views expressed above:

> *"Without technical skills and leadership skills, the Unit will continue to operate at a financial loss as ideas and fund raising can only be generated from skilled and well-informed employees who are clear about the industry and the challenges it is facing".*

> *"The Unit should focus on developing required skills; however, currently the focus is on raising funds to sustain the Unit. Since the development of required skills takes time; the Unit should make a consistent effort in the long term to allocate funds towards training and development of staff. The benefits will be realised in the long term".*

It was generally acknowledged that the skills gaps within the Unit were as a result of restructuring within the Unit and high staff turnover. The interviewees concurred that key and competent staff members were lost during the restructuring process, which left a huge skills gap within the Unit. For instance, another interviewee stated:

"The Unit promoted a lot of young and inexperienced staff to replace highly competent and experienced staff that left the Unit. How can the Unit expect inexperienced staff to be capable of delivering without providing proper training and development? This was a major flaw and a risk that the Unit had put itself into. The Unit should replace staff that have left with competent staff and stop promoting staff that are not suitably experienced to higher levels of competency as this creates a lot of unhappiness amongst other staff members".

A majority of the interviewees were of the view that a lack of technical skills and the inability to replace the skills that were lost was compounded by the lack of financial resources to recruit adequate replacements. One respondent confirmed this by stating that the Unit's low performance was as a result of lengthy gaps in terms of replacing skills that have been lost or non-replacement of staff in these positions with suitably skilled individuals. The CSIR (2011), states that professional and vocational training, as well as mentoring will be a significant component of the refocused Biosciences Unit to make sure that the right skills are available to internal staff who will ensure the future advancement of the Unit is secured. Furthermore, the strategy states that there is a need to re-skill certain employees to ensure alignment with the new Biosciences focus through mentoring and short courses.

4.4.2 How the Unit manages the risk of losing capabilities built over time

The results below show how the Unit manages the risk of losing capabilities built over time. In general, the results show that there are a number of different mitigating plans that are in place to address/manage the risk. The interviewees were asked how they manage the risk of losing capabilities built over time as depicted in the figure below. The responses in order of decreasing frequency are depicted in Figure 4.12 below.

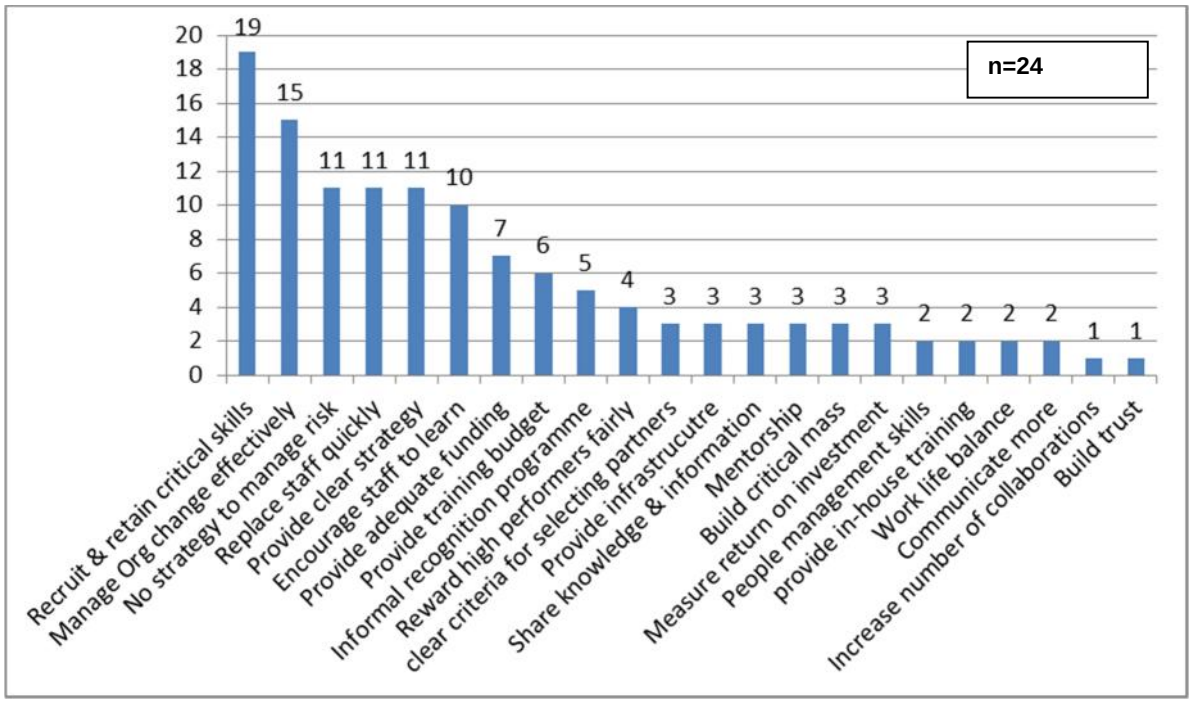


Figure 4.12: How the Unit manages the risk of losing capabilities built over time

In their responses, the majority mentioned that recruiting and retaining critical staff is one of the mechanisms used to manage the risk of losing capabilities over time. For example, one interviewee stated that:

> *"CSIR recruits only the bright minds, programmes such as performance bonus and career ladder have proved to be a strategy for retaining key staff within the Unit".*

Some respondents reported that mechanisms such as replacing staff quickly after losing critical skills have been put in place as a measure to reduce the risks of burnout and low staff morale within the Unit. However, some respondents reported that they were not aware of any plans that were in place to mitigate risks identified within the Unit. They suggested that the Biosciences Unit's leadership team should communicate the plans that are in place to all staff as the absence of a risk management plan has a huge impact on the Unit's deliverables. Another interviewee suggested that the Unit should look at putting together a programme for work-life balance to minimise staff burnout and high staff turnover.

According to the CSIR (2006), the growth of human capital and the retention of skills are crucial to enable the CSIR to fulfil its mandate. Furthermore, knowledge generation, professional growth of researchers, culture of learning and sharing creates opportunities for researchers to drive a fundamental CSIR human resource development.

One of the commentators mentioned that CSIR Biosciences should appoint a dedicated person like an Operations Manager or Quality Manager to establish systems in place to manage risks.

In general, the results showed that a majority of respondents were aware of some of the Unit's plans to mitigate risks of losing capabilities built over time.

4.5 SUMMARY OF DATA PRESENTATION

4.5.1 Processes used for learning and building technological capabilities

The findings showed that the CSIR Biosciences Unit has a number of established processes that are in place to learn and build technological capabilities. They also showed that the processes that the Unit used to learn and build technological capabilities are not adequately used as most of its processes are inwardly focused. The results show that the external processes in place are minimally utilised due to the Unit's financial constraints. External mechanisms such as networks and interacting with other Operating Units within the CSIR are also minimally utilised. Based on the results presented the current CSIR Biosciences processes used for learning and building technological capabilities are neither balanced nor properly integrated.

4.5.2 Factors facilitating learning and building technological capabilities

The findings highlight some factors that enable learning and building technological capabilities to take place within the Unit. The interviewees indicated factors such as

Biosciences leaders and staff members, actively living and embracing the innovative culture, knowledge sharing and creating an innovating environment as internal factors that facilitate learning and technological capabilities to take place within the Unit.

The findings reveal that the Unit has programmes to attract and motivate staff to perform at a higher level and in general the interviewees concur that the Unit has succeeded in utilising the programmes. The respondents identified programmes such as outreach programmes, recruitment and student programmes, and career ladders as examples of the types of programmes used in attracting and retaining the skills required within the Unit. Some respondents indicated that the Unit has been successful in attracting and retaining a number of global experts.

4.5.3 Factors Inhibiting Learning and Building Technological Capabilities

The interviewees identified lack of appropriate skills such as technical skills, limited funding, leadership and misaligned strategy and its implementation as some of the key barriers to learning and building technological capabilities. The interviewees attributed these shortcomings as barriers which affected the CSIR Biosciences Unit's ability to learn and build capabilities and deliver on its strategy. The results further showed that CSIR Biosciences is a learning organisation, but that financial constraints have resulted in the Unit focusing less and less on training and development of staff.

CHAPTER FIVE: ANALYSIS OF THE RESEARCH FINDINGS

5.1 INTRODUCTION

This chapter focuses on the analysis and synthesis of the data presented in Chapter Four as well as the knowledge and insights gained through the literature reviewed in Chapter Two. The analysis focuses on three key areas namely: mechanisms for learning and building technological capabilities; critical success factors; and barriers to learning and technological capability building. The research findings will be compared and contrasted with the reviewed literature to help answer the main research questions of this study.

The next section examines the mechanisms used for learning and building technological capabilities within the CSIR Biosciences Unit.

5.2 BACKGROUND

As described in Chapter Three, in this study a combination of primary data collection through interviews with primary respondents and external commentators was utilised, as well as documentary analysis. It focused on investigating the processes that CSIR Biosciences uses to learn and build technological capabilities. All data was analysed and relevant CSIR documents were reviewed.

5.3 MECHANISMS USED FOR LEARNING AND BUILDING TECHNOLOGICAL CAPABILITIES

To understand the mechanisms utilised in learning and building technological capabilities (TCs) in CSIR's Biosciences Unit, this study focused on interrogating the organisation's internal and external processes. Both the Unit's internal and external processes were analysed.

5.3.1 Internal Processes

According to Marcelle (2004), firms that are effective in learning and building technological capability deploy mechanisms that are integrated across the entire organisation to ensure that their efforts are effective in developing and strengthening the required skill sets. Marcelle (2004) notes that firms improve their effectiveness in learning and capability building by deploying a set of five integrated process mechanisms to: (1) allocate financial resources to TCB effort; (2) implement and support the TCB effort through appropriate management practice systems and decision-making rules; (3) enable an organisational culture in which the TCB effort is exercised with committed and skilled leadership; (4) access external technological capabilities from suppliers; and (5) access technological capabilities resources from local and external players (Marcelle, 2004, p. 5). Figueiredo (2002a) found that most firms that are in industrialising countries lack basic technological capabilities, and for them to become competitive and catch up with technological frontier companies, they should first acquire knowledge to build up their own technological capabilities.

As shown in Chapter Four, CSIR Biosciences deployed 29 mechanisms for learning and building technological capabilities. However, respondents confirmed that the most utilised mechanisms were internally focused. This approach suggests that the CSIR Biosciences Unit mainly utilised internal processes to support learning and building technological capabilities, with the result that their internal and external processes are not integrated. Figueiredo (2010) suggests that integration between internal and external learning mechanisms is effective in shaping the firms' capability building. The same view is shared by Marcelle (2005) where she argues that for firms to derive benefits, firms should have an integrated learning process towards building technological capabilities across the whole firm. For companies such as CSIR Biosciences, partnering with various external partners is critical to growing and strengthening technological capabilities. Therefore, their sources of learning and building technological capabilities should not solely be restricted to the organisation's internal resources (Marcelle, 2004).

