

**PERCEPTIONS AND EXPERIENCES OF EMPLOYEES ON THE ADOPTION AND
CONTINUED USE OF HIGH-PERFORMANCE COMPUTING SYSTEMS AT A
SELECTED HISTORICALLY DISADVANTAGED INSTITUTION, SOUTH AFRICA**

by

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DISSERTATION

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DEDICATION

I dedicate this dissertation to myself. I am glad to have worked on this topic and I have learned so much about technology and its relation to employees ever since. It has been a really challenging three years of researching but I am really proud to have gotten this far.

DECLARATION

I, Lethabo Ledwaba, student in the Department of Business Management, School of Economics and Management in the Faculty of Management and Law at the University of Limpopo, declare and certify that this dissertation entitled, Perceptions and Experiences Of Employees on The Adoption and Continued Use of High-Performance Computing Systems at a Selected Historically Disadvantaged Institution, is entirely the results of my own work and has never been submitted by me for a degree at this or any other university. I have faithfully and accurately cited all my sources.

Signature: *L Ledwaba*

Date: 20 July 2024

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ABSTRACT

The landscape of technology has significantly changed over the last decade. For the past two decades, the integration of technology has been something that a people have struggled adopting to. However, little research has been done to examine how this sense of technology integration develops and evolves. The adoption or rejection of new High-Performance Computing (HPC) technology is still up for debate, given its rapid development and increasing integration into users' personal and professional lives. The primary purpose of this study was to explore the perception and experiences of employees on the adoption and continued use of HPC systems at a Historically Disadvantaged Institution (HDI). A qualitative research design was implemented with the use of semi-structured interviews to collect data from a sample of 12 people within a department that mainly dealt with HPC in an HDI. Interviews were recorded using a recorder and transcribed. Thematic analysis approach was utilised to analyse and group emerging themes and sub-themes. Two themes, computer language background and continuous learning emerged as determinants of the adoption and continued use of HPC. The following four themes emerged in relation to the benefits of the adoption and continued use of HPC: solving complex problems, cost efficiency, innovation and job opportunities. The themes that emerged in relation to the impediments of the adoption and continued use of HPC are four, namely, load shedding, lack of data security, lack of resources and lack of exposure. On the other hand, only one theme, education, training and development emerged with regards to influencing the integration and continued use of HPC can be encouraged in HEIs. It is recommended that for future implications, studies should make use of computation knowledge to integrate solutions that will solve problems that affect the implementation and use of HPC in more industries.

Keywords: High performance computing, Perception, Technology, Need for cognition, Attitude, Intention, Innovation

LIST OF ABBREVIATES

HPC	-	High Performance Computing
4IR	-	Fourth Industrial Revolution
NC	-	Need for Cognition
FAT	-	Functional Attitude Theory
TPB	-	Theory of Planned Behaviour
TAM	-	Technology Acceptance Model
HDI	-	Historically Disadvantaged Institution
PEOU	-	Perceived Ease of Use
PU	-	Perceived Usefulness
ATU	-	Attitude Towards Usage
IBM	-	Institute of Business Machine

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION AND BACKGROUND OF THE STUDY

Ever since the incorporation of technology into education was acknowledged as a crucial factor in enhancing both instruction and learning outcomes (Sumak et al., 2011), research on why people choose to utilise technology in higher education has grown in popularity (Sumak et al., 2011). Technology has become a current growing infrastructure in these modern times (Cheon et al., 2012; Sa´nchez et al., 2020; Susskind, 2023). It is progressively being implemented in the global labour market (Bandalos et al., 2019), which makes it easier for organisations to automate routine tasks (Eickholtz & Shrestha, 2020; Vrontis et al., 2023). The option of whether to accept or reject technology is still up for debate because of its rapid advancement and incorporation into people's personal and professional lives (Manyika & Chuli, 2020). This has the potential to upset the balance between human and machine-based job responsibilities in the workplace (Ibukun & Daramola, 2019).

Recently, there has been a new integration of High-Performance Computing (HPC) Technology within Historically Disadvantaged Institutions (HDI) for the use of academics and students (Scott, 2022). In today's technological environment, the advent of HPC is transforming the face of humanity (Roberts, 2023). HPC is the capacity to process information at very high speeds and carry out intricate calculations (Edison et al., 2018). HPC is far more powerful than traditional computing (Mazzucato, 2018). Researchers in higher education institutions around the world are using HPC systems to assist them in addressing challenging problems in a range of fields, including business, science, engineering, and mathematics (Appleton, 2013; Yao & Lu, 2023). Every day, university researchers produce billions of files and petabytes of data (Turek & Calleja, 2022). Research on cancer, climate change, and other vital issues is frequently tracked by this data (Reuther & Tichenor, 2022).

Ferlie et al. (2021) are of the opinion that HPC varies depending on the institution. These HPC technology initiatives are being made possible by developments in cloud computing, advanced networks, security, and identity management. HPC gives the possibility to discover and find answers to some of the world's prime complications and misconceptions in business, engineering, and science and recently in HDI's (Salim et al., 2021). Rapid technological developments and a persistent desire to push the envelope of what is feasible, has characterised the intriguing evolution of HPC (Michalakes, 2020). HPC has advanced scientific research, national security, and economic competitiveness from its modest beginnings in the 1960s to the supercomputers of today (Sato et al., 2021).

The first supercomputers were created in the 1960s, which is when HPC originally emerged (Chen et al., 2018). These early computers, such as the International Business Machine (IBM) System/360 Model 91 and the CDC 6600, were made to execute complicated calculations at previously unheard-of rates (Kawase et al., 2019). The computers main application was in scientific research, where they were utilised to model weather patterns and simulate nuclear reactions (Kawase et al., 2019). Pathak et al. (2022) explained that parallel processing as a method of breaking a computer work into smaller, independent components that may be executed concurrently by several processors and it—became the emphasis of HPC in the 1970s and 1980s. Commodity-based HPC systems became popular in the 1990s, utilising readily available parts to construct supercomputers with high performance and low cost (Reinders et al., 2021).

Supported by organisations like IBM and Intel, the strategy of scientific research democratised access to HPC resources and fuelled the industry's expansion (Dabrowski et al., 2020). A wider range of applications, including financial modelling, data mining, research, and computer-aided engineering, were included in the emphasis of HPC during this time, moving beyond traditional scientific research (Dabrowski et al., 2020). In the last few decades, higher education institutions have been facing new tendencies such as massification and displacement from old technology to internationalisation and the growing importance of new digital technologies (Levy, 2023). Globalisation and the

increase of the knowledge economy has had a huge impact on research in higher education institutions (Wilson, 2021). It has changed the definition of efficiency, the foundations of the financial background of institutions, and importance of cooperation between academia and industrial sectors (Gordon & Cahill, 2020).

Today, Harmon (2023) emphasises that the field of HPC is currently seeing significant growth and development due to the constant pursuit of computing's full potential and the unwavering pursuit of performance. A new era of scientific discovery and innovation for employees is anticipated with the arrival of exascale computing, which seeks to produce supercomputers capability of completing a quintillion calculations per second (Michalakes, 2020). Meanwhile, cutting-edge innovations like neuromorphic and quantum computing provide fascinating peeks at what HPC may look like in the future and have the power to completely change on how employees handle and evaluate data (Pathek et al., 2022).

The integrated advancement of technology is used to permit and dominate employees in organisations (Coovert & Thompson, 2020). A study has shown on how the perceived usefulness of technology and the perceived use of it, can be the prime factors that control how employees react to certain technology (Venkatesh, 2012). Tasks in tertiary institutions are gradually being replaced by the progression of advanced technology and artificial intelligence (Rotman, 2019), whilst jobs are disappearing as an outcome of structural changes in the economy (Galston, 2018). According to Turnisky (2016), integrating technology into HDI's in underdeveloped nations entails more than just plugging in a computer. They require the education and knowledge to integrate the resources, whilst on the other hand, the developed and developing worlds are vastly different in terms of technology because they possess a wealth of knowledge, skills, expertise, and the competitive edge that most of the latter countries do not possess (Choi, 2014; Pandria et al., 2023). Academics are under pressure to incorporate technology into their lessons due to the exponential increase in the usage of technology for teaching and learning in HDIs (Demoulin & Coussement, 2020).

Although the benefits of integrating HPC technology into teaching in higher education institutions, particularly HDI's, have been extensively acknowledged, the general desire to use technology has not been accepted with the ease that would have been expected. Hew and Brush (2021) notes that the problem with technology acceptance is not just a lack of knowledge about how to use it, but also a lack of information and practices related to technology-based pedagogy (Rasheed et al., 2018). Many academics and industry researchers are concerned about end-user adoption intents and attitudes towards the various HDI technologies due to the growing reliance on technology (Arts et al., 2011; Kulviwat et al., 2017; Mayer & Mayer, 2023).

These challenges result in many people being reluctant to implement more advanced technology such as HPC and cloud computing (Galston, 2018). The reluctant behaviour of employees in relation to the use of the HPC is based on whether the new technology will enhance an organisation's competitive advantage or improve an employee's personal or work life (McDermott, 2015).

1.2 PROBLEM STATEMENT

The outbreak of the COVID-19 pandemic at the end of 2019 led to the closure of the tertiary institution systems worldwide in 2020 (Wajdi et al., 2021). This led to the need to implement multi-modal approaches such as migrating to full integration in the use of technology (Crawford et al., 2022). To mitigate any difficulties associated with in-person instruction, especially in HDIs, measures were put in place to ensure that work and education were conducted digitally as a result of the pandemic (Mutyasira, 2021). Almost all South African universities were compelled to reconsider how they approached the use of cutting-edge technologies, which also meant acquiring new skills (Zhu & Liu, 2020).

Brusi et al. (2022) state that although the need for acquiring new skills is very important to employees of all fields, transitioning from a local computer's graphical interface to a

remote computer integration one needs a larger cognitive shift than most new skill. As such, it could be considered quite daunting for people compared to other types of new skills (Shao & Purpur, 2023). Sharma et al. (2013) states that although employees are navigating their new approach with technology, they are reluctant to scale up and migrate to advanced HPC technology and cloud computing. The reluctance comes from lack the HPC support, appropriate HPC hardware and complexity of using HPC technology (Hemsoth, 2021). This is supported by Di Pietro et al. (2022, p. 33) by saying “there seems to be a problem of less clear use of HPC in HDI’s, because of the obstacles of inadequate studies and information”. Nonetheless, problems associated with learning HPC can be placed into a broader academic and higher education context (Cook & Sonnernberg, 2019).

High performance computing (HPC) technology is an essential component of the academic development of staff members in higher education institutions (Smith & Anderson, 2021). The great weakness in HPC is that despite its promise for providing mass computational resources for the scientific community, it has struggled to achieve enormous up-take in said communities because of a lack of training and experience in the research community (Alpert & Sheperd, 2019). Nevertheless, HPC lacks users who are willing to put it into practice, despite its significance for research and the hefty capital costs that are required. A review of technology integration literature reveals a lack of studies on how personnel in high-data-intensive industries use HPC systems (Ciglaric et al., 2020).

Previous studies in the field of HDI’s concentrated on how faculty members used digital library resources, how students and researchers used Technology Acceptance (TAM) models, and how employees used e-resources (Sarita, 2015). It appears that little research has examined employee’s perceptions or experiences towards the integration and use of HPC. Hence, the overarching question that this study sought to answer is: “What are the employees’ perceptions and experiences of the adoption and continued use of HPC at a selected HDI in South Africa?”.

1.3 AIM OF THE STUDY

The study aimed to investigate the perceptions and experiences of employees on the adoption and continued use of high-performance computing systems in order suggest possible strategies to encourage employees' adoption and continued use of HPC systems at a selected HDI.

1.4 RESEARCH OBJECTIVES

This study was aimed at addressing the following objectives:

- To establish the determinants of employees on the adoption and continued use of high-performance computing at a selected HDI.
- To explore the benefits of employees using high performance computing at a selected HDI.
- To ascertain the impediments of employees using high performance computing at a selected HDI.
- To recommend possible mechanisms to positively influence the integration and continued use of HPC in HEIs?

1.5 RESEARCH QUESTIONS

The current study sought to address the following research questions:

- What are the determinants of employees on the adoption and continued use of high-performance computing at a selected HDI?
- What are the perceived benefits of employees using high performance computing at a selected HDI?
- What are the perceived impediments of employees using high performance computing at a selected HDI?
- How can the adoption and continued use of HPC be influenced HEIs?

1.6 DEFINITION OF KEY CONCEPTS

- **High-performance computing**

High-Performance Computing is the ability to process data and perform complex calculations and experiments at high speed (Jones, 2018). It is the practice of using parallel data processing to improve computing performance and perform complex calculations (Rahul, 2021). In this study, the definition by Jones (2018) is adopted.

- **Technology**

Technology is the application of conceptual knowledge for achieving practical goals, especially in a reproducible way (Skolnikoff, 2021). The word technology can also mean the products resulting from such efforts, including both tangible tools such as utensils or machines, and intangible ones such as software. Technology plays a critical role in science, engineering, and everyday life (Mitsha, 2022). In this study, the definition by Skolnikoff is adopted.

- **Perception**

Perception can be defined as our recognition and interpretation of sensory information. Perception also includes how we respond to the information (Schacter, 2019). Perception is the ability to see, hear and become aware of something through the sense. For this study, the definition by Schacter was adopted.

- **Attitude**

Attitude is an intellectual and neural state of readiness that has developed over time and exerts a dynamic or directive effect on a person's response to situations and objects with which it is connected to (Allport, 2016). In this study attitude is referred to the way an individual views something or tends to behave towards it often in an evaluative way (Sherman & Jeffery, 2021).

- **Behaviour**

Behaviour is a range actions and mannerisms made by individuals, organisms, systems or artificial entities in some environment (Minton, et al., 2021). Behaviour is a way in which one acts or conducts oneself, especially towards others (Longbing, 2019). For this study, Minton was adopted.

1.7 SIGNIFICANCE OF THE STUDY

Despite the study's focus on South Africa, it is projected to result in the establishment of an access-utilisation framework for HPC systems not only in historically disadvantaged institutions, but in Africa and around the world. This study will add to the corpus of knowledge on HPC systems, the implementation of artificial intelligence and the use of the fourth industrial revolution leading to future researchers using these findings in their own studies. In terms of social value, this research will help implement a framework that institutions of higher learning can use in addressing the integration of new components of computing, upgrading the quality and knowledge of HPC systems and improving processes of machine learning. These factors will effectively encourage employees to use computing systems and to also empower other societies into using HPC more excessively and regularly.

HPC systems are a significant source of exports, jobs, and economic growth (Hong, 2013). As a result of the contribution to this study, higher learning institutions will be able to make substantial investments and implement all-inclusive approaches to position themselves at the lead and of the competition in implementation for global HPC leadership for both students and academics. (Fischer, 2014). This study has the potential to contribute to ongoing research to help with implementation on the use of HPC and advanced technology in work environments while also tackling the issues that employees encounter in the use adaptation of modern technology. These reinforced measures will assist in directing the perceptions, attitudes, and experiences of

employees to be able to coexist with implementation of advanced technology in the day-to-day activities.

1.8 OVERVIEW OF CHAPTERS

Chapter 1 – Introduction and background of the study

This chapter presents the introduction and background of the study. The problem statement was discussed, followed by the clarification of the aim and research objectives of this research. The research questions served as a guide for this study and the definitions were also provided. The significance of this study was explained and lastly the overview and structure of the study were provided.

Chapter 2 – Literature Review

The second chapter detailed the introduction and background of the variable and theoretical framework which entailed theories that were included into the study to incorporate the variables to help the reader understand how the theories integrate with the research objectives and the empirical literature which focused on answering the research questions.

Chapter 3 – Research Methodology

This chapter discusses the research methodology employed in this study. The chapter discussed the population and the study area and the focus being on individuals who have knowledge of the use of HPC systems. The researcher is using a qualitative study for this research and incorporating semi-structured interviews as means for research instrument. The use of sampling technique was a non-probability sampling using purposive sampling and an inductive approach. Data collection procedures were detailed, and all the ethical considerations taken to make sure the study has integrity.

Chapter 4 – Data Presentation and Discussion

This chapter discusses the demographic details of the participants and the themes that were formulated after data collection when the researcher was coding. Six themes were outlined from the questions that the participants responded to. It details out tables each with themes focusing on a variable and how participant's response regarding issues that they encounter while using HPC systems and the solutions thereof.

Chapter 5 – Recommendations and Conclusions

This chapter entails a summary of the methodology used and the findings that contributed to the study and previous studies that help to answer research questions. It also includes the suggestions and recommendations that are made to make the study better and for further research. It also discussed the limitations to the study, the theoretical and empirical framework that contributes to the variable of the study, the conclusion that has been drawn from the overall data that contributed to the study and the remarks.

1.9 CHAPTER SUMMARY

Chapter one served as an introduction and overview of what the study entails, including the introduction and background of the study which introduced the concept of HPC and its history, followed by the problem statement, purpose of the study, the lay out of the research objectives and research questions, definitions of key concepts and lastly, the significance of the study which pointed out why this research is being conducted in the first place and how this study will further contribute to other studies relating to the use of advanced technology in environments. The next chapter will focus on the detailed literature review looking into the perceptions and attitudes of employees on the adoption and continued use of high-performance computing.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter concentrates on the concept of HPC and the background. Additionally, this chapter discusses the theories that are associated with perceptions and behaviour of using HPC. It further discusses the empirical review of HPC, with specific focus on the determinants of the adoption of HPC as well as the benefits and challenges of using HPC.

2.2 BACKGROUND OF HIGH PERFORMANCE COMPUTING

This section focuses on the background of HPC, with specific focus on the description of what HPC is as well as its historical background.

2.2.1 High-Performance Computing

HPC is defined by the European Commission as the “thousands of processors working in parallel to analyse billions of pieces of data in real time, performing calculations thousands of times faster than a normal computer” (European Commission, 2020, p34). Another definition is “the use of parallel processing for running advanced, large-scale application programs efficiently, reliably and very quickly on supercomputer systems” which usually function at teraflops, or even petaflops, where a flop is a floating-point operation per second (Freiberger et al., 2022, p65). Although HPC is sometimes viewed to be the same as supercomputing, it is viewed as a subset of high-performance computing (Marty, 2019). HPC provides the ability to process data and perform complex calculations at quadrillions of calculations per second, orders of magnitude faster than ordinary high-speed computers (Naps et al., 2022).

HPC can be performed on dedicated supercomputers typically containing thousands of compute-nodes working together to complete one or more tasks in parallel. Lately,

these were "virtual supercomputers" comprising many inexpensive commodity computers configured in parallel or distributed settings (Cook & Cunningham, 2019). For instance, the Hadoop ecosystem is an open-source archetype that can be operated at low-cost to provide on-demand processing of big datasets that cannot fit on a single machine (Castellana et al., 2017). Although Hadoop-based systems were considered HPC, Apache as stated by Spark (2021) is becoming popular as it provides improved HPC. This shows that HPC is time dependent.

HPC is like supercomputer, but it has added advantage of computer clusters. HPC is used to solve advanced calculations in the field of science and engineering (Piper et al., 2018). All the applications which are solved by supercomputers can be solved by HPC. Scientists, engineers and analysts in the leading companies and research stations are depending on HPC to solve challenging problems in the fields like engineering, finance, revenue management, manufacturing, risk analysis, life and earth sciences etc. (Safar & Alkhezzi, 2019). All these problems can be solved by HPC and mainly it should have cost control. Xiao and Xiao (2022) attest that HPC allows scientists and engineers to solve scientific, engineering and business problems using different applications that require high computational capabilities. Admiraal et al. (2022) state that HPC applications are mainly categorised into two types, namely, closely coupled applications and loosely coupled applications.

Closely coupled applications are two or more components that interact with one another are dependent and must be present and functioning at the same time. However, in a loosely coupled application, the components can function independently. To run these HPC applications it requires expensive hardware, and users must wait to make use of the shared memory (Admiraal et al., 2022).

2.2.2 Historical viewpoint of High-Performance Computing

High performance computing, as a field, involves a great deal of interdisciplinary cooperation. Researchers in computer science work to push the boundaries of computational power, while computational scientists use those advances to achieve increasingly detailed and accurate simulations and analysis (Broll et al., 2019). HPC at shared resource centres enable broad access to cutting edge systems while maintaining high system utilisation (Brown, et al., 2016). Attempts to evaluate the productivity of an HPC system require understanding of what productivity means to all its users. While each of the above groups use HPC resources, their differing needs and experiences affect their definition of productivity (Becker & Quille, 2023). Using the working definition of HPC as the aggregation of computing power to yield much higher performance than can be extracted from a typical desktop system to solve large problems (Chen, 2018), we take a quick look at the historical developments in this space.

Introduced in 1954, the IBM 704 was “designed for higher speeds and larger capacities required by problems of increasing complexity and size which confront business, industry, government and science” (Chen et al., 2020). Along with the IBM 704 arrived the earliest generations of Fortran, whose current generation remains a popular language for HPC programming (Bellavista et al., 2022). The IBM 704 could be said to have been designed precisely for HPC. In 1963, Seymour Cray and Control Data Corporation (CDC) replaced vacuum tubes with transistors to create the CDC 6600, the world’s first actual supercomputer (Bondi, 2008). Cray is often viewed as the "Father of Supercomputing". CDC 6600 could handle 9 megaflops of processing power and was cooled by Freon. From the 1970s through the 1990s, vector processors dominated the HPC field by operating and processing large amounts of data simultaneously (Blumenfeld et al., 2018).

The early 1960s also led to the increased use of parallel computing with the advent of the first true multiprocessor system: the D825 arriving well after the IBM 704 (Chen et

al., 2020). Parallel systems were intimately intertwined with the support of HPC. Since the 1990s, massive parallel processors (MPP) became the norm (Wienke et al., 2016). Soon clusters replaced these MPP structures, as they provided open-source software, as well as commodity off-the-shelf hardware (Gangman & Vincenzo, 2019). The Roadrunner became the first petaflops supercomputer and the Tianhe-1 quickly followed as the first petaflops supercomputer with CPU-GPU heterogeneous architecture (Reed & Dongarra, 2015). Today's fastest supercomputer is Fugaku with a capability of 415.5 petaflops (Levy, 2023). The next generation exascale supercomputers dealt with several system research challenges, including energy, efficiency, interconnect technology, memory technology, scalable system software, exascale algorithms, and resilience (Anderson & Taylor, 2021). Distributed systems came into vogue in the 1970s, with the formalisation of early networking protocols and client-server computing.

The research into distributed computing theory and systems gained momentum in the 1980s, leading to distributed computing protocols, the Internet and the world-wide web in the 1990s, and cloud computing in the 21st century (Ben-Ari, 2023). Among other benefits, distributed systems offered yet another platform for realising HPC. Duval et al. (2021) state that the 21st century has been dominated by the fact that performance increases have hit a "power wall": increasing transistor and component density have resulted in heat dissipation, and therefore energy consumption, being the critical factor inhibiting performance advances in extreme-scale high performance computing (Chen, 2016). This, coupled with other factors, have resulted in the proliferation of alternative architectures such as ARM, and heterogeneous architectures where general-purpose cores are augmented by specialized accelerators that offer superior performance per watt (Xiao & Xiao, 2019). Since 2013 the Green500 list, tracking the most power efficient supercomputers on Earth, has complimented the Top500 list (Piper et al., 2018).

2.3 OVERVIEW OF RELEVANT THEORIES

Theoretical literature of this research is embodied on various philosophies that have been developed in order to provide a clear understanding on variables which contribute to use of high-performance computing systems, the introduction of HPC, how it benefits institutions of higher learning and the outcome of what it produces. This study uses Functional attitude theory (Turksma, 1957), Theory of Planned Behaviour (Ajzen, 1991) and Technology Acceptance Model (Davis, 1989) to intricate more on the objectives and the research questions. Functional attitude theory (Turksma, 1957) provides an explanation on how an individual's attitude towards things affects their decision making. Theory of Planned Behaviour (Ajzen, 1991) demonstrates how intention to use something can lead to a negative or positive reaction which is behaviour. The Technology Acceptance Model illustrates how individuals' behaviour integrates new technology.

2.3.1 Functional attitude theory (FAT)

The idea that attitudes have several purposes were initiated in the 1950s and 1960s (Smith et al., 1956; Katz, 1960). It was proposed that people form attitudes to help them achieve their objectives, and that while a given attitude may serve more than one purpose, it will usually serve one purpose more than the others (Katz et al., 1956). A person's attitude is a psychological term that encompasses their mental and emotional state, as well as their approach to a particular issue or point of view. Their mindset, perspective, and emotions are all part of their attitude (Richard, 2016).

According to Sherman (2021), attitudes are complicated and developed by life experiences. A person's attitude can take on a wide range of qualities, each of which is distinct in its own way. According to research, some attitudes are acquired from our parents through genetic transmission (Sherman, 2021). Evaluations expressed as a preference for or opposition to an object can also be referred to as attitudes. Often, adjectives like, detest, prefer, or hate are used to describe this (Stangor, 2020). Our

perception of our own traits and behaviours is greatly influenced by our attitudes. Similarly, attitudes have a significant impact on how someone behaves.

Albarracín (2015) attests that a few scholars concur that an attitude can be defined as a consistent and unwavering manner of feeling, thinking, or observing individuals, locations, occasions, or things. It could be about a concrete or abstract topic. But there's disagreement over exact definitions (Vogel, 2021). When someone makes the decision to react favourably to a circumstance, they typically view things more favourably and acknowledge that they cannot go back in time (Eagly, 2019). Future choices, though, may have an effect on subsequent events. These people typically focus on the positive aspects of circumstances rather than the negative ones. A person with a negative attitude is more inclined to react negatively to circumstances and they tend to look back on a problem (Main, 2011). Attitude aligns with the functional attitude theory of Katz (1960).

The functional approach generally contends that attitudes are important in bridging the gap between an individual's requirements, which include knowledge and other people—and their internal needs, which include safety and self-expression. As a result, every attitude a person adopts is supposed to help them in some manner to satisfy their needs. According to Katz (1960), attitudes can be divided into four main categories based on the needs they satisfy and the purposes they fulfil. These categories are knowledge, ego-defensive, utilitarian, and value-expressed attitudes. Figure 1 illustrates these categories. Regarding their purpose, attitudes are regarded as qualitative variables. Attitudes impact both behaviour and cognition (dependent variables) and are the independent variable of a specified function (utilitarian, social-adjustive, knowledge function and ego-defensive function).

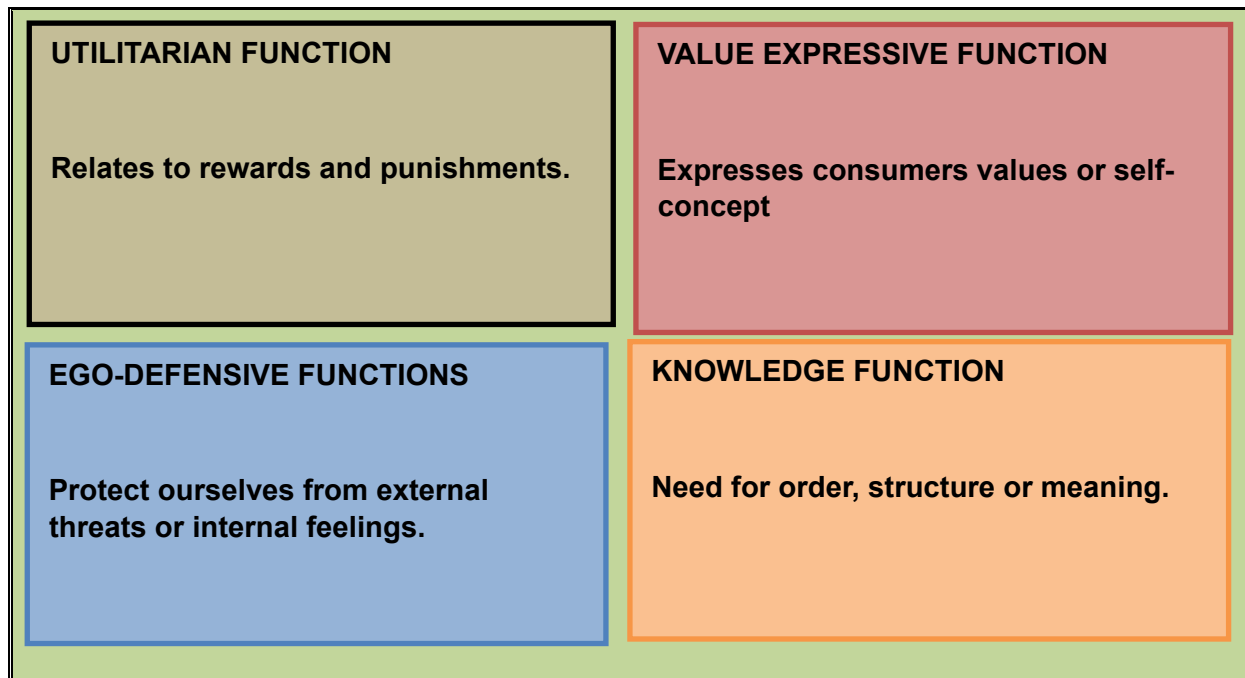


Figure 1: Functional approach (Adapted from Katz, 1960a, p.67)

Katz (1960) proposed the theory that even if two people have the same attitude, each person's use of that attitude may be completely different. Harris and Toledo (2017) are of the opinion that the goal of FAT is to understand why these attitudes develop in order to better understand how to influence them. While different attitudes serve different psychological functions, it is important to note that they are not mutually exclusive of one another as similar attitudes may be developed for different reasons by different people. Both Katz (1960) and Smith et al. (1956) conceptualised similar attitude functions—utilitarian, social-adjustive, value-expressive, ego-defensive, and knowledge—despite using distinct nomenclature. These four traditional functional attitudes are presented below in Table 1 with detailed information of how Katz thought they relate to individuals, followed by a synthesis of recent "neo functional" FAT studies, and a brief critique of FAT.

Table 1*The Functional Approach to the Study of Attitudes (Adapted from Katz, 1960b, p.169)*

Function	Description	Example
Utilitarian	Attitudes can help an individual fit in and be accepted by a social group.	A person develops a positive attitude towards a political viewpoint because it aligns with the views of their friends and family.
Value Expressive	Attitudes serve as a way for individuals to express their core values and identity.	An individual who values environmental sustainability expresses a positive attitude toward recycling.
Ego Defensive	Attitudes act as defence mechanisms, protecting the individual's self-esteem or justifying actions that might be socially unacceptable.	An individual insecure about their intellectual abilities develops a negative attitude towards academic institutions, viewing them as elitist
Knowledge	Attitudes provide a framework for understanding the world, making it more predictable and manageable.	An individual's attitude towards healthy eating helps them organize and guide their dietary choices.

2.3.1.1 Utilitarian attitudes

Numerous attitudes have a utilitarian purpose in which they increase benefits and reduce penalties derived from items in the surroundings (Katz 1960, Smith et al., 1956). Models of utilitarian attitudes are based on consequentialist theories, which hold that actions have consequences that lead to correct actions (Miller, 1990). It alludes to views of morality, according to which the best course of conduct in any given circumstance is the one that will maximise the ratio of pleasure to suffering for all impacted beings. Utilitarian functions contribute to enhancing utility since they are based on human's desire to distinguish between objects that cause pleasure and increase task efficiency

and those that cause pain and reduce task efficiency (Carpenter et al., 2013). An individual with a utilitarian attitude is concerned with how an object will assist in improving their quality of life.

2.3.1.2 Value-expressive attitudes

Value-expressive functions, which aid in the external manifestation of intrinsic values, are arguably the most challenging to understand and influence. Certain attitudes have significance for an individual because they express viewpoints that are fundamental to their self-concept, or their conception of who they are. According to Carpenter et al. (2013), an individual's attitude is "part of who they are" and how they show it tells others essential things about them. Value-relevance was employed by Hullett (2002) as a measure of an attitude's perceived usefulness in achieving a desired end-state (Craig, 2018). Rather than measuring how attitudes are expressed in respect to one's own values, it measures the relationship directly between values and attitudes (Anderson, 2012).

When examining the relationship between values, attitudes, and behaviours, communication behaviour can take centre stage when value-expressive communication of an attitude rather than value-relevance is the focus (Carpenter et al., 2013). Value-expressive attitudes are best described as existing to fulfil a person's need to feel distinct and authentic to themselves. They have no clear external aim. Being genuine to oneself is the only thing that matters to people who have value-expressive attitudes (Carpenter et al., 2013).

2.3.1.3 Ego-defensive attitudes

The purpose of ego-defensive functions is to shield the person from discomfort that can come from the outside or inside. People with ego-defensive attitudes are able to reject unpleasant or disagreeable features of themselves or the outside environment. Ego-defensive mindsets may support preserving one's own sense of worth. An attitude that

is maintained to shield oneself from unfavourable or frightening information is known as an ego-defensive function (Bazzini, 1995). Poor behaviour or personal shortcomings might pose a threat to one's sense of self-worth. Ego-defensive attitudes, according to Katz (1960), Shavitt, and Nelson (2002), support the maintenance of self-esteem through a variety of mechanisms.