Lammarino *et al*., (2009), state that building technological capabilities involves learning and the accumulation of new knowledge on the part of the firm, and is also

informed by the internal processes of the organisation which are aligned to the organisational objectives. Figueiredo (2002a) identified two processes by which technological learning can be achieved within the organisation i.) The path followed in the accumulation of technological capability ii.) the processes of knowledge accumulation by individuals within the organisation for the benefit of the organisation.

In light of the insights above, the analysis of the findings in this study reveal that the CSIR Biosciences Unit does not utilise a balanced internal and external approach to learning and building technological capabilities. As a result, they overlooked the duality of learning mechanisms that is needed to accumulate technological capabilities (Figueiredo, 2010). Respondents during the interviews concluded that even though CSIR Biosciences has various learning and building mechanisms in place to learn and build technological capabilities, their processes were not fully utilised. The respondents concurred that CSIR Biosciences should utilise both internal and external processes effectively to their benefit. This is confirmed by the internal mechanisms identified by Marcelle (2004) as the primary instruments mostly employed in building technological capabilities over the 29 processes that are in place.

5.3.2. External Process

According to Marcelle (2004), the importation of technological inputs is a major source of capability development in most organisations in industrialising countries. Organisations that are able to effectively manage external relationships to their benefit will more successfully advance their technological capability development objectives. Findings from this study indicate that CSIR Biosciences has several external learning processes in place towards learning and building technological capabilities. However, their utilisation of these external processes was very limited and underdeveloped. This analysis was confirmed by interviewees who concurred that within the Biosciences Unit, external partners are used as one of the effective mechanisms for learning and building technological capabilities through knowledge exchange, but according to them this mechanism is not used extensively due to

financial constraints. These partnerships nevertheless provide a minimal level of access to cutting edge technology, equipment and skills required by the Unit.

The findings from the study conducted at the Biosciences Unit shows that the external processes that are used by the Unit are insufficient and do not give equal attention to internal and external processes as stated by most respondents. In addition, as indicated in Chapter 4, most of the external partners are internationally based and interacting with them required providing funds for traveling to visit their companies and laboratories. The respondents acknowledged that limited financial resources and not interacting with these partners resulted in limited knowledge and competencies within the Unit.

Figueiredo (2002a) and Mazzoleni and Nelson (2007) suggest that organisations in "developing countries" should first acquire knowledge from external partners to build up and accumulate their own technological capabilities in order for them to become competitive and catch up with companies in the forefront of technological innovation. The above-mentioned authors encourage firms in industrialising countries to form international alliances and partnerships with firms that are in industrialised countries to access advanced know-how. Lamin and Dunlap (2011) assert that an increased interaction between industrialising country firms and external actors and clients will result in greater opportunities for absorbing the knowledge necessary for the creation of technological capabilities. This strongly suggests that in an organisation such as CSIR Biosciences Unit's participation and involvement with external partners can provide access to grow their knowledge and technological capabilities. The respondents were concerned that even though CSIR Biosciences has well-established external partners in place, in most cases interaction with external partners required funds for travelling as most partners are internationally-based. Due to financial constraints, the Unit was not able to bear the intended results.

Some respondents noted that the lack of international networks and exposure isolated the Unit from attracting funding and accessing advanced technology. This approach indicates that the organisation's existing model of learning and building technological capability is unbalanced and has very limited interaction with external partners. The results analysed in Marcelle (2004) show that firms that are effective at technological learning are able to manage both internal and external factors

simultaneously and achieving this balance has yielded significant benefits. This analysis suggests that lack of external relationships with external partners compromises the sources of technological know-how required from external partners.

5.4 FACTORS FACILITATING LEARNING AND TECHNOLOGICAL CAPABILITIES

This section looks at the factors that enable and impede learning and technological capability building within the CSIR.

The following processes are internal mechanisms which are actively utilised in the CSIR Biosciences Unit:

5.4.1 Recruitment of expatriates

Data analysed from the interviews revealed that 24 interviewees spoke about recruitment being one of the mechanisms for acquiring and building technological capabilities within the CSIR Biosciences Unit. For instance, recruitment of expatriates was used as a mechanism to learn and build technological capabilities that are lacking within the Unit thereby closing critical skills gaps. Respondents confirmed that the appointment of expatriates provided the Unit with competencies that it lacked, which would have required time and resources to acquire. According to Mumford (2000), recruitment of talented people plays a key role in developing knowledge of the organisation and building intended core skills for the organisation. The study conducted by UNIDO (2005) found that tapping into the global pool of knowledge is one of the mechanisms for building technological capabilities. The CSIR Biosciences Strategy states that recruitment of skilled personnel would be required to attain the required critical mass (CSIR, 2011). This finding indicates that CSIR Biosciences has an effective recruitment strategy that is diverse in attracting both local and international expertise to enhance their capabilities and close skills gaps.

The Unit seems to have benefited from the recruitment of expatriates. This finding is in line with the views shared by Fontes (2007) who asserts that knowledge flow between different geographical locations is seen as contributing to the development of technological capabilities. This suggests that the Unit has been proactive and focused in sourcing skills and expertise globally in order to acquire the kind of skills sets and knowledge that the Unit lacks.

5.4.2 Succession Planning

Ibarra (2005) suggests that implementing a succession plan programme becomes essential in terms of managing the continuity of skills and expertise by ensuring that replacements have been prepared to fill key vacancies at short notice by individuals who have been internally groomed by the organisation. The study revealed that the CSIR Biosciences Unit had recently established a succession plan programme. The Unit had identified a pool of employees with high potential and the likelihood to progress and to be groomed for key positions within the Unit. These individuals have development plans specifically tailored for each person in conjunction with a series of relevant training and courses that they are required to take. This finding closely mirrors Holbeche (2002) study on succession planning which suggests that organisations of any size should have developed succession plans for key individuals and posts in order to ensure that there is a ready supply of individuals prepared for the top positions in the future.

Some respondents reported pockets of success from areas such as “Project Management” where a successor was groomed for a position of a Project Manager as the current job holder was nearing the retirement age. The respondents felt that this process was beneficial to the Unit as there was a huge saving on recruitment costs and on orienting the individual to the culture of the Biosciences Unit. Ibarra (2005) asserts that a succession planning programme is an essential tool for managing continuity of talent by ensuring that replacements have been prepared to fill in vacancies as they would have been internally groomed by the organisation.

This finding points to the fact that most critical positions in the CSIR Biosciences Unit will be filled by internal staff who have been groomed and prepared over time to fill these positions. However, some respondents were concerned that the Unit does not have a plan in place to retain key employees and staff identified as successors. This suggests that although a succession plan is in place, a retention plan should also be in place to ensure that the organisation does not build capabilities and lose them. This view is supported by the current CSIR CEO, Dr Sibusiso Sibisi as outlined in the CSIR Human Capital Development Strategy (2006, p. 2) who stated that "*the growth of human capital and the retention of skills are crucial for the purposes of sustaining a strong science and technology base to enable the CSIR to fulfil its mandate*".

Armstrong (2006), taking a different view, asserts that a succession plan is based on accurate demand and supply forecasts. This theory may not be applicable to the CSIR Biosciences Unit as its future is dictated by the needs and priorities set by the current government. Therefore, its succession plan may not necessarily be based on accurate demand and supply forecasts but more on developing a pool of potential successors to fill in vacancies and key positions. Interviewees indicated that the organisation's succession plan was based on developing potential successors to fill in key positions that have been identified as critical within the Unit and by ensuring that the Biosciences Unit has the flow of talent it needs.

5.4.3 Mentorship Programme

Ehrich and Hansford (1999) assert that organisations that undertake and support mentorship programmes tend to have an increased performance and productivity level as well as competent employees. The current study revealed that the CSIR Biosciences Unit had recently formalised a mentorship programme to increase learning and to build technological capabilities within the Unit. The respondents also noted that the programme showed some positive strength towards learning and building technological capabilities within the Unit. Findings from interviewees revealed that in the past, the mentorship programme had not been formalised and was thus not focused, indicating that the Unit was using other mechanisms such as informal mentoring and coaching to encourage learning with the intention of building

and increasing technological capability. The CSIR Human Capital Development Strategy (2006) emphasises mentoring as a development tool for developing future leaders of the organisation. Mentorship was also identified as a key factor that is contributing positively towards learning and building technological capabilities due to its inter-activeness and the open dialogue generated between mentor and mentee, which includes sharing knowledge and expertise and learning together on a project.

According to Underhill (2006), the successful implementation of mentorship programmes tends to result in an increased retention rate, internal promotions, high job satisfaction and self-esteem, greater organisational commitment, increased promotional opportunities, more tenured individuals, less work stress, and the development of skills and knowledge required by the organisation. This view is in line with the aims of the CSIR (2012, p. 1) which states that mentoring within the Biosciences Unit will provide opportunities for the protégé to gain experience and skills, and contribute to the performance of individuals, their job satisfaction and growth as well as the performance of the Unit. Holbeche (2002) asserts that organisations that invest in growing the expertise of their junior employees by focusing on the talent existing within the organisation may benefit from increased employee commitment. This view was confirmed by one of the expert commentators interviewed who indicated that Biosciences has a number of experienced staff members who have been in the company for many years. Therefore, these individuals have institutional memory and experience that should be shared and transferred to their more junior colleagues toward increasing skills within the Unit. This finding indicates that organisations that have established processes of skills transfer/mentorship are likely to have an increased number of skilled and competent employees.

5.4.4 Criteria for selecting partners and suppliers

Marcelle (2004) indicates that establishing relationships with external partners requires organisations to have a selection criteria for suppliers, including the terms and conditions of the process of learning and technological capability building with

external partners. This process requires formal agreements with external partners for both implicit and explicit knowledge to be imported (Baskaran, 2001).

This study has shown that the CSIR Biosciences Unit does not have formalised selection criteria for selecting external partners for learning and building technological capabilities. The results indicate that some attempts have been made with local partners to form relationships to collaborate towards learning and building technological capabilities. However, the results showed that some of these interactions are based on personal relationships and track records.

A majority of respondents agreed that although the Unit did not have well-documented criteria for selecting external partners to learn and build technological capabilities, their engagement with local partners have produced positive results. The respondents provided examples such as, improved employees' technical skills and knowledge, increased collaborations, access to new technology that was non-existent in the Biosciences Unit and the opportunity to participate globally through international linkages. According to Lamin and Dunlap (2011) increased interaction with other partners will result in greater opportunities for absorbing necessary knowledge for the creation of technological capabilities required by the organisation.

According to the interviewees, the Biosciences Unit needs to establish a formal set of criteria for selection for engaging with external partners to stimulate learning and building of technological capabilities. Once the criteria are set and the process is established, it should be communicated widely within the Unit to ensure that the process is followed and applied consistently throughout the Unit.

5.4.5. Career Ladder System

A significant number of respondents agreed that career-wise, the CSIR provides opportunities for scientists, engineers, researchers and technologists to develop and progress on to the next level of their careers. They reported that a career ladder encourages staff to manage their careers and perform at a high level to meet the criteria for promotion. This view is in line with the CSIR career ladder framework which clearly maps out career growth opportunities for staff members based on

skills, performance, qualifications and experience required at each transition so that those with the aptitude for advancing through the levels will have sufficient contextual parameters for self and CSIR-inspired development (CSIR, 2006). Furthermore, the CSIR (2006) places great emphasis on utilising this mechanism for learning and building technological capabilities as it facilitates career development and employee recognition. This view is very much in line with the views expressed by Armstrong (2006), where the emphasis is on providing opportunities for people to develop and progress in their careers to ensure that the organisation has a pool of the skills sets and expertise it requires. A similar view is shared by Tanke (2000) who asserts that organisations that have established individual development plans enable employees to learn the necessary skills set and thereby progress through the career ladder. However, Mumford (2000) asserts that this approach is more likely to prove effective if it is targeted at performance enhancement and innovation.

Some respondents were of the view that the CSIR career ladder tool needs to be aligned with the new refocused Biosciences strategy. They reported that the career ladder had a great emphasis on individual learning and development whilst the Unit strategy encouraged team work and innovation. They believed that the misalignment of Biosciences strategy with the career ladder created a mismatch between individual career goals as well as team and organisational goals and to some extent, caused confusion.

A majority of respondents viewed the career ladder tool as a valuable springboard that has enabled opportunities for learning and development to take place, as the tool required individuals to produce a set of outputs in order to be promoted to the next level to take on greater responsibilities. This indicates that this mechanism is output driven and is highly focused on producing the organisation's desired results. The study conducted by Marcelle (2004) found that organisations that have established extensive human resources programmes and practices have seen increased individual motivation and performance. One of the expert commentators interviewed was of the opinion that the CSIR career ladder is in line with best practice and its scientific outputs have more value and impact on the economy, such as "publications, intellectual property and technology transfer". This view is in line with the CSIR (2006) which states that the career ladder at the CSIR has a set of criteria reflecting generally accepted standards for advancement in a research

career. However, Holbeche (2002) suggests that advancement up the corporate ladder is achieved as a result of the quality of people you attract and retain from the job market. Although the CSIR Biosciences career ladder system appears to be effective, more effort is needed in attracting and retaining good talent within the Unit.

Mumford (2000) suggests that this mechanism can be utilised by organisations as an intervention to retain employees and to increase a critical mass of skilled employees. Based on the above findings, the opportunities created for career advancement within the CSIR Biosciences Unit strongly correlates with the views of Holbeche and Mumford that this is an effective mechanism in achieving an organisation's desired objectives.

5.4.6 Performance Rewards System

The respondents reported that a performance reward system such as a bonus was used by the Biosciences Unit to reward and recognise good behaviour and performance within the Unit. They felt that this system was used to motivate employees to perform at a high level and to increase retention. The respondents further indicated that the performance management system and the reward system is effectively managed within the CSIR, and employees are rewarded according to the outputs they produce. According to Mumford and Licuanan (2004), organisations should develop management practices that are directed to evaluating and rewarding critical behaviour and performance that influence innovation. Rush *et al*., (1995) suggest that reward systems should include a dual ladder, which enables technologically innovative staff to progress within organisations without needing to move across to management posts. This view is in line with the CSIR performance reward philosophy which is used to motivate staff and to reward excellent performance (CSIR, 2010). The respondents perceived this programme as being of great importance in motivating staff to perform at a high level and that also ensures the retention of key staff.

However, others felt that the performance reward only recognises operating Units that have achieved a higher value on financial performance. According to the CSIR

Remuneration policy (2010), no bonus will be paid out to any of the CSIR Operating Units if the threshold margin is not achieved. This was seen as demotivating high performing employees from underperforming Units such as the Biosciences Unit as the performance reward system of CSIR is based on the overall Unit performance, not individual performance which is a determining factor for a performance bonus pay-out.

Tidd and Bessant (2009) argue that many organisations have reward systems which reflect performance of repeated tasks rather than encouraging the development of new ideas. They further point to the fact that these organisations measure progress based on how things are done by the book rather than encouraging challenges and changes in approach. The same view is shared by Shalley and Gilson (2004) who assert that organisations should put systems in place to track innovation so that they are able to appraise and ultimately reward it appropriately. This view is supported by the views of the respondents who indicated that although the CSIR rewards strategy is well received by staff, the system measured KPAs that are individual based rather than team based. Furthermore, some respondents felt that the KPAs lack innovation, and need to be reviewed and aligned with the new Biosciences Strategy and reflect innovation-based performance.

The respondents indicated that performance was rewarded based on clearly written key performance indicators achieved by the subordinate as discussed and agreed with the line manager at the beginning of the financial year. Although the respondents indicated that there was a high level of satisfaction with this programme, Tidd and Bessant (2009), Shalley and Gilson (2004) Mumford and Licuanan (2004), in their articles on private companies place emphasis on the development of new ideas and rewarding critical behaviour as well as performance that influences innovation, not repeated tasks. This finding suggests that an organisation such as the CSIR Biosciences Unit should in principle set key performance indicators and targets that encourage innovative behaviour and development of new ideas rather than measuring performance of repeated tasks. Mumford and Licuanan (2004) suggest that attention should be given to understanding how the performance strategies selected by leaders of such organisations shape the nature of the innovation they are willing to support and reward.

5.4.7 Graduate Programmes

A majority of the respondents reported that CSIR Student Programmes are strongly used within the Biosciences Unit as a mechanism to build its pipeline. The graduates form part of the Unit's organisational pipeline through which skills and experience are acquired during the programme. Funding is provided by the National Research Foundation (NRF) as well as the CSIR parliamentary grant to encourage the CSIR Biosciences Unit to collaborate with local universities by assigning students to CSIR researchers as their co-supervisors to assist them in obtaining their degrees. Holbeche (2002) suggests that organisations that involve and expose graduates through their projects are able to build the organisation's capabilities and expertise through the knowledge and experience acquired during the graduate programme. This view was confirmed by respondents who observed that students are exposed to CSIR projects to gain practical experience while studying.

The CSIR Human Capital Development Strategy (2006) emphasises building organisational capabilities through graduate programmes such as MSc studentships, PhD studentships and post-doctoral programmes. Respondents were of the opinion that these programmes are highly utilised by the Unit and are used as sources for developing the knowledge, skills and attitudes required by the Unit. This finding is in line with the views shared by Holbeche (2002), which asserts that the graduate programme forms part of the organisational pipeline, and it provides much needed skills and experience. This indicates that the Unit puts a significant amount of effort towards building their student pipeline to develop the relevant skills required to ensure that student degrees are in sync with the needs and expectations of the Biosciences Unit. This finding points to the fact that the Unit makes it its business to know the quality of the graduates produced by local universities and is interested in making sure that they support the universities to nurture the relevant skills and knowledge required by the Unit.

Respondents also thought it noteworthy to mention that there was a high completion rate in the number of their students who had doctorate and master's degrees in the Biosciences Unit in comparison to other Units within the CSIR. They noted that some of these students were absorbed by the Unit and some were absorbed by the

National System of Innovation (NSI) to address the huge challenge of shortage of scientists that the country is facing and to increase employability. According to the respondents, this programme is effective and supervisors are rewarded for graduating their students through the CSIR career ladder tool. Furthermore, to ensure that the programme does not lose its momentum, the Unit monitors supervisors' performances and rewards them on the basis of their student completion rate.

5.4.8 Communication

Holbeche (2002) posits that lack of communication in the workplace leads to suspicion from staff, demoralisation and loss of key personnel and business. This results in a high turnover of staff members due to the perception that their future progress within the organisation is uncertain. Armstrong (2006) suggests that a good channel of communication between the employer and employees is required to ensure that management keeps employees regularly informed regarding the policies and plans that affect them.

Based on the information obtained from this study, it has been determined that respondents were generally happy with the mechanisms used for disseminating information within the CSIR. They noted that employees are often invited by the leadership team to participate in meetings within the Unit to keep them informed and up to date with the latest developments taking place. Open communication and sharing of experiences and relevant issues was encouraged through open dialogue. This finding supports the study conducted by Holbeche (2002) in the UK manufacturing company that was acquired by a Swiss company in early 1998 which indicates that communication mechanisms need to be in place to encourage an upward flow of information and top-down announcements. The author found that during the merger between the two companies, lack of communication led to suspicion, demoralization, and loss of key staff members and business, even before the contract was signed between the two organisations (Holbeche, 2002, p. 401). Additionally, Armstrong (2006) emphasises that two-way communication is required so that management can keep employees informed of the policies and plans that

affect them. This kind of engagement motivates employees to contribute, commit and cooperate by facilitating knowledge, open communication and joint problem solving (Tidd and Bessant, 2009).

However, research conducted by Twiss (1992) shows that communication is influenced by how an organisation's system is designed to stimulate and facilitate the flow of information throughout the organisation. The findings of the study point to the fact that communication within the Unit is necessary and systems and structures have considerable influence on effective communication. In order to achieve intended outcomes, the Biosciences Unit's organisational systems and structures must be designed in such a way as to facilitate the flow of information from top to bottom and vice versa. That means that the structure and the systems utilised by the organisation dictate the speed at which information is disseminated and communicated within the Unit. A majority of the respondents considered the mechanisms within the Unit effective and reported a high level of satisfaction, which meant that information received by employees was timely and relevant.

5.4.9 Infrastructure

According to Juma and Yee-Cheong (2005), problems hindering technological capability in developing countries amongst others are due to the absence of adequate infrastructure. Figueiredo (2002a) asserts that because infrastructure is an intermediate input into production, its costs have a direct effect on a firm's profitability and competitiveness, as well as increasing its operational performance.

A majority of respondents concurred that the Biosciences Unit uses highly sophisticated technology and infrastructure due to the research that it conducts. The respondents felt that the Unit has invested a huge amount of money towards its infrastructure to ensure that the Unit delivers on the overall mandate of the CSIR. They further indicated that these machines are mostly sourced in industrialised countries, and the technology and the know-how to best operate this technology is acquired outside the country by sending out a number of employees to industrialised countries to learn how to best operate and use those machineries.

A number of participants were generally happy with the investment made towards Biosciences infrastructure, and believed that the Unit's infrastructure attracted a number of partners both locally and internationally to gain access to its infrastructure to learn how to best operate the machines. This indicates that the Unit's infrastructure has created greater opportunities for the Unit to interact with other external parties which increases opportunities for collaboration. However, according to (CSIR, 2011, p. 102) the Unit has been unable to maintain some of this key infrastructure due to financial constraints.

The section below looks at the internal barriers that might impede learning and technological capability building within the CSIR, highlighting these challenges as barriers to learning and building technological capabilities within CSIR Biosciences Unit. For the purpose of this study, respondents were asked to identify internal barriers that may have an impact on learning and building technological capabilities within the CSIR Biosciences Unit.