2.3.1.4 Knowledge attitudes

Individuals who adopt this attitude are better able to understand the world around them. People who have a knowledge attitude try to understand events because they want to know, not because it would instantly benefit them; rather, they just want to know (Carpenter et al., 2013). People who possess attitudes that fulfil a knowledge function are better able to comprehend the composition and functions of their environment (Katz, 1960). Individuals live in a very complex world, and their attitudes may help us make sense of it without advancing our wants beyond comprehension. Based on a fundamental need to know, some researchers suggest that the knowledge function motivates attitudes that have no other role than to educate people about the world (Locander, 1978).

Daniel Katz asserted, provocatively, in 1960 that "we are in a poor position to predict when and how it will change unless we know the psychological need which is met by the holding of an attitude" (p. 170). Katz surveyed many motivational theories and created a taxonomy of the purposes that an attitude could fulfil. The work of Katz and the parallel work of Smith et al. (1956) set up a research agenda for persuasion scholars to significantly enhance persuaders' capacity to target their audience through the use of functional attitude theory.

According to Katz's (1960) functional theory of attitudes, messages that aim to persuade individuals will have greater impact if they focus on the function of an attitude, or the reason why people in that context have that attitude. This suggests that a variety of psychological processes that workers engage in on a daily basis are impacted by

attitudes and ideas. Attitudes can affect many progressions, including being helpful, social, and lessening cognitive dissonance (Katz, 1960).

Smith et al. (1956) and Katz (1960) created typologies of human attitudes with respect to purposes they considered the attitudes assisted separately and independently (Turksma, 1957). Therefore, employees' attitudes are valuable because they are significant and fundamental to psychological performance, according to this idea. The purpose of an attitude is more essential than whether it is precise or accurate (Carpenter, 2012).

According to functional attitude theory, many attitudes are driven by factors other than hedonic incentives. Katz (1960) contended that a clear definition of attitudes is necessary in order to develop a robust theory of attitudes. For instance, Levin, Nichols, and Johnson (2018) discovered that there are additional forms of engagement that overlap with some of the attitude functions. Previously, dual-process models of persuasion had conceptualised involvement as dependent on positive or negative consequences. Different persuasion processes are consistently produced by these alternative forms of participation, which dual-process models are unable to explain. The efficacy of functional attitude theory as an explanatory mechanism must be demonstrated if attitude theory is to advance (Levin et al., 2018).

Petty and Wegener (2010) argue that there is a lack of consistency in the Functional Attitude Theory among research since there may be differences in the efficacy of matching between functions and matching does not necessarily result in greater persuasion. Clary et al. (2005) also motivated to state that the findings of a meta-analysis of the functional matching effect will be provided to determine an estimate of the effect size associated with matching versus mismatching. Furthermore, investigating functional attitude theory can advance our theoretical comprehension of attitudes. According to them, many views are driven by factors other than pure hedonism (Clary et al., 2005).

Katz (1960) showed that a clear definition of attitudes is necessary to develop a robust functional attitude theory. For instance, Levin et al. (2008) discovered that there are other forms of engagement that overlap with some of the attitude functions. Originally, dual-process models of persuasion had conceptualised involvement as dependent on positive or negative consequences. Different persuasion processes are consistently produced by these alternative forms of participation, which dual-process models are unable to explain (Ajzen, 2005). The usefulness of functional attitude theory as an explanatory mechanism must be proven if attitude theory is to advance.

Miller and Steinberg (2012) elucidated that communication differs depending on how much identifying information people have and utilise about the people they are speaking with. Persuading agents that comprehend the purpose of an attitude for a certain target might modify their persuasive strategy instead of focusing on sociological or cultural level audience information. It was hypothesised that this strategy would be more successful than other strategies.

Miller and Steinberg (2012) assert that communication varies based on the degree to which individuals possess and apply identifying information about the others they are conversing with. Instead of concentrating on audience information at the sociological or cultural level, persuasive agents who understand the purpose of an attitude for a particular target may alter their persuasive method. It was assumed that this approach would yield greater results than alternative approaches. Based on this theory, it is rational to comprehend the phenomenon because employees need to develop attitudes that lead them to persuasion on behaviour relating to the adoption of integrated technology in historically disadvantaged institutions.

2.3.2 Theory of Planned Behaviour

The idea of planned behaviour was first presented by Icke Ajzen and Martin Fishbein in 1975, and this model was created to calculate an individual's intention to engage in a behaviour at a specific location and time (James, 2018). As per Handderich (2005) and

Setiya (2018), intentions are mental states that comprise action plans that the agent has personally committed to. As plans of action, they can direct behaviour. The intention's content is represented by the action plan, and the agent's attitude towards this content is reflected in the commitment (Borchert 2006; Oppy, 2021). Both immediate intents and prospective intentions—which have not yet been carried out—can be referred to by the term "intention" (Mele, 2009). Immediate intentions are those that direct behaviour as it occurs. According to this perspective, an intention's content is the specific action plan in question, and its attitude is a dedication to carrying out this action (Mele, 2009). Similar mental states like beliefs and desires may also be present in intentions. However, the attitudes of the various mental states set them apart from one another (Oppy, 2021).

Even though human conduct is incredibly complicated and unpredictable, psychologists are still working to identify the key variables that influence how people set goals and carry them out. A restricted set of psychological variables, including (a) intention, (b) attitude towards the behaviour, (c) subjective norm, (d) perceived behavioural control, and (e) behavioural, normative, and control beliefs, are specified by the comprehensive theory of planned behaviour (Fishbein, 1992). According to the idea of planned conduct, people's attitudes towards engaging in the behaviour and the subjective norm have an impact on intention (Fishbein, 2008) Nonetheless, the idea of planned conduct holds that people's behavioural purpose is influenced by their attitude, subjective norms, and perceived control. Not surprisingly, in most studies, intention is driven by attitudes to a greater extent than by subjective norms (Eagly, 2008).

People's perception of control over behaviour is irrelevant to intentions when people have negative attitudes and feel pressure from society to refrain from performing certain actions, even though they are more likely to develop intentions to carry out the action in question if they have a positive attitude and believe the behaviour is controllable (Conner, 2011). Additionally, a study demonstrated that people are more likely to carry out an activity if they have already developed the related intentions (Sheppard et al., 2018).

According to Ajzen (2015), the paradigm theory of planned behaviours (TBA) is meant to describe all behaviours that humans can self-control. It also assumes that an individual's negative or positive feelings to an object or notion are a function of two factors: an individual's beliefs about a concept possessing, or not possessing certain individualities, and an individual's beliefs on an object or "concept" possessing or not possessing certain characteristics or attributes (Mussell, 2017). The Figure 2 depicts TBA as conceptualised by Ajzen and Fishbein (1980). It presents how attitude and perceived behaviour can lead to intention in a certain behaviour.

The theory of planned behaviour is a widely applied theoretical and methodological framework for understanding and predicting human behaviour (Ajzen, 1985; 1991; 2012). It has been found to predict behavioural intentions in a variety of areas ranging from family planning decisions, including choosing products preferences (Davidson & Jaccard, 1975; Wilson et al., 1975). Though the model has been found to be predictive of behavioural criteria, evidence to support its construct validity has been very limited (Miniard & Cohen, 1979; 1981; Warshaw, 1980). The model has been employed primarily to provide explanations about why employees do or do not perform a particular behaviour and to suggest strategies for changing that behaviour (Ajzen & Fishbein, 1980; Lutz, 1975).

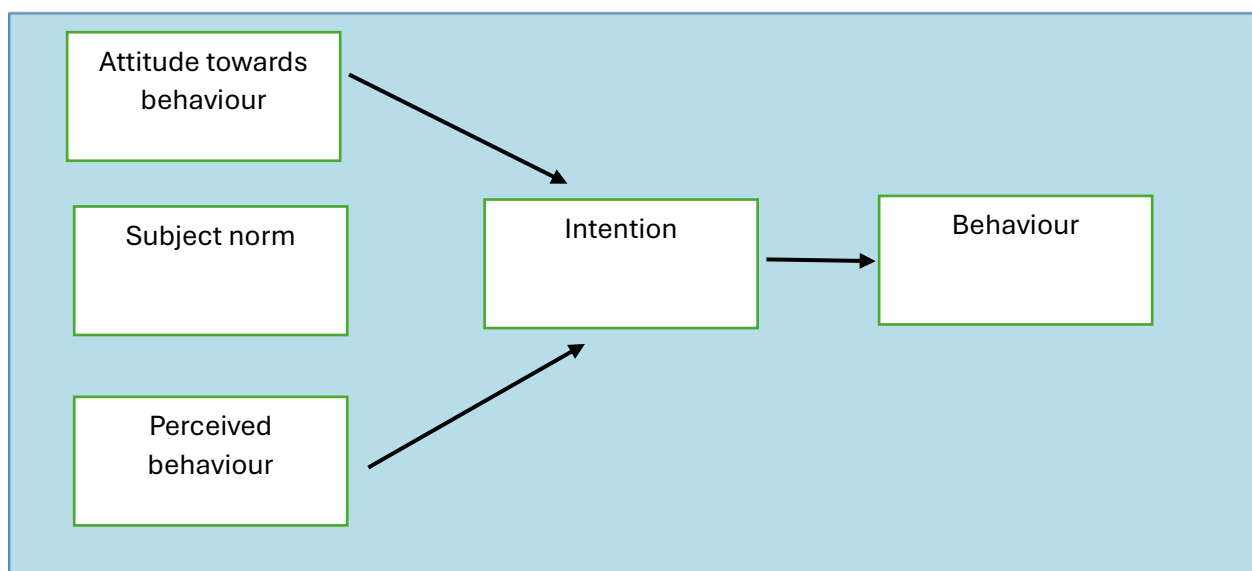


Figure 2: Theory of Planned Behaviour Model (Adapted from Ajzen, 1980, p.35).

TPB proposes that an intention to perform a given behaviour together with the perceived control over it is the best (and the only) predictor of performing the behaviour (Ajzen, 1991). A central factor in the theory of planned behaviour is the individual's intention to perform a given behaviour. Intentions are assumed to capture the motivational factors that influence a behaviour; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour. As a rule, the stronger the intention to engage in a behaviour, the more likely should be its performance. It should be clear, however, that a behavioural intention can find expression in behaviour only if the behaviour in question is under volitional control.

The behavioural intention results from a rational choice process and is itself a function of the attitude toward the behaviour, subjective norm. The attitude toward a behaviour is determined by the set of accessible behavioural beliefs that engaging in the behaviour will lead to certain outcomes. The subjective norm is an individual's perception of the social pressures to engage (or not to engage) in a behaviour. Subjective norms consist of normative beliefs about how significant others evaluate behaviour and individuals' motivation to conform to these.

According to the Theory of Planned Behaviour (TPB), the proximal antecedent of any given behaviour is the intention to perform the behaviour in question. However, intentions are expected to lead to behavioural performance only to extent that the employee has sufficient control over performance of the behaviour (Yang-Wallentin et al., 2014). A variety of other factors can also reduce the relation between intention and behaviour (Ogden, 2019). Among other things, predictive validity will tend to decline if intention and behaviour are not measured at the same level of generality or specificity, that is, if measures of these variables are not compatible; if new information becomes available that changes previously assessed intentions such that they are no longer predictive of behaviour; and if people forget to act on their intentions in a timely manner (Fishbein & Ajzen, 2010; Sheeran & Webb, 2016).

The intention in turn is determined by three factors: attitude toward the behaviour, which represents the employees' positive or negative evaluation of the behaviour, subjective norm, that is, the perceived social pressure to engage in the behaviour, and perceived behavioural control (McDermott et al., 2015). From a theoretical perspective, perceived behavioural control does not exert a direct influence on intention. Instead, it is expected to moderate the effects of attitude and subjective norm (Ajzen, 1985, 2012; La Barbera & Ajzen, 2020). Thus, for example, employees in a workplace are unlikely to form an intention to conserve energy merely because they believe that they can do so (Eagly & Chaiken, 2019). Nevertheless, perceptions of control may determine how and to what extent attitudes and subjective norms influence intentions to conserve energy (Cho & Lee, 2017).

This theory is relevant to this study because, as in the original theory of reasoned action, a central factor in the theory of planned behaviour is the employee's intention to perform a given behaviour (Fornell et al., 2017). Intentions are assumed to capture the motivational factors that influence a behaviour; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, to perform the behaviour (Hagger et al., 2013). As a rule, the stronger the intention to engage in a behaviour, the more likely should be its performance (Grudz et al., 2018). Meaning, if an HDI leaves the traditional way of manual work and fully integrates the use of advanced HPC technology into the day-to-day activities of employees, the intention to use HPC technology will be strong enough for employees to want to transition into it (Grudz et al., 2020)

It should be clear, however, that a behavioural intention can find expression in behaviour only if the behaviour in question is under volitional control, that is if the employee can decide at will to perform or not perform the behaviours (Downs, 2018). Although some behaviours may in fact meet this requirement quite well, the performance of most depends at least to some degree on such non-motivational factors as availability of requisite opportunities and resources (e.g., time, money, skills, cooperation of others; see Ajzen, 1985 for a discussion). Collectively, these factors

represent people's actual control over the behaviours. To the extent that an employee has the required opportunities and resources, and intends to perform the behaviour, he or she should succeed in doing so (Hair et al., 2016).

The idea that behavioural achievement will depend jointly on motivation (intention to use HPC) and ability (behavioural control to make use of HPC) is by no means new. It constitutes the basis for theorising on such diverse issues as animal learning (Hullett, 2007), level of aspiration (Lewin et al., 2011), performance on psychomotor and cognitive tasks (Locke, 2004; Vroom, 2010), and person perception and attribution (Anderson, 1974). Since qualitative comparative analysis will be used in this study, the purpose of these theoretical frameworks is for the research to compare the theories being formulated in the field with the ones that already exist on some of the variables that are being studied.

2.3.3 Technology Acceptance Model

The Technology Acceptance Model (TAM) was initially established by Davis (1986) and further created by Davis et al. (1989) to create a model for computer technology acceptance. Surendran (2012) verifies that the TAM is one of the concepts that has been applied to clarify an individual's acceptable behaviour. Institute of Technology, current literature indicates that TAM is a highly cited model. Chuttur (2019) argues that the wide acceptance of TAM is based on the fact that the model has a sound theoretical assumption and practical effectiveness. From the time it was proposed in 1985, the model has been refined to incorporate variables and relationships obtained from the Fishbein and Ajzen theory of reasoned action (TRA) of 1975. The output from the adjustments was a more refined model essential for anyone willing to interrogate the theory around technology acceptance and its utilisation in learning.

Concurring to Kashi and Zheng (2016), TAM substitutes some of the attitude factors with two variables of technology acceptance (perceived ease of use as well as perceived usefulness). It recommends that perceived ease of use as well as perceived

usefulness includes an individual's intention to utilise a framework with "intention to use" working as a mediator of framework utilisation (Shroff, 2019). Mainly, the TAM consists of different variables: attitude towards behaviour, behavioural intention, actual system use, perceived usefulness as well as perceived ease of use.

The model suggests that when users are presented with a new technology, a number of factors influence their decision about how and when they will use it, notably:

- *Perceived usefulness (PU)* – This was defined by Fred Davis as "the degree to which a person believes that using a particular system would enhance their job performance". It means whether or not someone perceives that technology to be useful for what they want to do.
- *Perceived ease-of-use (PEOU)* – Davis defined this as "the degree to which a person believes that using a particular system would be free from effort". If the technology is easy to use, then the barriers are conquered. If it's not easy to use and the interface is complicated, no one has a positive attitude towards it.

Figure 3 depicts the TAM developed by Davis (1989) which is regarded as one of the most popular research models to predict use and acceptance of information systems and technology by individual users. The TAM model is specifically meant to explain computer usage behaviour (p. 983). The goal of TAM is explaining user behaviour across a broad range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified (p. 985).

The model has been designed to show how employees come to accept and use technology. The theoretical basis is built on the premise that when users are presented with a new technology, three major factors influence their decision on how and when they will use it. The first determinant is its perceived usefulness (PU), the second is the perceived ease of use (PEOU), while the third determinant is user attitude towards usage (ATU). According to Davis (2008) PU is the degree to which a user believes that using a particular system would enhance his or her job performance. On the other hand, PEOU is the degree to which a user believes that using a particular technology would be free from effort.