5.5 FACTORS INHIBITING LEARNING AND TECHNOLOGICAL CAPABILITY BUILDING

Many public research organisations in most industrialising countries face challenges such as lack of relevance to industry needs and failure to transfer technology to industry, fragmentation within the Innovation System, limited access to resources and cut backs in government funding (Rush *et al*., 1995). The CSIR Biosciences Unit is not an exception in this regard, as these kinds of challenges have had a detrimental effect on the process of learning and building technological capabilities and are likely to have a compounded effect on how it learns and builds its technological capabilities. The current study highlights the following factors as inhibitors to learning and building technological capabilities within the Biosciences Unit:

- Limited funding
- Poor leadership and management practices
- Lack of technical skills
- Lack of internal collaboration

- Knowledge Management System (KMS)

5.5.1 Limited Funding

The Biosciences Unit is an Operating Unit of the CSIR and therefore primarily funded through an annual parliamentary grant. The annual budget for CSIR Biosciences is R154 million. Of the total, 16% of the CSIR Biosciences budget is allocated towards human capital development initiatives. CSIR (2011) clearly states that funding for human capital development is through a percentage of the parliamentary grant allocated specifically for this purpose to drive the operating Unit's strategy. This is in line with the CSIR Human Capital Development Strategy which states that a percentage of the parliamentary grant at Unit level should be allocated towards human capital development aligned with the Unit's strategy (CSIR, 2006). Menendez and Cruz-Castro (2003) assert that it is inevitable that a reduction of government funding combined with a lack of other external sources of funding will have a negative impact on public research organisations. Consequently, little or no funding has had a detrimental effect on building technological capabilities within the Biosciences Unit. Oni (1999) asserts that concerted efforts need to be made towards sustained funding to enable an investment in building capacity. Furthermore, government funding creates opportunities for PROs to network within and outside their respective regions towards the development of technological capabilities that will enable them to address the national challenges they are faced with (Menendez & Cruz-Castro, 2003).

Data analysed from interviewees indicates that the CSIR Biosciences Unit has been facing financial difficulties over the last 5 years due to the Unit not being successful in raising external funds to supplement funding from the government-issued parliamentary grant. They indicated that the parliamentary grant of R55 million (which is 36% of the R154 million operational budget) sourced from government was insufficient and has had an adverse effect on learning and development of technological capabilities. It has also resulted in the organisation being focused mainly on fundraising to sustain the organisation's business goals. This financial

pressure calls for PROs to develop strategies to diversify their sources of funding to further research and develop technological capabilities (Rush *et al*., 1995).

Furthermore, Kim (2000, p. 15) asserts that organisations in "developing countries" can use policy instruments such as Industrial and R&D policy instruments to stimulate technological learning and strengthen the supply of technological capabilities or invest in human resources for purposes of learning and development to influence the processes of building technological capabilities. This indicates that lack of funding towards training and development will inevitably impact negatively on the Unit's technological capability building as well as its performance.

The current study has revealed that the 16% that was supposed to be allocated towards human capital development initiatives was diverted towards sustaining the operations of the Business Unit due to the its financial constraints. Marcelle (2004) argues that a high degree of financial investment is necessary to ensure that resources are allocated towards building the relevant technological capabilities required by the organisation. This usually requires convincing government policy makers to supply sufficient resources to meet national goals (Rush *et al*., 1995). Thus, according to Arnold *et al*., (2007), the more government funding an organisation has, the better equipped it is to tackle market failures and to develop new capabilities. While government funding is more easily accessible for PROs, for more business oriented firms, Altenburg (2009) asserts that low income results in low productivity which reflects limited capacity to develop new technology, or to adopt and improve on existing technologies.

Findings from data analysed showed that respondents did not seem to have an alternative plan in place to diversify their funding streams as a means of augmenting their financial needs, but appeared to be solely dependent on government funding to train and develop their staff. That implies that no opportunity exists for generation of any other funding to support the Unit. However, the CSIR Biosciences Strategy, states that relying on one source for funding is risky as the funding sources are all time based contracts (CSIR, 2011, p. 100). This indicates that the Unit did not have other means of diversifying their funding in order to invest in learning and technological capabilities, even though its strategy clearly indicated the importance of diversifying funding. Rush *et al*., (1995), suggest that successful PROs reduce

uncertainty by creating new funding sources through building connections and strategic partnerships with industry. This points to the conclusion that without sustained funding the CSIR Biosciences Unit cannot attract the calibre of skills and expertise it needs and cannot effectively implement its new strategic plan.

5.5.2 Leadership and management practice

5.5.2.1 Poor leadership

According to Cimoli and Porcile (2009), leadership and management are strongly influenced by internal factors such as an organisational system that supports and diffuses learning and technological capabilities, and an enabling environment which promotes the culture of learning to achieve technological progress. Marcelle (2005) asserts that organisations should align their learning processes with the overall business strategy in order to realise benefits towards building technological capabilities. Respondents expressed their concerns about poor leadership within the Biosciences Unit. They indicated that there was a problem in terms of strong leadership within the Unit. For instance, they indicated that Biosciences has had four different Executive Directors in the past five years due to the restructuring of the organisation, and this has created instability and inconsistency within the Unit, which has subsequently had a negative impact on learning and capability building within the Unit. Their perception was that the repeated changes in the leadership team of the Biosciences Unit after every restructuring process came with a new strategic plan and intent, which impacted negatively on the existing path established towards learning and capability building.

The change in leadership disrupted the focus on existent learning and capability building mechanisms created as they had to change and learn new capabilities that were required to deliver on the new strategy. This affected the continuity and effective accumulation of learning and technological capabilities within the Unit. Respondents perceived this as an indication of a lack of good leadership within the Unit. According to Oni (1999), organisational success and effectiveness is influenced by the leadership and management of the organisation. This finding indicates that the Biosciences leadership team does not take ownership in

Biosciences strategy development even though they are part of the Biosciences leadership team; the responsibility seems to have been left solely to the Executive Director of the Unit. This situation seems to differ with the insights from the literature, which suggests that strategy development is a task that belongs to leadership and management as they are the ones who prescribe the organisational and innovative strategic goals (Marcelle, 2004). Therefore, the reasons for this ineffectiveness and lack of ownership can be explained by Figueiredo (2010) who argues that human resources and the knowledge base within a firm depends on the effort that its leadership makes to create these capabilities.

5.5.2.2 Organisational structure

Twiss (1992) suggests that organisational structure should be an enabling mechanism which reinforces and encourages integrative processes for speedy and effective innovation. A number of respondents stated that the structure of the CSIR Biosciences Unit was multi-layered and they perceived it as being "top heavy" and not conducive to innovation. They indicated that the structure and internal processes such as policies, CSIR structure and rigorous processes and systems forced them to operate in silos and is not conducive to team work and innovation. For instance, they reported that CSIR has a hierarchical structure which has several levels within the CSIR leadership structure at which projects have to be approved before they can be executed at Biosciences Unit.

Many respondents felt that the CSIR structure has too much "red tape" which stifles innovation. They felt that decisions take a long time and often impacts negatively on the delivery of the joint projects they have with external partners, as most partners are from industry where decisions are made more quickly. This also has a negative impact on the rate at which research is commercialised in order to achieve set societal goals. Furthermore, it may also reduce the probability of commercialisation that could help meet societal needs. Luthans (2011) suggests that organisations that support learning design horizontal structures and set up cross-functional teams that encourage employees to assume authority and make decisions directly related to their activities. This view is further supported by Sine *et al*., (2006), who are of the

opinion that innovative organisations are those that have horizontal structures as opposed to vertical structures with bureaucratic layers. This is particularly important for large organisations that operate in volatile and emerging economies. Hung *et al*., (2010) suggest that organisations that align their internal processes with strategy are likely to perform better.

The results from the data analysis clearly show that the organisational structure of the CSIR Biosciences Unit is not in sync with their new strategic objective which encourages innovation and team work (CSIR, 2011). However, Tidd and Bessant (2009) argue that there is no single best structure and that successful organisations tend to be those which develop the most suitable "fit"' between structure and operating contingencies. This view is supported by Figueiredo (2002a) who asserts that companies may succeed or deteriorate because of the way the functioning of the processes was organised. Therefore, given the fact that the CSIR Biosciences Unit is primarily a "knowledge" based organisation that encourages innovation, it is important to employ greater flexibility in order to achieve a successful implementation of the new strategic plan. It is also important to have the flexibility to allow for quick decision making, free flow of information and ideas from the top to the bottom and from the bottom up, as well as increased speed to enable delivery on the new strategy. Therefore, a flatter structure may be well suited for the Biosciences Unit and could have a greater influence on the speed at which they learn and build technological capabilities.

5.5.2.3 Lack of role clarity

Some respondents felt that employees within Biosciences were given very little time to understand the strategic plan and the responsibilities that come with the new structure and their roles within that structure. This was problematic in terms of defining roles, and created ambiguity and uncertainty which resulted in failure to deliver on strategy. Holbeche (2002) suggests that role clarity and responsibilities are particularly important to minimise the potential for role overlap or gaps which may threaten the success of the organisation. Respondents concurred that the new positons that were created such as the Business Area Leaders (BALs) and Science

Innovation leaders (SILs) were assigned to internal staff members who did not have the prerequisite skills and experience nor the required training to manage those key positions and this affected the overall performance of the Biosciences Unit and created a bad impression about the competency of the leadership team. This was further confirmed by one of the expert commentators interviewed who noted that lack of competent and experienced staff has had a negative impact on the number of potential funders for the Biosciences Unit, which ultimately affected its overall performance. Marcelle (2004) found that internal factors such as the competency of key management in leadership positions was an important factor in terms of firms being able to manage learning processes and reap potential benefits.

The above finding is reflective of the "Peter Principle" which states that workers are promoted to positions that they are not qualified for due to mistakes made by organisations in their promotion processes and decisions (Peter, 1969 as cited by Lazear, 2004). This finding clearly highlights the point that the process of promotion within the CSIR Biosciences Unit did not adequately take into consideration the level of competence of the employees who were promoted and their performance readiness was not assessed to determine their ability to take on a more senior position. This suggests that the promotion process was not properly carried out therefore the employees chosen for the positions were not suitably aligned with the requirements of the new role.

5.5.3 Technical Skills

Respondents identified the lack of appropriate technical skills as one of the main barriers for attracting funding and implementing the Biosciences Unit's strategy. They were of the opinion that not having the prerequisite skills and knowledge is hampering the progress of building technological capabilities as well as the Unit's ability to deliver on its new strategic goals.

The OECD in its Innovation Strategy indicates that the shortage of highly skilled individuals with the relevant skills and experience in "developing countries" was due to the lure of better opportunities abroad as well as the search for better living

conditions (OECD, 2010). Consequently, the lack of skills within the Biosciences Unit may have resulted in employees leaving the CSIR and joining other organisations that offer better rewards and improved living conditions. Figueiredo (2002a) suggests that organisations in developing countries must first acquire knowledge to build up and accumulate their own technological capabilities in order to catch up and become competitive. Respondents were of the opinion that employees who resigned from CSIR Biosciences left due to a series of restructuring processes that created a lack of confidence in job security within the Unit.