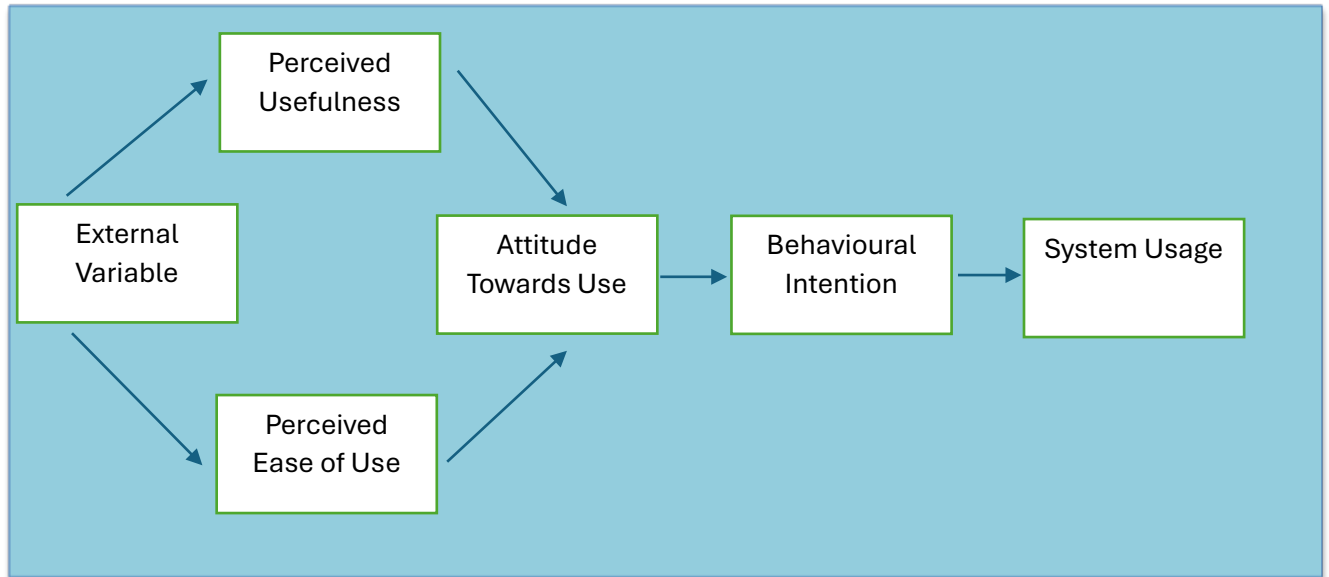


Figure 3: Technology Acceptance Model (Adapted from Davis, 1986, p.984)

In other words, it is the extent to which employees perceive a technology as better than its substitutes (Venkatesh & Bala, 2015). Commenting on the model, Chen et al. (2012) extend the argument that PU and PEOU positively affects the ATU of technology. Because new technologies such as personal computers are complex and an element of uncertainty exists in the minds of decision makers with respect to the successful adoption of them, people form attitudes and intentions toward trying to learn to use the new technology prior to initiating efforts directed at using (Singh et al., 2021). Attitudes towards usage and intentions to use may be ill-formed or lacking in conviction or else may occur only after preliminary strivings to learn to use the technology evolve. Thus, actual usage may not be a direct or immediate consequence of such attitudes and intentions (Singh et al., 2021).

Studies have also shown that perceived ease of use and perceived usefulness were predictive of staff members attitudes toward use of technology (Teo et al., 2008; Teo 2012; Teo & Noyes, 2011), while perceived ease of use predicted perceived usefulness of web technology in online learning environments (Liu et al., 2010) and e-learning systems (Badri et al., 2016). Attitudes were found to be a significant predictor of behavioural intentions, including employees' intentions to use HPC technology (Taylor &

Todd, 2021). TAM assumes that beliefs about usefulness and ease of use are always the primary determinants of use decisions. This was a conscious choice on the part of Davis et al. (1989), since they wanted to use "a belief set that readily generalises to different computer systems and user populations" (p. 988).

This phenomenon is being adopted for this study mainly because the fast growth of HPC technology has brought a large revolution in HDI's. The use of high-performance computing has developed an advanced learning context and granted academics and employees an excellent chance to cooperate with others. With TAM the distribution of instruction and computer-based resources of knowledge can be achieved without the restriction of space and time. Sánchez and Hueros (2016) designated that HPC systems contexts assisted educational systems to cross spatial and sequential difficulties, fostered significant learning, and offer convenience in addition to flexibility. Yoon and Kim (2018) recommended that the Technology Acceptance Model would be measured as a vital factor of the users' recognition as well as utilisation of HPC technology.

The expansion of information communication technology resulted in a variety of manuscripts have been issued on the environment of application of TAM in the academic community, (Teo, 2009; 2010; 2012; Yoon & Kim, 2018). Numerous investigations have utilised TAM to inspect employees' motivation to adopt HPC technology (Liaw et al., 2007; Van Raaij et al., 2008; Al-Adwan et al., 2013; Tabak et al., 2013; Šumakor et al., 2015; Ong, C.-S et al., 2019) to expect employees' intentions to apply onto the HPC systems (Liu, 2014). The consequences of these studies indicated that TAM could professionally predict and clarify users' adoption of HPC technology.

2.4 EMPIRICAL LITERATURE

This section reviewed existing empirical data according to the objectives and research questions the guided the current study.

2.4.1 Determinants of the adoption and continued use of HPC

Previous studies identified the following factors as possible determinants of the adoption and continued use of HPC: attitude (Conner & Mc Millian, 2020; Smith et al., 2018), intention (Skaalvik, 2016; Zhou et al., 2020), need for cognition (NC)/ cognitive needs (Gadden & Habib, 2019; Meier et al., 2014) and innovativeness (Avlonitis et al., 2018; Sood et al., 2018). These determinants are discussed independently.

2.4.1.1 Attitude

Attitude toward high-performance computer systems is defined as an individual's broad assessment or emotion of support or antagonism to computer technologies and detailed computer-related events (Smith et al., 2018). Statements on how employees interact with computer hardware, software, other individuals who work with computers, and computer-related activities are often included in computer systems attitude evaluations. When it comes to computer-related activities, single examples of conduct or groupings of behaviour are examined (Smith et al., 2018).

One of the key variables in forecasting people's behaviour is their attitude, by comprehending an individual's attitude toward something. One can accurately predict that an individual's general pattern of behaviour toward the object (Ajzen & Fishbein, 1977 as cited in Yushau, 2006). A "learned inclination to respond positively or negatively to a given object, situation, institution, or person" is how attitude is defined (Aiken, 2000 as cited in Yushau, 2006, p. 47). As a result, people's attitude influences everything they do and represents who they are, making it a determining element in their behaviour (Yushau, 2006).

Determining the employees' attitude toward HPC technology facilitates the tertiary institutions to consider and appraise the appropriate measures and training for its appropriate structures (Conner & Mc Millian, 2020). It is rather significant for employees in HDI's to have a good attitude regarding the work they do, hence all HPC

implementations that are to be done to reduce workplace and improve efficiency need to be addressed and employees should be given time to adapt to the new innovations (Aslan, 2018).

Rotter (2011) explains that attempts to predict behaviour from attitudes are largely based on a general notion of consistency. It is usually considered to be logical or consistent for an individual who holds a favourable attitude toward some object to perform favourable behaviours, and not to perform unfavourable behaviours, with respect to the object (Lu & Brown, 2013). Similarly, Carlson (2008) emphasis that an individual with an unfavourable attitude is expected to perform unfavourable behaviours, but not to perform favourable behaviours. For instance, if an employee produces an unfavourable attitude towards certain devices of HPC technology in an HDI, that particular employee is expected to not do the perform work on the technology which then leads to poor productivity (Edwards, 2017). The apparent simplicity of this notion is deceptive, since there is usually no theoretical basis for the assumption that a behaviour has favourable or unfavourable implications for the object under consideration (Magno, 2019).

Kalanda and Oliphant (2019) state that technical education is a wide-ranging term mentioning those facets of educational processes, involving in accumulation to general education; the study of technologies and associated sciences and acquisition of practical skills, attitudes, understanding and knowledge, relating to occupation in numerous sectors of economic and social life. There is a need for appropriate technical attitude in training at all levels in an HDI that has been sensed since independence (Ali, 2013). The variable attitude towards technology was conceptualised to determine whether they have a favourable attitude towards HPC technology. Cullingford (2016) states that determining the employees' attitudes toward HPC technology is the primary step to improve and implement a comprehensive technical education program.

In their study, Baikady and Mudhol (2022) found that the faculty and employees in universities prefer computer-based resources to traditional methods of teaching. Loan

(2019) found that employees use advanced technology for information seeking and rural students use it for acquiring knowledge. Bhat and Mudhol (2017) observed that both faculty members and employees have a positive attitude towards the usage of HPC technology for their studies and research.

Ahmed (2011) states that the findings of his study demonstrate that attitude plays a significant role in persuading the employees' intention to use HPC. This result was supported by many previous studies on the attitude and intention to use HPC in the academic sector. The majority of the studies found that attitude was a vital component that can lead to intention to use HPC technology (José Carlos & Ana Maria, 2011; Ahmed et al., 2011; Sujeet & Jyoti, 2013; Altawallbeh et al., 2015). This can be postulated that due to the components of attitude comprised of affect, cognition and behaviour based on psychology theory led to the positive reactions in employees' intention to use HPC in a tertiary institution.

Abdullah and Ward (2016) study showed that perceived ease of use and perceived usefulness were not significant predictors in influencing the intention to use of HPC. This can be due to the majority of the employees already having some knowledge about E-learning and they feel that the technology is convenient and has made them satisfied with the HPC technology. Attitude was removed from the TAM at a later stage because it was felt that attitude was not significantly linked to technology usage (Thompson et al., 2018). This is despite findings from research that provided support for the role of attitude towards use in the TAM (Lau & Woods, 2008; Teo, 2011).

In a study conducted by Sumak et al. (2011) and a later study by Geist and Reed (2017) on factors affecting the acceptance and use of HPC technology in the education sector, it was reported that the actual use of technology depends on behavioural intention and the attitude towards using the software. The study further reported that perceived use was the strongest and most important predictor of attitude toward using HPC technology. The study found that attitude did not contribute to the total variance accounted for in technology usage by a sample of preservice teachers (Sumak et al.,

2011; Lynn et al., 2018). As such, the results support previous studies which found the attitude construct in the TAM in HPC to be unnecessary. It was suggested for future studies to examine the attitude construct alongside various aspects of the users, environment and technological systems (Beer et al., 2019). There is evidence that found attitude to be a significant predictor of the intention to use technology, especially in settings where the use of technology is voluntary (Chau, 2015; Venkatesh, 2018; Morris et al., 2023).

2.4.1.2 Intention

According to Haggard and Cole (2013), intention refers to the motivational elements that drive a certain behaviour, where the stronger the intention to conduct the behaviour, the more liable it will be executed. An individual goal is to employ a technology that has a direct impact on actual usage (Chassagnon et al., 2008). Individual intention is inclined by behaviour and attitude that emanates from technology (Gerrans, 2007). Fried et al. (2011) illustrate that super computers, cluster computers and cloud computing produce secure and fast outcomes which make it much easier for employees to work with, which leads to a positive intention to use high performance computing.

Although much is already known about determinants of the intentions to use technology, much less is known about a crucial relationship between the intention to use it and actual usage of HPC technology (Skaalvik, 2016). Many people declare that they intend to use innovative technology, but fewer do (Venkatesh & Davis, 2017). In the context of learning a HPC in an HDI, using new technology requires an important change in behaviour. Often, a departure from the type of teaching and learning that an employee is used to and has observed in the past (Al-sa'd, 2021). This requires an orchestration of existing pedagogical competences with the novel tools, which can be accomplished in many ways (Drijvers et al., 2010). This process requires a substantial level of cognitive investment on the part of the employees who work with HPC technology (Skaalivik & Skaalivik, 2016).

On the basis of research from the field of tertiary institution differences, one can predict that employees show relatively stable individual differences in the degree to which they are willing to make such investments in order to implement the effective use of HPC (von Stumm & Ackerman, 2013). The results of previous studies supported that perceived usefulness was a strong determinant of students' attitudes and their intention to adopt the HPC technology for educational activities (Davis, 1986; Adam et al., 1992; Igbaria et al., 1997; Burton-Jones & Hubona, 2006; Shittu et al., 2011; Tunku Badariah et al., 2019). Overall attitude is the driving effect of employees' intention to use resources (Rotter, 2011).

The results of the study corroborated the findings of Sumak et al. (2011), who found that students' attitudes were a significant predictor of their behavioural intention to utilise internet software. Intention also positively influences the actual use of HPC in an HDI. The facilitating condition construct statistically influenced students' behavioural intentions towards utilising the Internet for learning, but it was a statistically unimportant predictor of students' attitudes towards internet adoption.

Behaviour is affected by perceptions of access to necessary skills, resources, and opportunities to perform the behaviour. If an individual does not have control over the circumstances, the individual may not have any or less intention to perform a particular behaviour. In behaviour intention research, perceived behavioural control has been found to be of a concern determinant of usage intention (Fusilier & Durlabhji, 2005; Bakarman & Almezeini, 2021). A study on technology usage such as the effect of computer self-efficacy, user-involvement and mandatory use of IT also found the same result (Compeau & Higgins, 1995; Hartwick & Barki, 1998; Moore & Benbasat, 2017).

Perceived usefulness and attitude towards the internet are the significant factors in determining the students' behavioural intention in using the technology for academic purposes (Habib et al., 2021; Zhou et al., 2020). These two constructs together explained 65% of the variance of behavioural intention. A similar study conducted by

Bidin (2016) on use of HPC for academic purposes also concludes that attitude variable significantly explains variance in intention.

2.4.1.3 Need for cognition

The findings on need for cognition (NC) and HPC show that the variables (cognitive activity and behaviour) combined makes for the type of computing integrating the technology and biology to reengineer the mind (Gadden & Habib, 2019). However, with major advances in education sectors like HDI's, researchers interested in computer intelligence became enthused. Goel et al. (2020) state that extensive biological understanding of how the brain works permits employees and academics to build computer systems modelled after the brain, and most significantly, to build a computer that could take part in past experiences to feature into its system.

Cognitive psychology is the scientific knowledge of psychology that studies cognition, namely the mental processes that underlie behaviour. Cognitive psychology has extensive domain research including working memory, attention, perception and knowledge representation, reasoning, creativity and problem solving (Hartono, 2007). One theory about the use of information technology systems that are considered highly influential and is commonly used to describe an individual acceptance of the use of information systems technology is the Technology Acceptance Model or TAM. This theory was first introduced by Davis (1986). TAM developed from the theory of reasoned action or TRA by Ajzen and Fishbein (1980). Cognitive factors use basic research with instruments, which based Davis (1989), is namely: perceived usefulness and perceived ease of use.

Research done in the field of information systems stated that the use of personal factors is very important for predicting the use and adoption of technology (Lucas, 1981: Nazar, 2008). Researchers have also noticed that personal factors are relatively volatile, such as individual attitudes (attitudes towards computers). According to Davis (1989), cognitive factors are divided into perceived usability (perceived usefulness) and

perceived ease of use. Perceived usefulness is an assertion about the decision-making process especially when a person believes that the system is useful then he/ she will use it, oppositely if a person believes that the system is less useful, and then he will not use it. Perceived ease of use according to Davis et al. (1989) is defined as a person's level of confidence that the use of a particular system is not required effort. Despite efforts by every person is different, but in general, to avoid rejection of users on the developed system, then the system must be easily applied by the user without removing the efforts that are considered burdensome (Swanson, 1974; Lucas, 1975; Schultz & Slevin, 1975; Robey, 1979; Ginzberg, 1981; Swanson, 1987).

Taking results into account it can be argued that NC is the crucial variable responsible for cognitive investment, which marks the difference between intention to use and actual use of technology in pedagogy (Courtney & Gordon, 2015). The effect of NC on HPC technology should be stronger in a context in which certain conditions are met. When use of technology is optional, not required by the teaching curriculum, when technology use is perceived as a complex and challenging task, and when its adaptability and benefits from use in the context of learning are not immediately, personally visible (Hayer, 2019). In terms of the Technology Acceptance Model: NC influences behavioural engagement in HPC technology to a greater extent when perceived usefulness and perceived ease of use of HPC technology are low, rather than high (Howard et al., 2017).

High NC is related to engagement in deep learning strategies, critical analysis, and content structuring while low NC relates to using low effort strategies such as memorizing and rehearsing (Evans et al., 2003; Cazan & Indreica, 2019). High NC therefore results in high effort spent on a complex task, but can diminish effort in burdensome tasks, which are perceived as simple and predictable (Cacioppo & Petty, 1982; Mussel et al., 2016). High levels of NC also predict high effort when a complex task seems optional, but not personally relevant for the present moment. For tasks which are highly personally relevant or surprising NC does not moderate effort (Petty & Cacioppo, 2016; Luttrell et al., 2017).

On the basis of research from the field of higher education, one can predict that people show relatively stable individual differences in the degree to which they are willing to make investments of cognitive skills relating to the use of HPC technology (von Stumm & Ackerman, 2013). Cacioppo and Petty (1982) use the term NC, also referred to as cognitive needs, to describe the differences in the tendency to engage in and enjoy effortful cognitive activity. Research shows that high levels of NC relate to an increase of cognitive resources spent specifically in response to situations placing high cognitive demands. Resources such as new technological equipment and computer-based resources for academics and administration (Cacioppo & Petty, 1982).