The interviewees further alluded to the fact that lack of technical skills within the Biosciences Unit is a major barrier to raising funds and sustaining the Unit. Figueiredo (2002a) in his definition of technological capabilities asserts that they are needed to generate and manage improvements in processes and production, products, equipment and engineering projects. This view is supported by the respondents who alluded to the fact that lack of technical skills within the Unit has adversely affected the Unit's performance. The OECD Innovation Strategy recommends that in order to overcome this challenge and bridge the gap created by the limited skilled resources, "developing countries" should utilise their international networks of potential sources to amass technological capabilities (OECD, 2010). Figueiredo (2002a) suggests that organisations in developing countries must first acquire knowledge to build up and accumulate their own technological capabilities in order to catch up and to become competitive. The contention is that ideas and proposals can only be generated from skilled and well-trained employees. Therefore, it is necessary for Biosciences Unit to invest in building technological capabilities to ensure that the Unit builds the required critical skills and retains them.

5.5.4 Collaboration with local partners

Collaboration generates a positive effect on the innovation performance of firms through knowledge spill-overs (Wang & Zhou, 2012). For an organisation in a developing country to build technological capabilities, it needs to build collaborations with other partners (Baskaran, 2001). This is because the degree of specialisation within public research organisations is diverse and requires the use of other

competencies as well as knowledge gained from others. If internal processes are well developed and managed properly, they will support organisational learning and capability building (Oni, 1999). Morrison *et al*., (2006) indicate that relationships formed by public research organisations with other actors within the National System of Innovation (NSI) is regarded as an important mechanism in creating exchanges and developing new knowledge towards building learning and technological capabilities. However, fragmentation within the NSI makes the relationship with other actors exceptionally difficult.

According to the respondents, CSIR Biosciences has established relationships with external partners within the National System of Innovation to learn and build technological capabilities. The respondents stated that the intention of establishing these relationships was to learn and build capabilities from partners/suppliers. This finding supports the views shared by Morrison *et al*., (2006) that organisations that participate and interact with other actors within the NSI are able to upgrade their technology by producing high quality products in a more efficient way. Furthermore, Collins *et al*., (2001) assert that the exchange of information through collaborative effort is known to facilitate learning and building of capabilities. Thus, the combination of knowledge sharing and ideas is positively related to learning and technological capability building. Although some respondents reported pockets of success within the Unit as a direct result of collaborations and the possibility of increasing these types of partnerships in the future, a majority of respondents, however, expressed the view that collaboration is not happening at an appropriate level. For example, the Biosciences Unit does not partner with other Operating Units within the CSIR to combine resources and effort towards achieving growth.

The same observation was made by one of the expert commentators interviewed who reported that the CSIR Biosciences Unit has a tendency of operating in silos, consequently they are isolated from other Operating Units within the CSIR. Cimoli and Porcile (2009) affirm that it is critical to create an environment which promotes collaboration to achieve technological progress. Lamin and Dunlap (2011) suggest that different Units within an organisation possess vastly differing streams of knowledge that can be potentially useful and transferable between Units within the organisation.

This finding indicates that lack of collaboration with other Units may prevent the Biosciences Unit from leveraging technical expertise and information from other Operating Units and deepening their technological capabilities. In contrast, the CSIR (2011) indicates that the Unit has a culture of collaboration and knowledge sharing that should enable it to leverage on internal relationships that have already been established with other Units to learn and build technological capabilities. This suggests that the strategy aims at striving to combine their resources with other Units to achieve growth. This clearly indicates that there is a disjuncture between Biosciences strategy and its implementation. The results as indicated by the interviewees show that there are none or few organisational practices that enable and induce collaboration to take place to build and increase the stock of technological capabilities within the Unit. This finding highlights the fact that there is a considerable degree of misalignment between the Biosciences strategy and its implementation.

5.5.5 Knowledge Management System

Marcelle (2004) indicates that organisations that build knowledge management systems to capture, organise and disseminate knowledge across the firm are more likely to be effective in building technological capabilities. These organisations tend to store knowledge in a repository and increase access in knowledge sharing within the organisation which tends to increase knowledge collaboration (Anand, 2011). Therefore, these organisations have a greater chance of building and developing technological capabilities through knowledge that originates from individuals and/or teams. Furthermore, these organisations tend to have a competitive advantage as the culture of knowledge sharing, trust, and openness are embedded within the organisation.

The present study showed that respondents viewed CSIR Biosciences as having no system in place to store and manage knowledge within the Unit. The respondents indicated that knowledge within the Unit is acquired in many different ways, for example, employees attend workshops and conferences and write scientific reports and academic papers which are not, however, centrally captured and accessed by

staff. This indicates that knowledge acquired within the Unit is not captured on the internal/centralised system. According to Armstrong (2006) organisations that capture organisational expertise and distribute it within are likely to achieve the biggest payoff. These organisations are able to get knowledge from those who have it and redistribute it to those who need it in order to improve organisational effectiveness.

Some respondents felt that the Unit did not have a work practice that facilitates knowledge sharing and knowledge management and this was seen as a major barrier towards learning and capability building. For example, respondents indicated that when employees are sent on exchange programmes to learn and build capabilities from other countries, the learning and experience that took place was not captured and shared amongst staff within the Unit. This was further exacerbated by the recruitment of expatriates who were employed to transfer skills and knowledge to the Unit, but due to lack of a knowledge management system, knowledge and experience gained from them was not captured. Holbeche (2002) asserts that knowledge and experience that people have should be shared across the firm to create a culture of knowledge sharing. Anand (2011) suggests that organisations should have processes of creating, gathering, organising and diffusing knowledge in order to build capabilities. This provides the organisation with a greater chance of building and developing technological capabilities through knowledge originating from these individuals (Anand, 2011).

Some respondents were concerned that the Unit had appointed champions to search for technology all over the world as a mechanism for building technological capabilities within the Unit. They concurred that this was a good strategy for building technological capabilities. However, the knowledge and technologies that were acquired through this exercise were neither sufficiently captured nor effectively managed. Champions were not forced to share and capture knowledge gained and technologies sourced within the Unit. Some champions were sharing information with their teams only but not the Unit since there were no processes in place for capturing and diffusing knowledge within the Unit. This indicates that the strategy for searching technologies as a means for building technological capabilities was good but, the implementation and intended purpose was not sufficiently thought through.

Based on the above, the study points to the fact that organisations that have knowledge storage repositories that are easily accessible, have effective learning and capability building processes which ensure that knowledge is utilised and shared effectively. Thus, the Biosciences Unit does not seem to have learning processes in place that take into account both current and past experiences. This is a major risk to the Biosciences Unit, as knowledge and competencies built over time are not transferred and retained within the Unit. This finding shows that the Biosciences Unit may not be able to track and exploit these technological trajectories as a result of the lack of a knowledge management system.

5.6 SUMMARY OF THE RESULTS

The literature reveals that organisations that learn and build technological capabilities have integrated processes in place towards learning and building technological capabilities. Therefore, if the processes are not fully integrated the organisation is likely to be limited in terms of the knowledge it is able to acquire as well as in the level of competency required and will lag behind its peers.

The study revealed that that the CSIR Biosciences Unit has established a number of processes for learning and building technological capabilities, as well as a number of competencies due to the utilisation of internal processes. The results show that although the Biosciences Unit has both internal and external learning processes in place to learn and build technological capabilities, the Unit tends to focus more on internal processes to support learning and technological capability building. This can be explained by the fact that while some of the internal mechanisms need to be improved as discussed in this chapter; the range and type of internal mechanisms are generally adequate. However, the condition of reduced funding affects the external processes more such that those are not adequate to compensate for the Unit's reliance on its internal mechanisms, thereby creating an imbalance between internal and external processes for capability building. Thus, the analysis given above strongly suggests that the current approach to learning and technological capability is inwardly focused and unbalanced, and is not fully integrated with other established organisational processes. The literature indicates that learning from

external sources is critical to growing and strengthening technological capabilities. This indicates that efforts should be made to ensure that a learning and technological capability building model is effective and integrated with other processes within the Unit to achieve a balanced model.

The core function of the CSIR Biosciences Unit is learning and innovation, which is reflective of an organisation that places value on learning and building of technological capabilities such as, mentoring, succession plan, high-tech infrastructure, recruitment of expatriates, communication, rewards, performance management, career ladder tool and effective graduate programme. The study showed that the Unit saw an increase in staff competencies and motivation through the above mentioned programmes. Employees seem to be generally happy and motivated due to the programmes that are in place, and the positive impact the programmes have had on learning and building technological capabilities.

The study revealed that some of the key barriers to learning and building technological capabilities within the Unit include a lack of technical skills, poor leadership and management practices, lack of a knowledge management system in place and lack of funding. Most employees have limited knowledge and lack the skills required to deliver on the Biosciences strategy, as a result the Unit is not able to raise funding and develop business. Furthermore, there is the ever present challenge of insufficient funding and poor leadership. Literature reveals poor leadership and insufficient funding, which has had a detrimental effect on processes for learning and building technological capabilities. This suggests that CSIR should review their strategies and come up with action plans to overcome these challenges. That means that its approach to learning and building technological capabilities should be strengthened by continuously revising the processes in an iterative and reversible manner. In addition the level of commitment and support at top management level needs to improve to a large extent.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter summarises the findings of the study and the conclusions that can be drawn from the literature reviewed and interviews based on four focus areas, namely: the role of public research organisations in industrialising countries, processes of learning and building technological capabilities, factors that facilitate learning and technological capability building, and factors that inhibit learning and technological capability building within the CSIR Biosciences Unit. The study examines learning and technological capability building within CSIR Biosciences Unit, and concludes with some recommendations for further study. The key question and sub-questions for the study were as follows:

How does CSIR Biosciences learn and build technological capabilities?

Sub - research question 1

What are the factors that facilitate learning and technological capability building within the CSIR Biosciences?

Sub-research question 2

What are the factors that inhibit learning and technological capability building within the CSIR Biosciences?

6.1.1 Key conclusion of the study

It is evident from this study that organisations that do not invest in learning and technological capability building are likely to lag behind and under-perform (Fagerberg *et al*., 2010). Research from organisations in industrialising countries highlight some of the challenges that firms in industrialising countries face such as, limited access to resources, cut-backs in government funding, lack of absorptive capacity and absence of adequate infrastructure which have detrimental effects on learning and technological capability building if not properly addressed. Marcelle (2004), for instance, provides some suggestions from the study that she conducted from firms in “developing countries”. The author argues that investing considerable

effort in learning and technological capability development provides firms with a competitive advantage. This means that firms in industrialising countries should put concerted effort towards investing in building technological capabilities if they are to succeed. In view of this research, this may be explained partly by pinpointing some of the successes and failures that were found during the course of this research study.

The literature reviewed also buttressed the view that organisations that invest considerably in learning and technological capability building are likely to succeed in sustaining their innovative capabilities and organisational growth (Figueiredo, 2002). The current study on the CSIR Biosciences Unit revealed a number of factors that influence and inhibit learning and technological capabilities to take place within the Unit.

6.2 Major findings on learning and technological capability building

The study using the CSIR Biosciences Unit as a case study was drawn from an in-depth review of relevant and related literature, CSIR documentary reviews, and interviews. The study seeks to understand the learning and technological capability building processes that CSIR Biosciences employs within their Business Unit, as well as factors that may inhibit or facilitate learning and technological capabilities to take place.