Merely labelling a message as complex and challenging generates motivational differences in processing of this message by individuals varying in NC (See et al., 2009). High NC therefore results in high effort spent on a complex task such as running experiments and projects on a supercomputer, but can diminish effort in burdensome tasks, which are perceived as simple and predictable (Cacioppo & Petty, 1982; Mussel et al., 2016). High levels of NC also predict high effort when a complex task seems optional, but not personally relevant for the present moment. For tasks which are highly personally relevant or surprising NC does not moderate effort (Petty & Cacioppo, 2016; Luttrell et al., 2017).

Baka (2017) states that the effect of NC on technology use should be stronger in a context in which certain conditions are met: (a) when use of technology is optional, not required by the teaching curriculum; (b) when HPC technology use is perceived as a complex and challenging task; and (c) when its adaptability and benefits from use in the context of learning are not immediately, personally visible. Technology Acceptance Model: NC influences behavioural engagement in HPC technology use to a greater extent when perceived usefulness and perceived ease of use of technology are low, rather than high (Hayes, 2019). That is, NC moderates the relationship between intentions and use, in such a way that when intentions to use a particular HPC technology in a particular context are low, the effect of NC on actual use of that HPC technology is strong (Coenders & Terlouw, 2015).

In a case when intentions to use this technology are high, employees are already strongly convinced of its benefits and ease of use, the effect of NC on actual technology use is weaker (Luttrell et al., 2017). It also needs to be noted by Mussel et al. (2016) that in universities, the direct effect of NC on technology use should be supplemented by an indirect effect. NC can be relevant for perceived ease of use of HPC technology (Luong et al., 2017). It appears that high NC is related to a broader goal of engagement in technology use, because of the complexity of this intellectual task (Meier et al., 2014). With low NC, there is no such general motivation and therefore what strongly predicts behaviour is implementation intention based on pedagogical usefulness of technology (Petty & Cacipoppo, 2016).

Need for cognition moderates the relationship between intentions and use, in such a way that when intentions to use a particular technology in a particular context are low, the effect of NC on actual use of that HPC technology is strong (Ruscio & Roche, 2012). In a case when intentions to use this technology are high, Pierce and Ball (2020) state that an individual is already strongly convinced of its benefits and ease of use, the effect of NC on actual technology use is weaker. It also needs to be noted that the direct effect of NC on HPC technology use should be supplemented by an indirect effect. NC can be relevant for perceived ease of use of HPC technology (Coenders & Terlowu, 2015).

Research by Venkatesh (2018) shows, for example, that computer playfulness is related to perceived ease of use of such technology. Computer playfulness is a construct defined as being specific to the use of computer technology, but it is like NC in that both relate to intrinsic motivation and engagement in a task (Bas, 2013). Being intrinsically motivated to engage in a task lowers the perception of effort spent on the task, despite an objectively greater effort (Ryan & Deci, 2018). Therefore, it can be argued that high NC increases the general strength of intentions to use HPC technology, through increased perceived ease of use (Brown, 2014).

2.4.1.4 Innovativeness

HPC systems enable advances in the use of Artificial Intelligence (AI) and big data technologies in our culture, so the significance of the application of HPC and innovativeness endures to upsurge (Ezell & Atkinson, 2020). Technology innovation done with the application of HPC is anticipated to offer opportunities for technology commercialisation and acquisition to tertiary institutions (Freeman, 2019). Transitions created from learning materials and experiments have altered the future of computing innovation (Hoffman, 2011).

Technology is changing every single day and unless employees adapt to it, it is very unfortunate that they will be left behind (de Vries, 2014). The innovation of HPC technology is fundamental to the lives and the growth of employees in an institution because it is the kind of technology that encompasses efficiency and can reduce workload for some employees in environments like universities and schools (Dennell, 2021). At the same time technological innovativeness is suggested to increase organisational innovativeness and environmental innovativeness, which both potentially impact new product success positively (Sood et al., 2018). Accordingly, Gatignon and Xuereb (2009) found how that technologically newer products have a higher new product performance and have a way of positively impacting the use of it to employees in the sectors.

Market innovativeness of new products is high if the innovation encompasses a significant increase in value in comparison to prior HPC systems (Chandy & Tellis, 2010; Jordan & Segelod, 2020). Technology innovativeness relates to the internal changes of the innovating unit that are induced by the innovation (Avlonitis et al., 2018). Technology innovativeness therefore covers the degree to which existing resources are appropriate for the development of an innovation (Danneels & Kleinschmidt, 2017) and relates to changes in strategy, structure, processes, competences, or incentive systems (Avlonitis et al., 2014; Jordan & Segelod, 2020).

The incremental pace of change created by technology innovation has allowed tertiary institutions to gradually adjust roles and responsibilities, training, and communications to prepare their employees to be productive with new processes and tools created by innovation. However, some predict that we are now amid the next technological innovation, machine learning and artificial intelligence (AI), which is speculated to result in transformative changes in the education sector (Frey & Osborne, 2017; Illanes, 2018). If the predictions of transformational change come true, there could be major job displacement and institutions of higher learning will need to prepare for employees to reskill. As a result, HDI's may have to invest in the advancement of HPC technology.

2.4.2 Benefits of the adoption and continued use of HPC

The review of empirical findings reveals the following as possible benefits of the adoption and continued use of HPC: growth and sustainability (Shannon, 2017; Tomley & Searcy, 2023), improved speed (Fossum et al., 2022) and efficiency and scalability and flexibility (Chaudhury et al., 2018). These benefits are individually discussed.

2.4.2.1 Growth and sustainability

Shannon (2017) states that apart from immediate economic factors, HPC is vital to the sustainability, growth and competitiveness of many industrial sectors including pharmaceuticals, energy, manufacturing, and many others. The 2020 Top500 list which tracks the 500 fastest computers on Earth found that 58% of machines were located in industry followed by 20% in research, 11% in academia, 7% in government and the rest in other sectors (Sham et al., 2017). HPC is also essential to energy, national laboratories, and defence, and impacts the lives of billions of people daily in ways they often do not realise. Dozens of the world's fastest computers are used in weather forecasting and household names such as Disney use a cluster of computers to create animation (Tomley & Searcy, 2023). Many of the fastest computers on earth have contributed towards efforts to fight the COVID-19 pandemic (Steane, 2015). This is important as it has been shown that algorithms for homogeneous platforms are not

always optimal on heterogeneous ones opening up promising new advances (Saito, 2019).

Sustainability computing power in HPC means that it remains relevant in today's world. However, as scientific and societal challenges become more complex and require increasing computing power, HPC hardware quickly becomes outdated. As a result, sustaining an HPC center requires periodic hardware updates, possible expansions, and regular maintenance and staffing. Typically, an HPC cluster needs replacement every five years, coinciding with the maximum warranty period offered by hardware manufacturers.

Lui et al. (2021) state that running an HPC beyond its warranty period poses a significant risk of malfunction leading to service disruption. Even though 50% of the HPC centers we studied require a service fee, the fee collected is not sufficient to cover maintenance, and staffing, let alone purchasing an entire HPC cluster. Many centers, such as the Vermont Advanced Computing Centre (VACC), offer free or paid services in tiers, and some, including the CHTC at UW- Madison and BCHPC at UWEC, offer a "buy-in" option or "condominium" model, where researchers or university community members can purchase nodes for priority access. However, all HPC studied rely on funding from central and/ or local governments, as federal funding through research or instrumentation grants and state appropriations and endowment funds often provides significant hardware and operating cost support.

A significant correlation in the growth of HPC use in undergraduate education has been observed worldwide (Chaudhury et al., 2018; Cui et al., 2016; Karsakov et al., 2015; Mullen et al., 2017; Neelima, 2017). In many cases, these developments occurred across more than one discipline giving rise to growth in multidisciplinary computational sciences (Chaudhury et al., 2018; Fernández et al., 2021; Ponce et al., 2019; Raj et al., 2020; Vavilala, 2020). HPC resources have been used worldwide to perform cutting-edge research in many fields to accelerate the rate of scientific discovery (Pyzer-Knapp et al., 2022). Private companies have been early adopters of HPC, accounting for about

30% of supercomputer customers in the U.S. as early as 1982. The use of HPC in industry is widespread and has given rise to a need for sustainable computing (Shuja et al., 2017).

2.4.2.2 Improved speed and efficiency

Fossum et al. (2022) believe that HPC allows you to perform calculations and simulations much faster than you can on a regular desktop computer or laptop. This lets one complete task quickly, save time and money, and make more informed decisions. HPC is mainly about lightning-fast processing, which means HPC systems can perform massive amounts of calculations very quickly. In comparison, regular processors and computing systems would take longer: days, weeks or even months to perform these same calculations (Bethune et al., 2012). HPC systems typically use the latest CPUs and GPUs, as well as low-latency networking fabrics and block storage devices, to improve processing speeds and computing performance (Hati & Bhattacharyya, 2016). HPC achieves these goals by aggregating computing power, so even advanced applications can run efficiently, reliably and quickly as per user needs and expectations. It thus delivers much higher power and better performance than traditional computers, workstations and servers (Suhail et al., 2020).

Gomes et al. (2022) add to stating that HPC holds immense significance due to its ability to process vast quantities of data at exceptional speeds. The ability to solve intricate computational problems is unlocked, paving the way for substantial advancements in diverse sectors such as healthcare, engineering, and science. With HPC, creating more precise simulations and models is made possible, acting as a catalyst for innovation and discovery. It also aids in decision-making processes, enabling the extraction of insights from extensive data sets (Gomes et al., 2022). These insights become instrumental in shaping business strategies and policies. Moreover, HPC allows for exploring complex phenomena that are otherwise impossible to study in a laboratory setting (Lynn et al., 2020). This brings a deeper understanding of the universe, from studying climate trends to decoding the human genome.

Mullen et al. (2017) also emphasise that HPC processes large amounts of data faster than standard PCs, provides faster insights, and provides enterprises with the opportunity to stay ahead of the competition. HPC solutions are millions of times more powerful than the fastest laptops (Shuja et al., 2017). This capability allows enterprises to perform large-scale analytical calculations such as millions of scenarios with terabytes of data. For example, scenario planning requires important analytical calculations provided by HPC (Habib, et al., 2021). Weather forecasts or risk management assessments. Organisations can also run design simulations before physically building chips, cars, and so on. HPC provides outstanding performance that enables organisations to do more at less cost. Users can handle more HPC workloads and save labour costs without worrying about the cost and maintenance of the underlying infrastructure (Asif et al., 2020).

2.4.2.3 Flexibility and scalability

Chaudhury et al. (2018) stated that users can scale to much larger problem sizes and configurations when running on HPC. HPC resources now also include purpose-built accelerator technologies such as GPUs for modern compute-intensive workloads. Users can scale services to fit their needs, customise applications and access specialised HPC data centers from anywhere with an internet connection (Radenski, 2019). HPC can be used to create simulations, eliminating the need for physical tests. For example, when testing automotive accidents, it is much easier and less expensive to generate a simulation than it is to perform a crash test (Pratim, 2021). Users can scale services to fit their needs, customise applications and access specialised HPC data centers from anywhere with an internet connection (Reed, 2014).

Many modern-day applications require a lot of physical testing before they can be released for public or commercial use. Self-driven vehicles are one example. Application researchers, developers and testers can create powerful simulations using HPC systems, thus minimising or even eliminating the need for expensive or repeated physical tests (Naps et al., 2022).

2.4.3 Impediments of the adoption and continued use of HPC

There are various impediments linked to the adoption and continued use of HPC as identified in the empirical literature. These include lack of tools (Rudd et al., 2013; Schmidberger & Bruegge, 2021), lack of knowledge (McCathy & Hayes, 2022; O'Brien et al., 2019), outdated curriculum (Croteau et al., 2023; Kumar et al., 2020) and funding constraints (Michalakes, 2020; Tyner, 2018). These impediments are discussed below.

2.4.3.1. Lack of tools

Given HPC's importance, Rudd et al. (2013) state that HPC is needed from undergraduate through to post-graduate levels, from computing to non-computing disciplines. However, there are many barriers inhibiting the adoption and integration of HPC into computing education (Squires et al., 2020). For instance, almost all HPC platforms and/or applications require an understanding of parallelism, an inherently difficult concept to grasp. Currently, a substantial portion of HPC education seems ad hoc, and requires a more structured approach (Squires et al., 2018). HPC also requires appropriate infrastructures to support student learning, and guidance to faculty on how to incorporate HPC into their curricula (Schmidberger & Bruegge, 2021). Finally, new approaches are needed to advance the education of interdisciplinary specialists.

Neelima (2017) emphasises that unlike the broader software engineering field, development effort estimations are much less established for the HPC community. A long-standing concern in the HPC field is the ever-growing gap between hardware complexities and tools available to support developers, effectively resulting in a productivity bottleneck (Kruchten, 2020). Many of the issues surrounding the tools are general problems for the wider HPC community, particularly those that pertain to developer productivity: tools do not scale well, tools differ across platforms, and effective tools can sometimes lag behind the hardware by years (Al-Jody, 2021).

More relevant to HPC education are additional problems imposed by tools that are difficult to learn and usually expensive for universities (Adenaike, 2024). The broader computing education research community has long recognised the importance of tools for helping students learn HPC (Hodgson & Shah, 2017). In the space of introductory programming efforts, tools have been the dominant focus of researchers looking to support teaching and learning (Khamprem & Boonmoh, 2019). Not only does this paper highlight the large number of purpose-built educational tools, but also includes numerous reviews dedicated purely to tools supporting learning. Educators continue to develop tools supporting introductory HPC, but the same cannot be said for tools appropriate for the more difficult topic of HPC (Abbasi et al., 2021).

2.4.3.2 Lack of knowledge

According to O'Brien (2022), the field of HPC is complex. From the perspective of HPC system composition, it involves computing subsystems, interconnection network subsystems, storage subsystems, and other components. From the perspective of multi-layer structure (bottom to top), it involves high performance processor design, architecture design, system software, resource management systems, parallel algorithm design, and cross-domain parallel application development (O'Brien, 2022). From the perspective of HPC application fields, it involves broad areas such as computational fluid dynamics and biomedicine, as well as meteorological and ocean forecasting (Mattson et al., 2016). This breadth and complexity increase the difficulty of including necessary elements in both computing and non-computing education (O'Brien et al., 2019). Because of a lack of relevant HPC knowledge, non-computing majors usually struggle to understand concepts such as scalability, concurrency, parallel I/O, and reliability (McCathy & Hayes, 2022).

Amid the COVID-19 crisis, Thaheem et al. (2021) carried out a survey to explore the benefits and challenges confronted by researchers in HPC practices, where technological challenges, personal constraints, and lack of infrastructure were reported as the major challenges. Similar challenges have been informed by Soomro et al.

(2020) and Noor et al. (2020), where employees showed resistance to integrating HPC technology in their instructional practices due to the lack of adequate infrastructure and technological competencies. This situation points out attention for concerned authorities to endow all educational institutions with sufficient and contemporary technologies to acquire optimal research and learning outcomes (Rafi et al., 2022).

Becker and Quile (2019) emphasise that employees and researchers tend to have a low level of understanding, focusing instead on optimising HPC applications. Non-computing majors can better understand challenging HPC notions by connecting their domain concepts with the corresponding HPC concepts (Broll et al., 2019). Competency-based HPC, in contrast to knowledge-based approaches, focuses on cultivating students' ability to comprehensively apply knowledge and skills in multiple fields as well as to communicate with other professionals (Cooper & Cunnigham, 2019).

2.4.3.3 Outdated curriculum

Despite the benefits of using HPC, there is a gap in HPC expertise, making the adoption of HPC a challenge (Brett et al., 2019). Few educators have the knowledge and skills to teach HPC, leading to limited educational opportunities for employees. In addition, HPC is applied in a large number of disciplines, making it more difficult for computing students to understand the different domains (Kumar et al., 2020). For a computing department that wants to adopt HPC coursework, just getting started poses serious difficulties (Safar & Alkhezzi, 2019). More specifically, launching an HPC application is not a simple matter of creating a "hello world" program, as these applications contain multiple components that require different handling (Brusi et al., 2021). Therefore, HPC is obviously harder for domain experts who are not computing knowledgeable, requiring a serious learning curve (Andrew, 2020).

Cunningham (2017), reflects on the growing importance of parallel computing in undergraduate curricula, stating that previous curricular volumes had parallelism topics

distributed across disparate Knowledge Areas (KAs) as electives. Given the increased importance of HPC, “it seemed crucial to identify essential concepts in this area and to promote those topics to the core” (Van der Kleij et al., 2019, p. 29). As a result, computer systems introduced a new knowledge area in parallel and distributed computing (De Meester et al., 2020). Similarly, the CE2016 (the ACM/IEEE joint computer engineering) curricula report included several knowledge units in its recommendations such as multi/many-core architectures, distributed system architectures, system architectural design and evaluation, and concurrent hardware and software design (Vuopala et al., 2016).