Findings from the research showed that the CSIR Biosciences Unit has a strategy that has a clear vision and goals. However, the strategy lacked effective implementation. The ineffective implementation of the strategy resulted in the Unit being unsuccessful in raising and diversifying its funding, losing “credibility” in the market and the industries it serves and thereby underperforming. CSIR Biosciences Unit employees who were interviewed attributed the shortcomings of strategy implementation to lack of a clear direction from the Biosciences Unit’s leadership as well as inexperienced staff members who were promoted to positions of greater responsibility within the Unit. It is evident from this study that strong leadership within the Biosciences Unit is vital to ensure that key projects are allocated to staff with the prerequisite experience and competence to drive its strategic plan, and provide clear direction for effective implementation. To regain its “credibility” and

market share the vision of the Unit needs to be shared successfully and this requires appointing competent staff to lead and manage its projects effectively. This could lead to increased commitment towards successful strategy implementation. The success of the Biosciences Unit hinges on strategic choices made by its leadership team as well as on the support and guidance provided to staff members with regards to how the strategy should be implemented to ensure that it achieves its intended goals.

The results showed that the structure of the Biosciences Unit was not in sync with its strategic objectives. For example, interviewees were concerned about the creation of new roles that overlapped with other roles, as well as promoting staff members to higher positions when they did not have the prerequisite skills and the experience required to manage those positions. The above suggests that the structure of the Unit was inadequately equipped to support the implementation of the new Biosciences strategy. This highlighted the point that for the Unit to achieve its desired performance levels, the structure and strategy needed to be aligned, to avoid the overlap and conflict of roles and ensure a clear allocation of the resources required to drive its strategy.

The Biosciences Unit has had a number of organisational restructuring processes which resulted in the loss of key staff members. Any planned organisational restructuring processes within Biosciences could pose the risk of losing more staff due to job insecurity and uncertainty. It is vital for the Unit to manage change strategically to avoid the risk of losing key staff. A clear strategy combined with open communication with staff on organisational change are likely to increase job security and loyalty towards the Unit, which could result in increased levels of commitment and a higher retention rate .

The Biosciences Unit is a learning organisation, therefore, its strength should lie in building the knowledge and capabilities required to empower its employees and increase their levels of competence. Respondents identified a lack of technical skills as one of the barriers hampering the growth of technological capabilities and the Unit's performance. Interviewees attributed a number of things to the Unit's underperformance including, a lack of technical skills, inexperienced staff members, and a lack of concerted effort from the Unit's leadership to invest in building the

technological capabilities that are required . Not having the right technical skills also adversely impacts on the Unit's operational performance and its sustainability.

This suggests that it is important for the Unit to think strategically around their choices when investing in technological capabilities as acquiring these skills are critical to the Biosciences Unit, and can significantly improve technological capabilities as well as its operational performance.

Sustained funding towards learning and building technological capabilities was also identified as one of the barriers towards learning and building technological capabilities. The results revealed that the Units' Parliamentary Grant (PG) had been reduced, putting more pressure on the Unit to raise funding. Limited funding from government funders was identified as a major impediment as well as the challenge of sourcing external funding to supplement government funding has had an adverse effect on learning and technological capability building. The low levels of technological capability building within Biosciences Unit could be attributed to the limited funding/investment towards learning and technological capabilities required by the Unit. In the past PROs were seen as important structures that contribute to economic development (Mazzoleni & Nelson, 2007). The CSIR Biosciences mandate is to offer new innovations to the industries it serves through translation of research outputs into market ready products that have an impact on society (CSIR, 2014). Effective interaction by CSIR Biosciences with policy makers and end-users could potentially result in policy makers being more informed about some of the strategic research programmes run by the Biosciences Unit that contribute to economic development. Increased communication and interaction with policy makers could lead to an increase of the parliamentary grant given to the Unit. The evidence that has emerged from the study indicates that the current approach employed by that CSIR Biosciences Unit needs to be reviewed.

It is evident that internal and external learning processes are in place to learn and build technological capabilities, however, there seems to be greater focus on utilising internal learning processes to build technological capabilities due to the Unit having very limited funding allocated to external travel to meet with potential partners abroad. There is conclusive evidence that the lack of engagement with external partners may limit the organisation from learning and sharing knowledge that could

create opportunities to learn and adapt technologies from advanced countries to grow their economy. The study also highlights the point that although the Unit's focus was more towards utilising internal learning processes, their limited interaction with external partners such as attending conferences/workshops, exchange programmes and collaborations on projects yielded significant results which benefited the Unit. For Biosciences to utilise both internal and external learning processes, there is a need for its leadership to make well thought through choices on the type of technological capabilities that the Unit needs to invest in, in order to derive maximum benefits. Marcelle (2004), notes that firms that are effective in learning and building technological capabilities are able to manage both internal and external factors simultaneously in order to yield significant benefits. Farrel and Bryan (2008) assert that the winners will be organisations that make thoughtful choices when building technological capabilities.

The findings of the study further indicated that although the Unit had a number of strategic partners that they collaborated with to learn from, there was no formal criteria in place to select those partners. The selection of external partners was based on either personal relationships formed with these external partners or based on their reputation or on referrals. The reviewed literature suggests that having a formal agreement as well as a selection criteria when choosing external partners is necessary to set terms and conditions for learning and building technological capabilities (Marcelle, 2004). The lack of a well-structured selection criteria when choosing partners results in inconsistencies during the process and an undesirable outcome.

One of the key barriers that was identified as an impediment to building learning and technological capabilities over time, was a lack of a knowledge management system. The CSIR Biosciences Unit is a learning organisation that supports continuous learning and knowledge sharing across the entire organisation. The study showed that the Unit has a number of internal and external learning processes that are in place to learn and build technological capabilities, however, the knowledge acquired/gained from both internal and external processes was not formally captured and stored in a place where it is easily accessible. Furthermore, the Unit employs a number of expatriates to transfer skills to local staff members and not having a

proper system of managing knowledge as well as monitoring acquired skills poses the risk of losing knowledge and experience that has been gained over time.

The development/acquiring of infrastructure was identified as one of the solid investments made towards learning and building technological capabilities. Respondents were generally happy about the investment made by the Unit towards its infrastructure. The study showed that investing in the Unit's infrastructure has resulted in increased competencies and more interaction with other partners that visited the CSIR Biosciences Unit in order to access and learn how to best operate their machines and equipment. By providing access and service to infrastructure externally, the Unit could benefit through increased collaboration and support from external partners which could stimulate sustained partnerships worldwide as well as increased funding. These kinds of collaborations have the cumulative effect of beneficial relationships, sustained partnerships and opportunities to access complementary assets between the Biosciences Unit and other external partners which could potentially increase internal technological capabilities.

The current CSIR career ladder was identified as one of the mechanisms that motivates and incentivises researchers to further their careers. The CSIR career ladder was developed prior to the formulation of the new Biosciences strategy. The study showed that the current CSIR career ladder is leaning towards promoting and rewarding individual work more than team effort. For example, interviewees stated that there are more rewards for individual publications and patents that attract funding and less support for team work. The current model needs to be revised to ensure alignment with the new Biosciences strategy which promotes team work and innovation.

Mentorship and Succession plan were identified as mechanisms that were established to learn and increase skills that are required within the Unit. Ehrich and Hansford (1999) confirm that organisations that undertake and support mentorship programmes tend to have an increased performance and productivity level as well as competent employees. These programmes seem to be well supported within the Unit, thus effective utilisation of these programmes are likely to yield significant benefits to the Biosciences Unit.

One of the key learnings from this research study is that limited funding combined with ineffective and inconsistent leadership has consequences and impacts on the CSIR Biosciences Unit's ability to retain employees with highly specialised skill sets that are not easily available. This has in general reduced the potential impact of the Unit's outputs on the wider society. This buttresses the point that the ability to manage strategic change and develop integrated learning processes could lead to greater effectiveness in accumulating technological capability within the Biosciences Unit.

Recommendations to the CSIR Biosciences Unit and relevant policy makers/stakeholders on measures that will help to mitigate some of the challenges that it is facing are presented below.

6.3 RECOMMENDATIONS

This section presents recommendations that have been put forward to the CSIR Biosciences Unit, based on the findings that have emerged from the research study conducted at the Unit. These recommendations are considerations towards effective learning and technological capability building.

1. The management of the Biosciences Unit should consider reviewing the Biosciences strategy and structure to ensure alignment to the needs of the strategy. A strategy and structure that is closely aligned will most likely provide clarity on the nature and responsibility of the roles required to drive the strategy as well as the level of accountability that is associated with each role. This will minimise problems of conflicting priorities and roles, as well as problems with resource allocation in terms of strategy implementation (Ehlers & Lazenby, 2010).

2. The Biosciences Unit has experienced a high staff turnover of Executive Directors as well as frequent revisions of its strategy which has had the resultant effect of low staff morale, a silo mentality and loss of key staff members, which has greatly compromised the continuity of the Unit's

research programmes. The CSIR board and HR department should consider investigating the reasons for high staff turnover including that of Executive Directors to minimise staff turnover. The problem of high staff turnover in the Unit's management may also be an indication of a lack of direction and clarity by the CSIR leadership on how these prevailing challenges ought to be managed.

3. The CSIR HR department and top management should consider investing in leadership training and development of a leadership team to support the Biosciences Unit and strengthen its leadership skills and levels of accountability. This could assist its management by encouraging them to take ownership and be accountable for their actions/decisions, for instance take ownership of the Biosciences Unit's strategy, which was developed by its management team.

4. Given that the CSIR Biosciences Unit's strategy leans more towards applied research and producing tangible products for the market, the Unit's management should consider interacting more with potential clients, end-users and policy makers to understand their needs in order to produce products that are more relevant to their needs and make an impact on the lives of South Africans. This approach could act as leverage to accessing alternative sources of funding from both government and other external parties.

5. The Biosciences Unit has both internal and external learning processes in place to learn and build technological capabilities. The management of the Biosciences Unit as well as its HR department should consider reviewing their current learning processes (both internal and external) by making well informed choices around technological capabilities that the Unit seeks to build. This will assist the Unit in focusing their efforts on investing in the technological capabilities that are required to drive its strategy.

6. The management of the Biosciences Unit and its HR department should consider developing a Knowledge Management system to capture the

knowledge and experience gained by staff members to avoid losing knowledge and skills that have been developed. Having a knowledge management system within the Unit means that knowledge and information stored on the system is easily retrievable when needed. This could potentially limit dependence on individual institutional memory and increase staff access to knowledge and information.

7. The Biosciences Unit's management should consider developing and formally implementing criteria for selecting strategic partners to ensure consistency in selecting external partnerships within the Unit. Developing the appropriate selection criteria could assist the Unit in making well informed choices when selecting strategic partners that they want to collaborate with and gain knowledge and experience from.

8. The Unit's HR department should consider addressing its technical skills shortage and increasing its stock of technological capabilities by attracting and appointing experienced and skilled employees as well as utilising retired workforce in transferring skills to junior staff members. Employing competent individuals will assist in building and increasing the technical skills required and improving the Biosciences Unit's profile in the market place.

9. The current CSIR funding model has proved to be inadequate with regards to supplementing the Biosciences Unit's funding streams. Biosciences leadership and Commercialisation department should consider reviewing their current funding model and aligning it with the market demands to enable access to additional sources of funding.

10. CSIR leadership should consider re-aligning or formulating a new career ladder that is in line with the new Biosciences strategy. The revised career ladder should incentivise team work/collaboration and innovation more, rather than current emphasis on individual accomplishments.

11. The management of the Biosciences Unit should consider allowing external markets to gain access to the Unit's infrastructure and services. This could

supplement the Unit's limited funding and increase the number of potential partners that collaborate with the Unit.

6.4 LIMITATIONS OF THE RESEARCH

- The scope of the study was limited to the CSIR Biosciences Unit and did not include other CSIR Operating Units or other PROs in South Africa and other industrialising countries.

- The research for this study was conducted around a particular point in time. There is a need to conduct a longitudinal study at CSIR Biosciences Unit to cover the years that were not investigated in the past years.

6.5 SUGGESTIONS FOR FUTURE RESEARCH

The research identified that learning and technological capability building in public research organisations in industrialising countries is necessary for these organisations to become relevant and provide innovative solutions to the industries it serves. A number of barriers and factors influencing technological capabilities within CSIR Biosciences Unit were researched but not extensively.

- The scope of this research was confined to CSIR Biosciences. It is recommended that comparative studies be carried out in other CSIR Operating Units due to the vastly differing nature of their business.

- Furthermore, there is a need to conduct larger cross sectional or comparative studies involving other PROs in South Africa as well as in other industrialising countries.

- Future research studying factors that motivate and influence the behaviour of employees in PROs in industrialising countries to innovate is recommended.

REFERENCES

Abramovitz, M. (1994) "The Origins of the Postwar Catch-Up and Convergence.

Boom", in Fagerberg, J., Verspagen, B. and von Tunzelmann, N. eds. (1994). The Dynamics of Technology, Trade and Growth, Aldershot: London, pp. 21-52.

Altenburg, T. (2009). Building Inclusive Innovation Systems in Developing Countries: Challenges for IS Research, in *Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting*, Lundvall, B., Joseph, K. J., Chaminade, C. and Vang, J. Cheltenham, UK, pp. 33–56.

Anand, A. and Singh, M.D. (2011). Understanding Knowledge Management: A literature review. International Journal of Engineering Science and Technology

Archibugi, D. and Coco, A. (2005). Measuring technological capabilities at the country level: A survey and a menu for choice, Research Policy 34(2), 175-194.

Armstrong, M. (2006). A handbook of human resource management practice (10 Ed.). UK: Kogan Page Publishers.

Arnold E., Bell, M., Bessant, J. and Brimble, P. (2000). Enhancing Policy and Institutional Support for Industrial Technology Development in Thailand. The overall policy framework and development of the Industrial Innovation System, Volume1, Worldbank.

Arnold, E. and Thuriaux, B. (1997). Developing firms' technological capabilities.1-42.

Arnold, E., Brown, N., Eriksson, A., Jansson, T., Muscio, A., Nahlinder, J., and Zaman, R. (2007). The Role of Industrial Research Institutes in the National Innovation System. Vinnova Analysis, 1-192.

Arocena, R. and Sutz, J. (2000). Looking at national systems of innovation from the South. *Industry and Innovation* 7.1 (2000): 55-75.

Arundel, A., Lorenz, E., Lundvall, B. and Valeyre, A. (2007). How Europe's economies learn: a comparison of work organization and innovation mode for the EU-15, Industrial and corporate change, 16, 1175-1210.

Bangens, L., and Laage-Hellman, J. (2002). Development of technological capability in South African industry: and industry network approach.

Baskaran, A. (2001). Competence building in complex systems in the developing countries: the case of satellite building in India, 109-121.

Brookes, J. (1995). Training and development competence: A practical guide. London: Kogan Page Publisher.

Bryan, L. and Farrel, D. (2008). Leading through uncertainty, McKinsey Quarterly, December, 1-13.

Carnall, C.A. (1995). Managing Change in Organizations (2nd Ed.). UK: Prentice Hall International.

Chipika, S. and Wilson, G. (2006). Enabling technological learning among light engineering SMEs in Zimbabwe through networking. Technovation, 26(8), 969- 979.

Cimoli, M., and Porcile, G. (2009). Sources of learning paths and technological capabilities: an introductory roadmap of development processes. Economics of Innovation and New Technology, 18(7), 675-694.

Clark, W. and Juma, C. (2002). Mobilizing Science and Technology for Sustainable Development, Report on the Forum on Science and Technology for Sustainability, Cambridge, MA, 10 –12 April.

Cohen, W.M., and Levinthal, D.A. (1990). Absorptive Capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35, 128-152.

Collins, C.J., Smith, K.G., and Stevens, C.K. (2001). Human resource practices, knowledge-creation capability and performance in high technology firms, 1-31.

Cooper, R.B. (1994). The inertial impact of culture on IT implementation, Information & Management, 27(1), 17-31.

Cooper, D.R. and Schindler, P.S. (2011). Business research methods, 11th Edition, The McGraw-Hill Companies, Inc, 1221 Avenue of the Americas, New York.

Cozzens, S.E. and Kaplinsky, R. (2009). Innovation, poverty and inequality: cause, coincidence, or co-evolution?, in *Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting*, Lundvall, B., Joseph, K. J., Chaminade, C. and Vang, J. Cheltenham, UK, pp. 57-82.

CSIR. (2006). Human Capital Development Strategy: Engineering and Technology Skills. Pretoria, Gauteng.

CSIR. (2010). Remuneration Policy (1-19), Pretoria, Gauteng.

CSIR. (2011). Repositioning Biosciences to serve a national role in translating research outcomes from various stakeholders to market ready technologies, services and products. Pretoria, Gauteng.

CSIR. (2012). Biomentor4U- Biosciences Mentoring and coaching: framework and guidelines (1-12). Pretoria, Gauteng.

CSIR. (2014). Annual Report 2013/14. Pretoria, Gauteng.

DeMarrais, K. (2004). The research act: A theoretical introduction to sociological methods (2nd ed.). New York: McGraw-Hill.

Deshpande, R. and Webster, F. (1989). Organizational Culture and Marketing: Defining the Research Agenda. Journal of Marketing, 53 (January), 3 -15.

DST (2013). The Bioeconomy strategy, version 11. Department of Science and Technology, Republic of South Africa.

Ehlers, T. and Lazenby, K. (2010). Strategic Management: South African Concepts and Cases. 3rd edition, Van Schaik Publishers: Pretoria.

Ehrich, L.C. and Hansford, B. (1999). Mentoring: Pros and Cons for HRM, 1-19.

Fagerberg, J., and Srholec, M. (2008). National innovation systems, capabilities and economic development. Research policy 37, 1417-1435.

Fagerberg, J., Srholec, M., and Verspagen, B. (2010). Innovation and Economic Development. In B. Hall, and N. Rosenberg (Eds.), Handbook of the Economics of Innovation. Vol. II. North Holland.

Figueiredo, P. N. (2002a). Does technological learning pay off? Inter-firm differences in technological capability-accumulation paths and operational performance improvement, 73-94.

Figueiredo, P.N. (2002b). Learning processes features and technological capability-accumulation: explaining inter-firm differences. 22, 685-698.

Figueiredo, P.N. (2010). Uncovering the learning mechanisms underlying pathways of disruptive innovation capability accumulation in later comer natural resource-processing firms: evidence from Brazil, 1-46.

Fontes, M. (2007). Technological Entrepreneurship and Capability Building in Biotechnology, 19(3), 351-367.

Forsten, J. (2000). Building and exploiting a global network around a large public research institution, 1-6.
Geffen, C. and Judd, K. (2004). Innovation through initiatives: A framework for building new capabilities in the public sector, 281-306.
Grieve, R. (2004). Appropriate Technology in a Globalizing World. International Journal of Technology Management and Sustainable Development, 3(3), 173-187.
Hipkin, I. (2004). Determining technology strategy in developing countries. 32, 245-260.

Holbeche, L. (2002). Aligning human resources and business strategy. New Delhi: Elsevier Butterworth Heinemann.
Huang, T. (1999). Who shall follow? Factors affecting the adoption of succession plans in Taiwan, 32(6), 609 – 616.

Hung R.Y.Y., Yang B., Ya-Hui, L. B., Mclean G.N., and Kuo Y.M. (2010). Dynamic Capability: Impact of Process Alignment and Organizational Learning Culture on Performance. Journal of World Business 45(3): 285-294.
Ibarra, P. (2005). Succession planning: An idea whose time has come. Public management journal, 18-25.

Jaruzelski, B., Loehr, J., and Holman, R. (2011). The global innovation 1000: Making ideas work, strategy and business, 65, Winter, http://www.strategy-business.com/article/11404?pg=all, accessed Feb 08, 2015.

Juma, C., and Yee-Cheong, L. (2005). Innovation: Applying Knowledge in Development. London: Earthscan.
Ke, W., and Wei, K.K. (2008). Organizational culture and leadership in ERP implementation. Decision Support Systems 45, 208–218.
Kim, L. (2000). The dynamics of technological learning in industrialisation. International social science journal, 1-35.

Kishimoto, C. (2004). Clustering and Upgrading in Global Value Chains: The Taiwanese Personal Computer Industry, in H. Schmitz (ed.). Local Enterprises in the Global Economy: Issues of Governance and Upgrading, Cheltenham: Edward Elgar.

Kuemmerle, W. (1997). Building Effective R&D Capabilities Abroad. 61-70.

Kumar, V., Kumar, U., and Persaud, A., (1999). Building Technological Capability Through Importing Technology: The Case of Indonesian Manufacturing Industry. Journal of Technology Transfer, 24, (1999), 81-96.

Lamin, A., and Dunlap, D. (2011). Complex technological capabilities in emerging economy firms: The role of organizational relationships. Journal of International Management, 17, 211-228.

Lammarino, S., Piva, M., Vivarelli, M., and Von Tunzelmann, N. (2009). Technological capabilities and patterns of cooperation of UK firms: A regional investigation. 4129, 1-21.

Lau, C. M., and Woodman, R. W. (1995). Understanding organizational change: A schematic perspective. Academy of Management Journal, 38, 537-554.

Lazear, E.P. (2004). The Peter Principle: A theory of decline. Journal of Political Economy, 112(1), 141-163.

Luthans, F. (2011). Organizational behaviour (11th Ed.). New York, NY: McGraw-Hill Irwin.

Marcelle, G. (2004). Technological learning. A strategic imperative for firms in the developing world. UK: Edward Elgar Publishing Inc.

Marcelle, G. (2005). How do telecom firms build capabilities? Lessons from Africa. Telecommunication Policy 29, 549-572.

Mazzoleni, R., and Nelson, R.R. (2007). Public research institutions and economic catch-up, 36, 1512-1528.

Menendez, L.S., and Cruz-Castro, L. (2003). Coping with environmental pressures: public research organisations responses to funding crises, 1293-1308.

Merriam, S.B. (2009). Qualitative research: A guide to design and implementation. San Francisco: Jossey-Bass.