Croteau et al. (2023) emphasised the identification of three major challenges in HPC that limit widespread adoption of HPC concepts in computing and engineering curricula. These can be characterized as W-HW, stands for What to teach (Curricula), How to teach (Practical Environments), and Who teaches (Faculty) and learns (Students). We discuss each of these in the following subsections (Croteau et al., 2023).

2.4.3.4 Funding constraints

The adoption of HPC and the continuous use of HPC requires a huge investment. The costly nature of the adoption of HPC is accompanied by the necessity of substantial ongoing capital and operational investments. Investments in HPC may additionally require investments in data centre space, power and electricity, air-conditioning, high-performance network access, and highly skilled staff support (Tyner 2018). Furthermore, HPC is time dependent as the rapid advancement in technology was found to a direct effect in its relevance on a particular era, which compel organisations to continuously invest on the latest technology in the market (Michalakes, 2020).

2.4.4 The integration and continued use of HPC in HDIs

Transue (2020) states that the interdisciplinary nature of HPC allows for numerous educational opportunities. Here, we provide examples of “low fidelity” HPC integration

into otherwise non-HPC courses. The idea here is likened to low-fidelity prototyping, where software designers focus on depicting concepts without significant time and financial investment in the development process (Darling-Aduana & Heinrich, 2018). Such low fidelity prototyping also requires little programming skill, allowing the implementor to focus on fundamental design (Vinogradana et al., 2021). Thus, this approach provides an opportunity for course designers with little HPC expertise to inject fundamental HPC concepts in the form of low-fidelity HPC components into non-HPC courses (Mattson et al., 2016). By identifying examples of such low-effort HPC integration, the way is paved for instructors who are non-expert in HPC to gradually introduce its elements into their courses (Shannon, 2017).

2.4.2.1 HPC in courses

HPC, like any other fast-paced, advanced and continuously evolving computing area—is rich with several exploratory and research opportunities, which lends itself well to meeting learning outcomes of broader Project-Based Learning (PBL), such as capstone and research courses (Becker & Quille, 2023). PBL has been shown not only to help staff and students understand a subject area better, but also to provide motivation (O'Brien, 2019). PBL is common in engineering education, allowing students to apply knowledge in a self-directed manner. For example, HPC project topics have been integrated into a PDC, though not necessarily HPC, coursework for software engineering and computer systems engineering students (Freiberger et al., 2016). In this course, instructors teach the fundamentals of parallel computing, and students can then self-learn and explore a wider variety of topics not formally taught by the instructors; these topics could include HPC (Copper & Cunningham, 2019). Students subsequently relay core concepts they learned in their individual projects through oral presentations in class.

Samuel et al. (2022) also explained that the pivotal need for HPC has led to the introduction of High-Performance Data Analytics (HPDA) as a new sub-discipline of data science 2013. Researchers active in HPDA have been exploring, evaluating, and

demonstrating the application of HPC technologies to data analytics challenges (Hassan, 2021). On the educational front, the ubiquity of HPC in data science applications means that many data science programs include material on Hadoop, Mapreduce, Spark, NoSQL, and other concepts in their coursework. The Park City report specifically mentions these topics in its curriculum guidelines for undergraduate data science programs (Townsend-Nicholson, 2020).

2.4.2.2 Broader Efforts

Several efforts have sought to integrate parallel programming concepts into courses that are not necessarily dedicated to HPC, giving rise to valuable lessons for other efforts looking to build on these (Squires et al., 2018). Despite the serious challenges of teaching parallelism to undergraduate students early in their course progression, there are benefits in exposing students to such parallel models early (Bondi, 2008). By merely letting students acknowledge the existence of parallelism, they become aware of parallelism and can apply it in later courses should they need it. In addition, students are typically thrilled to learn a real-world and relevant “hot topic” (Cook & Sonnernberg, 2019). Even without practical opportunities, a breadth-first approach in the form of paper discussions allows students to appreciate the wide-ranging relevance of parallelism (Asif et al., 2020).

Reinders (2021) states that many data science programs are situated in computing-focused departments or colleges. Computing-heavy curricula are more likely to present HPC concepts, while business and statistics-oriented programs are not. Given the importance of HPC in this field, this educational gap could be filled by the low fidelity approach discussed earlier, with more advanced courses available to the interested student.

2.4.2.3 Educational Tools

Although few educational tools exist for teaching “strictly HPC” content, several do exist for fundamental concepts that are relevant to parallel computing (Blumenfeld et al., 2011). HPC provides a large collection of activities, categorised into various course and curricula views, to help instructors find relevant material for their HPC courses (Broll et al., 2019). Parallel AR uses an analogy to visualise fundamental parallel scheduling policies, focusing on concepts without requiring students to program (Chen, 2016). Also recognising the importance of visualisation, TSGL is a thread-safe graphics library that helps instructors and students visualise the underlying execution of their parallel programs (Peckham et al., 2023). Block-based programming extensions are also starting to emerge, for both parallel programming and distributed programming (Brusi et al., 2019).

Cárdenas-Moncada et al. (2020) mentioned that from the tools and education aspects, HPC programming interfaces such as Spark, Hadoop, and their software stacks are intensively utilised in data science. These parallel and distributed APIs have generally met data scientists’ requirements in terms of high computational performance, while Big Data frameworks such as Spark have performed likewise in terms of high-level programming, resiliency and I/O handling (Kruchten, 2020). For less computing-intensive data science programs, plug-and-play options that require little technical intervention is needed to reach educational goals (Vavilala, 2020).

2.4.2.4 Building a Professional HPC Educator Community

Chen et al. (2020) state that attracting HPC researchers with good communication skills to the HPC education community can greatly reduce the pressure on instructors and allow the content of HPC education to be updated as the state-of-the-art progresses. HPC researchers can also benefit from the HPC education community. For example, researchers can decompose the latest scientific research questions and post them (Reed & Dongama, 2017). The questions can be followed by more students worldwide

and solved; research topics can attract the attention of more outstanding students all over the world, allowing their own research to expand in new ways (Saito et al., 2019). In short, we need to use the HPC education community to build a bridge between HPC researchers and students (Tom & Searcy, 2023).

Thaheem et al. (2021) explained how general-purpose resources are not enough to teach either HPC to the extent needed to achieve high competence in the areas. Given that it is very difficult to replicate real HPC settings using working environments available at most university campuses, students and educators need easier access to modern infrastructure for HPC learning and experimentation (Lui et al., 2022). This access could be provided by raising awareness about the available infrastructures and how to build them at low cost. One possible approach to accomplish low-cost construction would be to use "Budget Beowulf Clusters" that may not be truly HPC but help students and lecturers understand the concept of HPC, (Taimalu & Luik, 2019).

Noor et al. (2020) support the notion by expressing that, for temporary projects, cloud solutions are less costly for running HPC applications than using normal traditional HPC. Due to high cost, maintenance and large power consumption, traditional HPC vendors haven't built large HPC clusters. For small scale companies, running their HPC applications in cloud is better. That HPC cluster should have the capability to run multiple HPC applications simultaneously.

2.5 CHAPTER SUMMARY

The above chapter detailed the introduction and background of HPC together with the theories that align with the research concepts and also looked into the empirical studies relating to HPC including the determinants, benefits and impediments on the adoption and continued use of HPC. The next chapter presents the research methodology part of this study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

This section focuses on the research approach and paradigms, study area and population of the study, research instruments and data collection methods that were used and the ethical considerations that were taken to conduct this study.

3.2 RESEARCH PARADIGM

Perera (2019) explains that paradigms are general viewpoints or ideologies. Research paradigms are a set of common beliefs and agreements shared by scientists on how problems can be understood and addressed (Perera, 2019). Research paradigms can also be referred to as ways scientists respond to three basic questions of ontology, epistemology, and methodological questions (Perera, 2019). Deshpande (1983) and Mertens (2021) mentioned that a paradigm is a set of assumptions that provides a conceptual framework or a philosophical one for a world view, which enable researchers to construct organised studies around the world. Research paradigms can be categorised in positivism, interpretivism, post-positivism, Critical theory (ideology), Constructivism and/or Pragmatism. According to Lincoln and Guba (2000), a paradigm comprises four elements, namely, epistemology, ontology, methodology and axiology. Since this is a qualitative study, the researcher adopted research paradigm for interpretivism.

3.2.1 Epistemology

The epistemology of a research paradigm refers to how people come to know something, how people know the truth or reality (Krauss, 2005; Nguyen, 2019), or what counts as knowledge? Epistemology is another component of research paradigm dealing with how knowledge is gained from different sources. It is simply known as

theory and philosophy of knowledge. Trochim (2020) contends, “epistemology is the philosophy of knowledge or how we come to know p. 758”. Similarly, Saunders et.al (2019) describes epistemology as “the theory or science of the method or grounds of knowledge’ expanding this into a set of claims or assumptions about the ways in which it is possible to gain knowledge of reality” (as cited in Flowers, 2019, p 2). Epistemology poses the following questions: What is the relationship between the knower and what is known? How do we know what we know? What counts as knowledge? Epistemology in qualitative research means that the researcher tries to get close to the participants under study as possible. Thus, subjective evidence of the study critically depends on the participants’ view and on connection between researchers and participants (Patton, 2012; Okesina, 2020).

There are two broad epistemological positions: positivism and interpretivism. The term positivism refers to a branch of philosophy that rose to prominence during the early nineteenth century because of the works of the French philosopher Auguste Comte (Richards, 2003, p. 37; Fraser & Robinson, 2021). On the other hand, Interpretivism is a “response to the over-dominance of positivism” (Grix, 2004, p. 82). Interpretivism rejects the notion that a single, verifiable reality exists independent of our senses. This study adopted interpretivism because of the values and dispositions that influence the knowledge constructed through interactions, with the phenomenon and participants in the study.

The central point of interpretivist paradigm is to understand the subjective world of human experience (Guba & Lincoln, 2000). This means that concerted effort is made to understand the viewpoint of the research observer or researcher. This paradigm ensures that emphasis is placed on understanding the individuals and their interpretation of the world around them (Cooksey & Mc Donald, 2020). For this reason, interpretive researchers start with individuals and try to understand their interpretations of the world surrounding them, while actual words of individuals become the evidence of realities (Krauss, 2005; Makombe 2023). This mean that reality is interpreted through

the meanings that people give to their lives, and this meaning can be discovered through language or dialogue.

Interpretivism is based on the assumption that reality is subjective, multiple and socially constructed. This implies that people's reality can only be understood through their experience of that reality, which may be different from another person's shaped by the individuals' historical or social perspective (Grix, 2004; Scotland, 2012). Interpretive approaches rely on questioning and observation to discover or generate a rich and deep understanding of the phenomenon being investigated. This is closely associated with qualitative methods of data collection (Grix, 2019; Scott & Morrison, 2021). This study adopted an interpretivist study because the researcher is trying to understand the viewpoints and experiences of people using HPC.

3.2.2 Ontology

Ontology deals with the philosophical assumptions about the nature of reality or existence. It is simply called theory of reality. As stated by Scotland (2012), Okesina, (2020) explains that ontology is a branch of philosophy concerned with the assumptions we make in order to believe that something makes sense or is real, or the very nature or essence of the social phenomenon we are investigating. Similarly, in Krauss's, (2018) words, "ontology involves the philosophy of reality (p. 758)". Moreover, Scott and Morrison (2021) states that ontology deals with the level of reality present in certain events and objects, but more importantly with the systems which shape our perceptions of these events and objects (p. 170)".

There are two broad contrasting positions objectivism and constructionism; objectivism holds that there is an independent reality and constructionism that assumes that reality is the product of social processes (Neuman, 2003; Nguyen, 2019). Creswell (2017) reports that ontology relates to the nature of reality and its characteristics. Therefore, when qualitative researchers conduct research, they are embracing the probability of multiple realities. The researcher used the constructivist's perspective as it is subjective

and multiple, this was by means of interaction with the research participants to gather different viewpoints, opinions and interpretations of different participants in order to understand the phenomenon under study.

3.2.3 Methodology

Methodology refers to how the researcher goes about practically finding out whatever he or she believes can be known (Melnikova, 2018). It is a research strategy that translates ontological and epistemological principles into guidelines that show how research is to be conducted (Melnikova, 2018), and principles, procedures, and practices that govern research (Kazdin, 1992; 2003, cited in Marczyk et al., 2020). It “is concerned with the discussion of how a particular piece of research should be undertaken” (Grix, 2019, p.2). It is the methodological question that leads the researcher to ask how the world should be studied. Creswell (2014) alludes that methodological assumption is characterised as inductive, emerging, and shaped by the researcher’s experience in collecting and analysing data. Williams (2021) emphasises that methodology assumption aims to describe, evaluate, and justify the use of methods. Therefore, methodological assumption focuses on the research approach used as well as the data collection and analysis methods used (Saunders et al., 2019).

3.3 QUALITATIVE RESEARCH APPROACH

As the research approach is informed by the epistemological and ontological stance of the researcher, the interpretivist and constructivist nature of this study is associated with a qualitative research approach (Creswell & Clark, 2017). Hence, a qualitative research approach, which is exploratory and subjective in nature was adopted in this study because the study focuses on a phenomenon that is unfamiliar in the HDI context (Creswell & Clark, 2017). Qualitative research inquiry involves data collection of introspection, personal experiences, interviews, observations, stories about life, interactions and visual texts which are significant to people’s life (Aspers & Corte, 2019).

A qualitative research approach is informed by the interpretivism research paradigm and considers that a phenomenon can be researched fully, if the researcher can allow participants to explain what they feel about a given topic. In a qualitative research approach, the major goal is to gather facts then construct a theory from the findings. A qualitative research approach has several advantages which makes it to be widely used in the existing literature. One of the advantages is that it allows the researcher to observe how the respondents feel about the topic (Queirós et al., 2017; Martens, 2022).

According to Saunders and Lewis (2019), a qualitative research design allows the researcher to understand why the participants behave in a certain manner. The adoption of a qualitative research approach in this study enabled the researcher to directly get the participants' views and gain new insights about how the HPC affects behaviour in a historically disadvantaged institution. Thus, a qualitative enquiry assisted to explore people's behaviour, perceptions or perspectives, attitudes, feelings and experiences by means of a narrative approach through the use of semi-structured interviews (Mohajan, 2018).

3.4 RESEARCH DESIGN

Research design refers to the overall strategy utilised to carry that defines a succinct and logical plan to tackle established research question(s) through the collection, interpretation, analysis, and discussion of data (Claybaugh, 2020). Research design can also be defined as the use of evidence-based procedures, protocols, and guidelines that provide tools and framework for conducting a research study" (Majid, 2018; p.45). According to Fine and Hancock (2020), a qualitative research approach facilitates the exploration of participants' inner experiences and the understanding of how meanings are shaped by and within culture. A cross-sectional study that is exploratory in nature was used in this study to record the participants' actual experiences using HPC in an HDI. A cross-sectional study is a type of research design in which data is collected from any different individuals at a single point in time (Creswell, 2013). He also emphasised that the exploratory research is a methodology that investigates subjects and research

issues that haven't been thoroughly examined before. Rather of offering definitive evidence, exploratory research is carried out to ascertain the nature of the problem in order to have a better knowledge of the situation (Saunders et al., 2019).

Exploratory research is also often referred to as interpretive research due to its flexible and open-ended nature (Brown, 2018; Makombe 2023). Exploratory research is often qualitative in nature, linking the usage of a semi-structured interview as the main technique. For this study, both primary and secondary exploratory research methods were used; primary exploratory research was used in collecting data through interviews and secondary exploratory research was used by means of existing literature (Singh, 2019).

The purpose of this study was understanding the perceptions and experiences of employees and to allow for more a contextual engagement into understanding all the processes and behaviours associated with the HPC technology and how they are integrated by employees in the workplace. Thus, an exploratory design of a qualitative research approach was used to determine the opinions and attitudes of a population and to enable a much deeper understanding of the context and experiences surrounding this technology (Xiaoying et al., 2017).

3.5 STUDY AREA

Lewis (2019) states that study area is a geographic boundary created to define the extent of your analysis. In this study, the study area was based at a historically disadvantaged institution. The study area chosen for this research was the University of Limpopo, which is situated in Mankweng, Turfloop. This institution was chosen namely because it is named as one of the traditional HDI in South Africa. HDI's are known to be traditional institutions that are undeveloped or still developing and as such, a lot of area and phenomena are not explored. The aim of this study was to investigate the perceptions and experiences of employees on the adoption and continued use of HPC in an HDI.