Metcalfe, S. (1995). The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives. In Stoneman P. (ed.) Handbook of the Economics of Innovation and Technological Change, Oxford. Oxford U.P.

Miles, M. B., and Huberman, A. M. (1994). Qualitative data analysis: a sourcebook of new methods. Beverly Hills, CA: Sage, 262.

Morrison, A., Pietrobelli, C., and Rabellotti, R. (2006). Global value chains and technological capabilities: A framework to study industrial innovation in developing countries.

Mouton, J. (2003). How to Succeed in your Master's and Doctoral Studies a South African Guide and Resource Book, Van Schaik Publishers, Pretoria.

Mumford, M.D. (2000). Managing creative people: strategies and tactics for innovation. Elsevier Science Direct, 10, 313-351.

Mumford, M.D., and Licuanan, B. (2004). Leading for innovation: Conclusions, issues, and directions, 163-171.

Numprasertchai, S., and Igel, B. (2005). Managing Knowledge through Collaboration: Multiple Case Studies of Managing Research in University Laboratories in Thailand. Technovation 25 (10), 1173-1182.

OECD (2010). Innovation to strengthen growth and address global and social challenges: Key Findings. OECD Ministerial report on the OECD Innovation Strategy.

Oni, B. (1999). A framework for technological capacity building in Nigeria: Lessons from developed countries. 64, 1-56.

Pavitt, K. (1987). The objectives of technology policy. Science and public policy 14(4), 182-188.

Ritchie J., and Lewis, J. (2003). Qualitative Research Practice. Sage Publications, London.

Roberts, A. (2000). Mentoring Revisited: a phenomenological reading of the literature' in Mentoring & Tutoring, 8(2), 145–170.

Rush, H., Hobday, M., Bessant, J., and Arnold, E. (1995). Strategies for best practice in research and technology institutes: an overview of a benchmarking exercise.17-31.

Saunders, M.N.K., Lewis, P., and Thornhill, A. (2009). Research Methods for Business Students (5th Ed.). Harlow, United Kingdom: FT Prentice Hall.

Schein, E. H. (1985). Organizational Culture and Leadership (1st Ed.). San Francisco: Jossey-Bass.

Senge, P.M. (1990). The fifth discipline: The art of and practice of the learning organisation. Currency Doubleday Publisher.

Shalley, C. E., and Gilson, L.L. (2004). What leaders need to know: A review of social and contextual factors that can foster or hinder creativity. 33-53.

Silverman, D. (2010). Doing qualitative research: A Practical Handbook, 3rd ed. Sage, London.

Sine, W, D., Mitsuhashi, H., and Kirsch, D. A. (2006). Revisiting Burns and Stalker: Formal structure and new venture performance in emerging economic sectors, 49, 121-132.

Slowinski, G. and Sagal, M.W. (2010). Good practices in open innovation. 38-45.

South Africa. (1999). Skills Development Levies Act, no. 9 of 1999. Pretoria: Government Printer.

Stevens E., and Dimitriadis, S. (2004) New service development through the lens of organisational learning: evidence from longitudinal case studies. Journal of business research, 57(10), 1074–1084.

Swanson, R. A. (1995). Human resource development: performance is the key. Human Resource Development Quarterly, 6(2), 207-213.

Swanson, R. A. (2001). Human resource development and its underlying theory. Human Resource Development International, 4(3), 299-312.

Tanke, M.L. (2000). Human resources management for the hospitality industry, London: Cengage Learning.

Tidd, J., and Bessant, J. (2009). Managing innovation: integrating technological, market and organizational change (4th Ed.). England: John Wiley & Sons Ltd.

Twiss, B.C. (1992). Managing technological lnnovation. Pietman, London.

Underhill, C.M. (2006). The effectiveness of mentoring programs in corporate settings: A meta-analytical review of the literature, Science direct, 68, 292-307.

UNIDO (2005). Industrial Development Report 2005, Capability Building for Catching up: Historical, empirical and policy dimensions, United Nations Industrial Development Organisation, Vienna. P1-400.

Wang, A., and Zhou, Z. (2012). The dual role of local sites in assisting firms with developing technological capabilities: evidence from China. Science direct, 1-14.

Weinberger, L.A. (2006). Human Resource Development International. 1(1), 75-93.

Wood, D. and Weigel (2011). International Collaboration on Satellite-Enabled Projects in Developing Countries.

Wood, D. and Weigel, A. (2010). Building technological capability within satellite programs in developing countries, 1-14.

World Bank. (2015): New Country Classifications Retrieved 20 February, 2015, from http://data.worldbank.org/news/2015-country-classifications.

Businessdictionary.com (No date): Human Resource Management (HRM). Retrieved 20 February, 2015, from http://www.businessdictionary.com/definition/human-resource-management-HRM.

Yin, R. K. (1994). Case Study Research, Sage Publications, Thousand Oaks, CA.

Yin, R.K. (2003). Case Study Research: Design and Methods. (3rd Ed). Sage Publications, Thousand Oaks, CA.

Yin, R.K. (2009). Case Study research: design and Methods (4th Ed.), Sage publications, Thousand Oaks, CA.

APPENDIXES

FRAMEWORK FOR LEARNING AND BUILDING TECHNOLOGICAL CAPABILITIES IN PUBLIC RESEARCH ORGANISATION IN A DEVELOPING COUNTRY

INTERVIEW PROTOCOL AND QUESTIONS TO THE CSIR BIOSCIENCES OPERATING UNIT IN SOUTH AFRICA

The purpose of these questions is to investigate the process which CSIR in South Africa use in building technological capabilities.

Much has been written about how best to develop technological capabilities in general, however there is only limited evidence on the process through which capability building is done within public research organizations in developing countries. Therefore, little is known about the specifics of the process, including considerations such as speed and decision making in the capability building process. Public Research Organizations (PROs) use highly sophisticated technology and machinery which is mostly sourced internationally, the technology and the know-how to best operate this technology and machinery inevitably lies outside the acquiring countries which turn to be mostly within the developed countries. Given the speed, level of globalisation and the manner in which technology evolves, the need to be relevant and keep abreast with these international changes in research, puts research institutions within the developing countries on the high alert to ensure their relevancy for the countries within which they operate and for the general welfare of the citizenship with which they are entrusted. Thus the need to build relevant capabilities becomes not only a requirement but a basic necessity.

The interview is directed AT Technology Platform Managers, Commercialisation Managers, Science Innovation Leaders, Business Area Leaders, Senior Researchers, Chief Researchers, Operating Unit (OU) Director, Strategic Research Managers and Project Managers. The interview has been structured into two separate parts. Below are the questions:

APPENDIX A

Respondent Profile

This section provides general profile of the respondents from Biosciences Unit of the CSIR. The respondents are involved in building technological capabilities within their research group to shape the direction of R&D.

Employee name (incl position): .....

Date: ……..

Number of years in the current position: .....

Do you have a dedicated budget for building human capital? .....

Do you have formal agreements in place with external collaborators for human capital development?.....

How long have you been in this position? .....

What is the nature of the research that you are leading?

.....

How many people are reporting to you: .....

Do you have other sources of funding for building human capital?

What type of skills and knowledge do you currently have in your group?

…….

APPENDIX B

The second part of the questions:

The aim of this section is to investigate and understand processes that CSIR Biosciences follow in building technological capabilities. The respondents' views will be used to understand the process that they use to build capabilities for technology and innovation.

Learning processes and technological capability building

Technological capabilities are defined in this research as a collection of skills, knowledge, aptitudes and attitudes which confer the ability to operate, to understand, and to create production processes.

1. What are the main internal processes or mechanisms that CSIR or your Operating Unit (OU) uses for learning and building technological capabilities?

2. How long have you been using the current internal processes of building technological capabilities in your OU? Have the processes changed, if yes when, and why?

3. How do you organise and capture learning?

4. What are the most important technological capabilities that are required in your research group or within your Operating Unit?

5. What do you consider to be the most important gaps in technological capability within your OU/research group and how do you close these gaps?

    - How do you ensure that your team acquires those capabilities?

6. Who are the decision makers responsible for ensuring that building technological capabilities within your OU takes place?

7. How is knowledge and information in your Unit communicated and diffused widely across your OU?

8. What programmes do you have in place for attracting and retaining talent? How are these programmes benefiting your organization/OU?

Managing relationships with external suppliers and other partners within NSI

1. How do you select your external suppliers or collaborators? Is there a set criteria that you use to select them? If yes, please provide information.

2. Are these relationship benefiting you, if yes, please indicate how are they benefiting you in building technological capabilities that your OU/research group requires.

3. On average, how many organisations do you collaborate with both locally and internationally to access knowledge and build technological capabilities?

    - How do you exchange knowledge with these organisations?

4. Do you have any champions who search for new knowledge and understand technologies that assist the organization to build technological capabilities? If yes, how are they being utilised?

Factors facilitating learning and technological capability building

1. In your opinion, what are the indicators for learning and technological capability building that you have within your OU and/ within the CSIR?

2. How do you motivate your staff to learn and build technological capabilities?

3. How does your OU measure and evaluate learning and technological capabilities? (similar to question 1)

4. How do you keep your employees motivated to learn and build technological capabilities? (similar to question 2)

5. What incentives do you have in place to motivate your employees to stay committed to your organization and perform? If yes, please specify

Factors inhibiting learning and technological capability building

1. In your opinion, what are the main challenges that hinder/inhibit learning and technological capability building within your OU and/ with the CSIR

2. How does your OU reduce the risk of losing technological capabilities that have been built over time? In my questions- I have captured the risks that they have identified that can hinder learning

APPENDIX C

The Graduate School of Business Administration
2 St David's Place, Parktown, Johannesburg, 2193, South Africa
PO Box 98, WITS, 2050
Telephone: +27 11 717 3600
Facsimile: +27 11 717 3514
Website: www.wbs.ac.za

22 June 2013

Dear Respondent,

I am a student at the Graduate School of Business, University of the Witwatersrand, Johannesburg, studying a Master of Management in Innovation Studies (MM Innovation Studies). I am required to conduct a research as part of the fulfilment of the requirements for the degree.

My research aims to investigate the process that Public Research Organisations (PROs) in South Africa, such as the Council for Scientific and Industrial Research (CSIR), use for building technological capabilities, and will be using CSIR Biosciences as a case study. This study is significant because while technological capability building is critical and necessary for Public Research Organisations in developing countries, it has largely been left unexplored by many scholars and authors in the field of innovation studies.

In carrying out this research project, I will be interviewing respondents who are knowledgeable about the issue under investigation and you have been identified as a qualified source of information and insight. I am writing to request your permission to interview you about CSIR's approach to technological capability building.

The interview should take approximately 60 minutes of your time and your co-operation would be much appreciated. Information supplied as part of the interview will be used for academic purposes only, and if you wish, any comments can be non-attributable.

I will be contacting your office to arrange a suitable and convenient time to undertake the interview and look forward to your cooperation.

My research is supervised by Professor Gillian Marcelle and she is available to answer any queries that you may have regarding the research process. You can contact Professor Marcelle at her email: gillian.marcelle@wits.ac.za

Yours sincerely,

Dineo Sekwele
MM Innovation Studies Student
Wits Business School