Specific areas that were located for the possibility of this study were Mathematics and Physics Department, ICT department and Computer Science department. This was mainly because these were the only selected areas where employees had knowledge and made use of the integration of HPC systems in their daily activities. These are individuals that are likely to invest in the improvement of this technology, shared the experiences and perceptions regarding the integration of HPC and how it affects their behaviour.

3.6 POPULATION

Brown (2018, p.12) and Hammersley (2021) describes population in research as the “universe of units from which a sample is to be drawn”. In addition, Hanlon and Larget (2020, p.7) define population as “all the individuals or units of interest; typically, there is not available data for almost all individuals in a population”. The population of interest for this study focused on the employees at the Mathematics and Physics department, ICT and the Computer Science department in this historically disadvantaged institution. The rationale of selecting the individuals in these three departments was mainly because of their knowledge and use of high-performance computing systems on super computers and cloud computing. The study narrowed down to the population that had knowledge on the use of HPC specifically. Target population was an estimate of +/- 50 people from all three sections.

3.7 SAMPLING STRATEGY

A sample is a subset of the population that has been chosen for inclusion in a certain study (Peven et al., 2019). According to Tam (2020), qualitative researchers’ uses sample of settings, events, and processes and individuals. For this method, the researcher adopted non-probability sampling strategy in the form of purposive sampling. One technique for choosing units using a subjective approach is non-probability sampling (Creswell, 2017). The researcher intended to readily target the accessible population with specific individuals that might offer clear insight on the use of HPC and

how it influences behaviour, therefore they integrated a non-probability sample technique for this study.

Purposive sampling was used in this investigation. A collection of non-probability sampling approaches known as "purposeful sampling" pick units based on the qualities that a sample must have (Nikolopoulou, 2023). This approach entails expanding and improving the growing theory during the analytical process by following the data's lead (Ligita et al., 2020). Because participants in this study needed to be well-versed in both computers use and HPC systems, the researcher decided to employ this kind of sampling. According to Creswell (2017), you should choose participants carefully in order to see if they can shed light on your research subject.

3.8 SAMPLE SIZE

For this study, a sample size of 12 was conducted. This resulted from the available subjects who agreed to take part in the study voluntarily. According to Firchow and MacGinty (2020), a typical range for a qualitative study is eight (8) to fifteen (15) individuals. According to Creswell (2017), the typical range for a case study is three (3) to five (5) participants; for phenomenological research, it is ten (10) to fifteen (15); and for a grounded theory study, it is fifteen (15) to twenty (20). Some suggest 5–10 individuals, although this can potentially be as low as 4 or as high as 12 (Krueger & Casey, 2009). The sample consisted of participants from Mathematics and Physics department (10), and others from ICT (1) and Computer Science Department (1) who occupy positions as principal system scientists, researchers and technicians. These participants were selected because they had in-depth knowledge of how HPC technology works.

3.9 DATA COLLECTION INSTRUMENT

For this study, semi-structured interviews were integrated. According to Knott et al., (2022), semi-structured interviews are open-ended, allowing for the discussion of fresh

concepts that arise from the interviewee's responses. In a semi-structured interview, the interviewer usually has a list of themes they want to cover. Semi-structured interviews are frequently employed in qualitative research (Edwards, 2016). Using this method, the researcher made sure that every interview question was given precisely the same questions, in the same order and sequence, with space for clarifications and follow-up inquiries. This makes it possible to confidently compare responses between survey periods or sample subgroups, as well as to accurately aggregate responses (Elfil & Negida, 2022). Questions were organised in a sense of answering to the study research objectives and the aim of the study.

3.10 DATA COLLECTION PROCEDURES

Gate keeping permission was requested from the University Registrar and participants were located through the Head of Department in departments involved with HPC. This was then narrowed down to one department that dealt with the use of these systems specifically. A request email was sent to the Director of the centre and permission was granted. Participants emails were tracked using the University website. Emails were sent to potential participants during the months of February and March 2023, and appointments as per their schedules.

Interviews were conducted from March to May 2023, looking into the availability of the participants for face-to-face interviews. Follow-up interviews were conducted telephonically with the same participants between mid-April and mid-May 2024. The interviewing process began with structured questions, participants conversed about an inclusive variety of matters involving the variables in the study throughout a prolonged interview. These interviews were conducted during the stipulated months as per the participants' availability. All face-to-face interviews were recorded through tape recording device and varied in length from 10-40 minutes.

Memoranda was transcribed while attending taped interviews, typing transcripts, and reflecting upon an interview in addition to interviews. The researcher expected to

acquire additional information throughout this study, such as additional comments from the participants. The interviews were conducted until data was saturated. Saturation is an important indicator that a sample is adequate for the phenomenon studied – that data collected have captured the diversity, depth, and nuances of the issues studied – and thereby demonstrates content validity (Francis et al., 2010; Tam, 2020). All taped interviews, memoranda, and notes were entered into files and permission to use them was requested from the participants.

3.11 DATA ANALYSIS METHODS

Thematic analysis, also known as descriptive coding, is a method for analysing qualitative data that involves reading through a set of data and looking into patterns in the meaning of the data to find themes and sub-themes (Braun & Clarke, 2012). The researcher made use of thematic analysis and Microsoft Excel as a form of qualitative data analysis. The most significant aspect of qualitative research was the interpretation of data collected from respondents because data sources range from interviews questions, the written content must be precise and understandable.

Data analysis process involved dividing the data into more manageable units, allowing it to be grouped into meaningful patterns and themes (Saunders et al., 2019; Ringui, 2021). Themes and sub-themes were produced and classed through a hierarchical system and the themes were linked to the research objectives and questions (Ryan & Bernard, 2015; Hsieh & Shannon, 2019). The steps that were taken into the process of thematic analysis as suggested by (Mc Millian & Schumacher, 2014) are outlined below:

- **Familiarisation** - the researcher became familiar with some of the initial key words that were brought up by participants whilst transcribing the audio onto the Microsoft Excel sheet. This helped in identifying the key areas that were affecting the participants whilst answering the questions.

- **Coding** - The identification of key areas that were found whilst transcribing was grouped into codes that can be used as themes and sub-themes that the researcher can use in this study.
- **Generating themes** - Within the generated codes, the researcher identified a pattern and found key words that would accommodate the codes. Six themes were generated after the coding.
- **Reviewing the themes** – The researcher had to review and make sure that the generated themes names were able to accommodate all the incidents that led to all the participants answers.
- **Defining the themes** – Generating key words or names that would be suitable for all the collective answers from the participants. Those were generated as per the participant's similar responses.
- **Report** - The researcher reported on the participants' answers to the questions asked as per the themes that were generated.

The data was analysed using the Microsoft Office Suite (Strauss & Corbin, 1990). Worldwide, qualitative data analysis is done using the Microsoft Office Suite, particularly Word and Excel (Bree & Gallagher, 2016; Ose, 2019). As recommended by Ose (2016) and later by Martens (2022), the gathered information was converted from audio to text and stored in Word documents. After that, the text was moved from a Word document into an Excel spreadsheet for coding, and it was arranged according to the substance of related subjects. After being coded and sorted, the text was moved back into Word to be further organised, presented, and discussed.

3.12 RELIABILITY, VALIDITY AND GENERALISABILITY OF THE STUDY

Drost (2011) defines reliability as the degree to which measurements may be repeated by various individuals on different occasions, in different conditions, and ostensibly using different devices that measure the same construct or skill. According to Drost (2011), validity refers to how well a measure captures the underlying construct that it is intended to measure. Nikolopoulou (2022) explains generalisability as the degree to

which the results of can be applied to a broader context. Research results are considered generalisable when the findings can be applied to most contexts, most people, most of the time. According to Bajpai & Bajpai (2020), reliability and validity are psychometric qualities of measuring scales that are crucial for determining the suitability and accuracy of a scientific research's processes. While validity and reliability are frequently employed in quantitative research, the study's trustworthiness is the determining factor in qualitative research. This includes the use of the four criteria to evaluate or ensure the trustworthiness of the study, namely, credibility, transferability, dependability and confirmability (Drost, 2018).

- **Credibility**

According to Bryman (2012), credibility is a gauge of the validity of qualitative research and the degree to which the study's conclusions are true. To show that the research study findings are true, it basically asks the researcher to provide a direct connection between the findings and reality. In this research, credibility was ensured by means of reducing research bias by engaging with other researchers on related information and using existing research and ensuring that data interpretations are transparent.

- **Transferability**

Transferability refers to the extent of similarities between the research and other previously conducted research (Eriksson & Kovalainen, 2008). In this study transferability was ensured through the use of the researcher's findings conforming to the existing theories and literature review of previous studies. This will enable other researchers to be able to view results and findings and apply them to different settings.

- **Dependability**

Shanton (2004) and Tam (2020) explains dependability as the measure of the extent to which a research study could be repeated by a separate researcher and reveal the same findings. In this study, the consistency and the reliability of how the interviews were documented ensured the dependability of the study. Allowing participant

evaluations of the findings, interpretations from permitting someone outside the research to critique, follow and audit the research process.

- **Confirmability**

Confirmability in qualitative research is assured when data are checked and rechecked throughout data collection and analysis to ensure results would likely be repeatable by others (Patton, 2012). For the study, the research used descriptive coding to trail data saturation. Audit trail was used to ensure that confirmability is used in this study by detailing the process of using thematic analysis to code topic that were familiar for the formation of themes.

3.13 ETHICAL CONSIDERATIONS

When conducting research, especially qualitative research that may be personally intrusive and cause psychological pain, it is crucial to take ethical considerations into account. Kivunja and Kuyini (2017) underlined how crucial it is to keep ethical considerations in mind at every stage of the research process. Before beginning this investigation, the Turfloop Research Ethics Committee (TREC) granted ethical approval (See Appendix A). In order to assure ethical compliance, the Ethics Committee determined that all pertinent ethical standards that apply to this study have been taken into consideration. Since this study is qualitative in nature, McMillan and Schumacher's (2014; 2019) stated ethical principles—permission, wilful involvement, informed consent, risk and damage, anonymity, withdrawal, and confidentiality—have all been taken into consideration. The subsections below describe in detail the steps taken by the researcher to comply with research ethical principles throughout this study.

- **Permission**

Gallagher et al. (2010) state that permission is the action of officially allowing an individual consent to do a particular thing. A Turfloop Research Ethics Committee (TREC) certificate was issued. To conduct this research around the institution,

gatekeeping permission was requested from the University Registrar and once it was obtained, permission to conduct interviews was requested from the Director of the School of Physics and Mathematics.

- **Informed Consent**

Heath et al., (2019) state that providing informed consent to study participants meant that they understood what participation in the study involved and that they chose to participate voluntarily. Respondents were sent a consent form and an information sheet, stating clear specifics of the study. All participants were informed of all steps that will be taken during the interview process. The researcher provided full information of the study to the participants.

- **Wilful participation**

Lincoln and Guba (2000) explain that wilful participation is when people voluntarily participate in a study or research. In this study, wilful participation was ensured by notably letting participants to partaking in this study without being forced or feeling obligated. Participants were not forced to participate as subjects to the study, however they were informed of the importance of their contribution to the study.

- **Risks and Harm**

The study did not pose any physical or psychological risks or any other harmful risks to the participants for participating in the research. An invitation email and a request letter were sent out to participants containing details relating to the study and a request for interview appointments was issued on when data collection will commence as per the participants schedules. Participation in this research study posed no potential threats to the participants.

- **Anonymity**

An informed consent was signed by participants such that no personal data was obtained, and participants' identities remained anonymous throughout the course of the

study. During data analysis, the researcher made use of pseudonyms instead of their real names in order to protect their identities.

- **Withdrawal**

Before the start of the interviews, each and every participant was made aware that they can withdraw from the data collection/ interview proceedings if they felt like their rights have not been regarded.

- **Confidentiality**

Confidentiality involves protecting the identity and information of participants from unauthorized access or disclosure (Fitzgerald & Hamilton, 2012). Throughout the interview, confidentiality was maintained, and no personal questions were asked. The study's findings were analysed and made available to interested parties. Participants were given all necessary information to ensure that the risks and benefits of the study were recognised, and they were also advised that they could withdraw from the study at any given time.

- **Respect and Dignity**

The researcher respected all participants, irrespective of their age and gender. The researcher was polite and professional towards all the research participants to show them that their views, lifestyle, and beliefs were to be understood and respected even if they contradict those of the researcher.

- **Benefits**

The researcher informed the participants that the research was not conducted for any financial gain and that they would not receive anything apart from expanding their knowledge. The researcher promoted the safety of the research participants and provided them with information and knowledge that will be permanent after the study.

3.14 CHAPTER SUMMARY

This chapter detailed out and gave a full description on study area, research design, data collection method, data analysis, data collection instrument and the population of the sample of the study. Next, the researcher explored the options that could contribute to the reliability and the validity of the study. Ethical considerations were also pointed out and fully discussed and identified as a key step to take whenever data collection involved a targeted population. The next chapter discussed the data analysis and the findings on the study.

CHAPTER 4: DATA PRESENTATION AND DISCUSSION

4.1 INTRODUCTION

The chapter will focus on the analysis of the data collected in this study and thematic analysis was used. Thematic analysis is one of the most common forms of analysis within qualitative research (Clarke, 2017). It emphasises identifying, analysing and interpreting patterns (or "themes") within qualitative data. McQueen (2013) emphasised that themes and sub-themes emerged from the data collected through participants. Thematic analysis in the form of an inductive approach was used, whereby meaning was derived and themes identified from data had no preconceptions. Thus, the process of analysing data was done without any expected outcome (Clarke & Braun, 2013). There were nine (9) themes derived from data collection namely: Transition and behaviour on the adoption of HPC, Lack of exposure on HPC, Lack of funding, Lack of data, Load shedding, Solving complex problems, Cost efficiency, Innovation and Computer background. These themes were accompanied by six sub-themes.

4.2 DEMOGRAPHIC DETAILS

The participants that formed part of this study were of both males and females. Amongst those were three females and nine males. Their ages ranged from 25 - 45 years and they were all Black Africans. Ten had their PhDs in Computer science, Physics and Mathematics. One was a lecturer in accounting, and one was an IT technician. All questions were asked and answered in the English medium language. The experience and knowledge in the world of HPC was from 2-10 years. Their knowledge on HPC was advanced.

4.3 PRESENTATION OF FINDINGS

The chapter focuses on the themes that relate to the research objectives of the study. Thus, the presentation of the current study's findings in relation to the effect of behaviour towards HPC technology is structured according to three objectives.

4.3.1 The determinants of the adoption and continued use of HPC

A total of two themes emerged as determinants of employees' adoption and continued use of HPC in a selected HDI. These themes are computer language background and commitment to continuous learning as illustrated in Table 2. These two themes are discussed separately.

Table 2

Determinants of employees to adopt and use HPC in an HDI

N	(%)	Theme
5	42%	Computer language background
2	16%	Continuous learning

4.3.1.1 Computer Language Background

Computer language background as a theme linked to the determinants of the adoption and continued use of HPC was identified by 42% (N=5) of the participants. Computer language or programming language came up as many of the participants working in the material modelling centre, making use of HPC, were not familiar with the programming language and do not have any computer science background. The nature of the participants' duties requires good computer language background in order to run experiments and read calculations or rather understand certain things that are related to

HPC and programming. It would be much easier for participants to use HPC once they learn the HPC language. The extracts that support these are presented below:

Participant 3 said:

“My biggest challenge is that I do not have a background in computer science so time and again, you find that when, I have to develop certain aspects of my work that requires some sort of coding, it takes me a step or two back as I have to acclimatize and then get to work. Even if there is support, some things are too scientific and do not require system administration personnel”.

Participant 9 who works as a senior researcher also added by saying:

“I do not have the background as I did not do computer science, so everything that I know was self-taught attending workshops for beginners and staff. Having to do something requires asking for assistance”.

Participant 6 also supported this statement by saying:

“Background is usually the deciding factor when it comes to HPC. If you are not familiar with those machines, sometimes it might be a disadvantage to you if you do not have the knowledge, because most times, there is always an update in the programming language which could be difficult to alter through it, one needs some sort of workshop training and attending of programming courses in order to understand the programming language to be able to run experiments and projects efficiently. It is rather empirical for anyone who wants to jump into the world of HPC to at least learn the systems and the language first. It makes things less complicated”.

It apparent from the extracts that computer language background determines the adoption and/or continued use of HPC. Thus, poor background of computer language may influence employees' decision to adopt and/or continue to use HPC in such a way that hinders innovativeness and creativity. Previous studies revealed that individuals have problems in writing (McCracken et. al, 2019), reading (Lister et al., 2021) as well

as designing (Tenenber, 2016) a simple programming code, which requires good background of computer language.

4.3.1.2 Continuous learning

Continuous learning was identified by 16% (N=2) of the participants as a theme linked to the determinants of the adoption and continued use of HPC. For employees to make use of the adoption of HPC in the daily work and in societies, they do not need to learn HPC language only but keep up with updates as technology constantly advances. Hence, the nature of the participants' job involves using the latest technology in the market. The extracts below attest to this.

Participant 4 who works as a senior researcher also attested that:

“One challenge, even for people who have done computer science, is the constantly learning new computer codes, so one constantly has to check the updates”.

Participant 11 also stated that:

“One always has to be update with it comes to computer codes because they are the ones you have to learn first to understand the computer language”.

The continuous advancement in technology implies that makes it is almost impossible to know everything about the new computer codes in the absence of continuous learning, making it imperative for the participants to keep up with the use of new knowledge. This implies that the participants' commitment to continuous learning contributes to employees' adoption and continued use of HPC systems in the daily work. Studies by Cacioppo and Petty (1982) and Mussel et al. (2016) state that need for knowledge moderates the relationship between intentions and use, in such a way that when intentions to use a particular technology in a particular context are low, the effect of need for knowledge on actual use of that technology is strong. In a case when intentions to use this technology are high, an individual is already strongly convinced of its benefits and ease of use, the effect of need for knowledge on actual technology use

is weaker. Thus, their eagerness to continuously learn would enable them to acquire knowledge and skills needed to adopt and continue to use HPC. On the other hand, the lack of required knowledge and cognitive skills hinders chances of adopting or continuing to use HPC.

4.3.2 The benefits of the adoption and continued use of using HPC

A total of four themes emerged as determinants of employees' adoption and continued use of HPC in a selected HDI. These themes are solving complex problems, cost efficiency, innovation and job opportunities as depicted in Table 3. These two four are discussed independently in the following sub-headings.

Table 3

Benefits on the adoption and use of HPC

N	(%)	Theme
8	67%	Solving Complex problems
6	50%	Cost efficiency
4	33%	Innovation
2	13%	Job- opportunities

4.3.2.1 Solving complex problems

One of the themes the emerged in relation to the benefits of using HPC identified by the participants is its efficiency in solving complex problems. Solving complex problems as a theme was reported by 67% (N=8) participants. As the nature of their job involves solving complex calculations and running experiments, the use of HPC was reported that it enables the participants to efficiently and speedily solve complex calculations as well as running most experiments that are numerical.

Participant 6 explained that:

“HPC comes in very handy when it comes to large scale computing. A lot of industries make use of it in processing big data. Examples of sectors that can make use of HPC are agricultural sector, mining sector and the water and sanitation sector. In those sectors calculations can run in trying to predict the amount of water that will be needed, predicting the weather and the rainfall that is likely to forecast in a certain area. So, it makes work much easier even for other people, but it solely depends on the industry that you are working it”.

Participant 9 said:

“Since the integration of HPC, I think work has gotten so much easier. We run simulations and that requires for a very effective machine. Not only in academia, but also in the field of research, we deal with a lot of calculations and looking into our field, physics and mathematics are always on calculations. So, it is rather very important to use HPC especially now, we are busy with a battery project. For us to provide effective batteries with reliable power, we need to run and test the data on an HPC, so that we know that the calculations are correct”.

Participant 8 also added that:

“When working on HPC, one is about to pull simultaneously calculations and run them on the server without the system crashing. This really helps because I am able to solve big complex that would properly not be possible when using a supercomputer.”

Participant 1 supported the above the statement by emphasizing that:

“Almost 80% of the time, my colleagues together with the students are on the server, running calculations and experiments. Most of our work is reliant on the server so you can understand the capacity it has to withhold in order to accommodate all running calculations at the same time. With the support of the components and updates that we do on our servers, we are able to run big data on the HPC without the systems crashing, so that is one thing I like about HPC. Also, supercomputer is run manually by

the user, HPC stores everything in the cloud so it is better to use cloud even for storage purposes”.

Participant 2:

“High performance computing provides high performance when one is working, making it easier to work faster and more efficiently to meet your needs”.

Participant 2 also added to say:

“In societies, we run models that are of higher demands in resources. By using high performance computing, it allows us to run the experiments endlessly. When working with large data, it allows high speed of processing it. HPC is mainly about lightning-fast processing, that means that HPC systems can perform massive amounts of calculations very quickly in a very short space of time.”

Participant 8 states:

“HPC changes with time, it is better to save money by upgrading systems rather than buying a supercomputer”.

Participant 4 also stated that:

“With the use of HPC, I can work faster and accurately. I can get the results of my calculations quickly. Though, I don't have experience of using HPC in societies. This can be suited to those who are involved in community engagement workshops.

Participant 5 explained:

“As technology advances, we also found the use of HPC better than using a supercomputer, it is much better than the hardware computer. With HPC, everything is uploaded on a software system. Formulae are already set in the systems, so every calculation becomes easier to solve”.

The above excerpts show that the use of HPC makes it possible to access and handle big data effectively, efficiently and timeously to solve complex problems. The current

findings are supported by studies from Fernández et al. (2021) stating that HPC processes large amounts of data faster than standard PCs, provides faster insights, and provides enterprises with the opportunity to stay ahead of the competition. HPC solutions are millions of times more powerful than the fastest laptops. This capability allows enterprises to perform large-scale analytical calculations such as Millions of scenarios with terabytes of data. Cui et al. (2016), also supports the statement by stating that High Performance Computing (HPC) provides the ability to process data and perform complex calculations at quadrillions of calculations per second, orders of magnitude faster than ordinary high-speed computers.

4.3.2.2 Cost Efficiency

Cost efficiency as a theme in relation to benefits of employees' adoption and continued use of HPC was reported by 50% (N=6). This implies that using HPC is perceived as being much cheaper than using the traditional way of computing through supercomputers. The extracts that show the benefits of HPC are presented below.

Participant 6 stated that:

“It is cost saving to use HPC rather than the traditional way of computing. With HPC, one is able to analyse large complex data in a short amount of time and most programs run on a license that is paid once annually. So, it is much easier to make use of HPC to help with design material and running as assimilations without having to break the bank.”

Participant 10 explained that:

“If you are using a supercomputer to run applications 24/7, if applications are not frequent, they do not require special software, then they can be accessible to the cloud. HPC is cheaper to rent on the cloud than buy a supercomputer”.

Participant 1 added to say:

“In terms of computing, it solely depends on the simulations, calculations, and application other run better on supercomputer, some need HPC to perform better. Expense wise – preferably HPC”.

Participant 5 concluded to say:

“It is much cheaper to use clusters in HPC is much better than buying super computers”.

The excerpts above shows that indeed the use of HPC can benefit the organisation, which also serve to motivate that investing in HPC is an effective way of digitalisation. The current findings are supported Chaudhury et al. (2018), on the development of cloud HPC has meant that businesses do not need to invest in expensive infrastructure. In this case, HPC is usually rented via public clouds by Cloud Service Providers which is a more cost-effective solution for smaller businesses. HPC provides outstanding performance that enables organisations to do more at less cost (Chaudhury et al., 2018).

4.3.2.3 Innovation

Innovation is another theme that emerged in relation to the benefits of the adoption and continued use of HPC. It was reported by 33% (N=4) of participants. Thus, the participants perceive that the use of HPC has allowed for a culture of innovation and creativity. This is supported by the following extracts:

Participant 1 explained:

“Research studies are very important, many designs such as nano batteries and alloy should be taken into consideration. Optimizing of cost to get materials for the new developments and creations of the ideas that we want to initiate for the centre and the institution at large”.

Participant 3 also stated that:

“We are quite big in terms of innovation, batteries and alloys – study, highly intensive computational problems”.

Participant 6 emphasised:

“It is a very necessity for us to be creative and innovative because we are in competition with other institutions. Do research on new ideas/unique so to stand out. Perspective, new tools in order to develop new idea”.

Participant 4 added to say:

“We always must be innovative because of the running of simulations; upgrades are always introduced. Machine learning”.

Participant 12 concluded to say:

“Our day-to-day work focuses primarily on HPC through material modelling and has enabled us to navigate and gravitate towards finding solutions to current challenges such as energy storage. The development of the energy sector – development of new technology batteries, which I think is a fascinating subject that could bring excellent change to a lot of projects which require the use of electricity.”

Pyzer-Knapp et al. (2022) state that HPC systems are designed to process and analyse massive datasets at unprecedented speeds, enabling researchers, scientists, and engineers to gain insights, make discoveries, and develop innovative solutions to complex problems. These extracts imply that the use of HPC enhances the participants' innovativeness, which also show the participants positive view of the prospects of HPC integration. Studies from Shuja et al. (2017) support the notion by stating that HPC plays a pivotal role in advancing research in fields like climate modelling, genomics, astrophysics, and materials science. It empowers scientists to conduct simulations, run experiments, and perform data analysis that were once deemed impossible or impractical.

As a result, HPC accelerates the pace of scientific discovery and contributes to the advancement of human knowledge and understanding. High-Performance Computing (HPC) stands as a catalyst for innovation, driving advancements in science, engineering, healthcare, finance, and many other fields (Joel et al., 2015). Its ability to process massive datasets, simulate complex systems, and solve intricate computational problems enables researchers, scientists, and engineers to push the boundaries of what is possible and unlock new opportunities for discovery and innovation (Ponce et al., 2019).

4.3.2.4 Job Opportunities

The fourth theme in relation to the benefits of the use of HPC relates directly to the participants as employees as it focuses on the opportunities that are available in HPC. Job opportunities as a theme was reported by 13% (N=2) of the participants. They reported that HPC has opportunities of employment but only for those who get exposed to the work of artificial intelligence, which is supported by the excerpts below.

Participant 3 explained that *“I only got to be knowledgeable about the existence of HPC at the beginning of my post-graduate degree and because of that I am still learning on how to use HPC. And it is only when you take an initiative to learn more about that you realise how broad the field is. It holds a lot of employment for people who want to do it. I just think it needs to be given more attention and support so that other people also know about it”*.

Participant 2 supported that *“HPC has a lot of opportunities, good market with good money too. If only can gain knowledge about it, it would make so much of a difference because they are a lot of job on the mark and no people to hire because not a lot of people know about this expertise”*.

Career opportunities for those with HPC knowledge and skills are quite sufficient but more people are need into the field. Vavilala (2020) confirms by mentioning that High

performance computing is a good area to go into as people can use the skills that they have learnt as researchers, while extending my knowledge of computing. He further stated that HPC consultants also needs to be quick to learn, to keep up with the ever-changing landscape of high-performance computing.

4.3.3 The impediments of the adoption and continued use of using HPC

A total of four themes emerged as impediments of the adoption and continued use of HPC in a selected HDI. These three themes are load shedding, lack of data security, lack of resources and lack of exposure as shown in Table 4. The following sub-headings discuss these four themes.

Table 4

Impediments of the adoption and use of HPC

N	(%)	Theme
10	83%	Load shedding
8	67%	Lack of data security
6	50%	Lack of resources
4	33%	Lack of exposure

4.3.2.1 Load shedding

Load shedding as one of the impediments of adopting and using HPC systems was reported by 83% (N=10) of the participants. The participants reported that effective use of HPC requires the servers and supercomputer to always run calculations and experiments, which is hampered when there are regular power cuts because backup systems take time to kick in. Thus, load shedding makes it impossible for the HPC to effectively deliver what it is supposed to deliver, resulting in failed experiments. The excerpts below attest to this:

Participant 2 said:

“Frustrations are based on the outrages that we have, you might find that you are running a problem in an HPC facility, and you are in a remote setting and not in the server room, as a user you would be interfering with the experiment if there is an outage. This also disturbs the user accessibility and depending on whether if the facility does not have a sufficient back-up system, it would ultimately mean the disruption of whatever experiment or problem that was running and given the context of the University situation, you might have that translating to disturbing the users work depending on if it is possible to restart the experiment after the backup systems has kicked in, sometimes, you can and sometimes you cannot”.

Participant 9 supported the statement to say:

“As someone who runs calculations, load shedding is a huge factor that affects us. You find that you are running a simulation and then all of a sudden, there is an outage, and your calculations crash. It is only when there is a backup system kicks in, that you will now have a challenge called the queuing system, meaning you will have to queue to run your calculations”.

Load shedding can also have an impact on the hardware equipment machines and systems that are kept in the laboratory where some of the projects which have been running for months are done.

Participant 12 attested that:

“Load shedding messes up a lot of things because they are systems that must be air conditioned on a day to day basis and they are different filters of conditioning, some might need water and some need air generally, so if load shedding hits and the backup systems kicks in a little stronger, it would filter our air conditioner which could lead it to start to overheating which may then result in a multi-million and system to burn and get damaged. So not only does it pull us back in terms of our work but also irreplaceable expensive machinery that has to support us to continue doing our projects”.

Participant 7 suggested a solution by saying:

“In terms of load shedding, Limpopo has high exposure to the sun, we can use solar systems to take the sun rays and convert them into energy. In transmitting energy into powerful and useful energy, wind turbines in the Karoo area in the Western Cape can be of good use for that. How to store that energy, well we create batteries. The innovation of batteries can be used to store much needed energy. Which will also relieve electricity supply from power stations, and it will eventually decrease load shedding all together nationwide”.

Load shedding also result in data loss. The participants reported that since back-up systems do not kick in immediately, experiments and calculations that were running get wiped out because of power outage and in most cases, data that was running is sometimes lost and cannot be recovered, meaning that they must restart the systems, and run the experiments from the beginning. This posed as a negative effect to the effectiveness and efficiency of their work because if a huge amount of data was wiped out from the systems due to load shedding, it forces them to push back on deadlines and submissions that must be made. This is supported by the excerpts below:

Participant 3, who works as an Associate Professor in the centre said:

“Having to lose data time and again is very worrisome but then again, it has to do with policies of stakeholders like CHPC. Such stakeholders have a 90-day policy where you have to remove your existing data and all that. Because of such instances, together with load shedding, you find that there has been a project that has been running for an entire day and you are unable to recover it. You do not know if people have access to it. It is very unsettling”.

Participant 10 who works as a senior researcher supported this statement when he said:

“Data can easily be stolen if Cluster HPC or our institution in general does not have enough knowledge in computer building and. Transferring data from the CHPC facility

which is in Cape Town means they do not know what happens from the moment our data is uploaded and transmitted to the server and if the data is not secure, an individual can easily access and steal your research and claim it as theirs. Load shedding makes it worse because with all that happening, years of data can easily be wiped out and never recovered”.

Participant 12 who is currently doing his postdoctoral fellowship gave means to an existing solution when he said:

“Unlike an HPC system, a supercomputer is run by the user, so you know the systems that you use. It is much easier to run an application in the cloud, but anything can happen. Some data can be lost because everything has a loophole, so it is better to manage your information on the supercomputer rather than using an HPC system. With a supercomputer, no one will be able to access your information because you are able to solely encrypt”.

With load shedding being a national problem, this problem may hinder the adoption and continued use of HPC, until a permanent solution is found. This supported by Heifetz (2024) by opinionising that loadshedding is more than just an inconvenience, and it has real consequences on our daily lives, including our security. The loss of communication with alarm systems during power outages, the influx of false alarm signals and the impact on the false HPC simulations can all put our safety at risk. Both institutions and their organisations using HPC must take steps to prepare for and minimise the effects of loadshedding, such as investing in advanced technology, backup generators and alternative communication methods that offset risk (Heifetz, 2024).

4.3.2.2 Lack of data security

The second theme in relation to the impediments of the adoption and continued use of HPC is the lack of data security. The theme was identified by 67% (N=8) of the participants. The participants identified lack of privacy and strong security on the HPC servers when using HPC to run calculations and experiments. Thus, there is fear of

being hacked, whereby one's calculations or research are stolen and published without their knowledge and consent. This is supported by the extracts that follow:

Participant 5 reported that:

“Our servers are easily accessible from anywhere, one can go abroad and still be able to access our servers, meaning there is a high probability of being hacked so security has two layers. Since we go through the University, it must manage some layers of security and we systems scientists also have to configure and manage our own systems on the HPC environment. We sometimes must restrict access to other users both physically and through data because people can read your data”.

Participant 11 who works as a lecturer added to say:

“We need protection of our data, but we never really know how safe and protected it is because it is on a server that is probably used by thousands of people in an hour. Someone who is really good at cybercrime can easily get access to running data and steal it. We just need to be careful when we come to malware because it really takes us backwards in terms of research”.

With all these security issues that are being faced in terms of running HPC systems, two participants seemed to have a solution as to how they can configure the issue of privacy.

Participant 2 suggested that:

“Access has to be controlled into the premises because they are expensive. There are a lot of investments behind the running of the experiments. Time should be permitted into the premises, the use of biometrics, users' limitations, and control in terms of interfacing HPC. What kind of features can a user reach, the freedom and access that the user has, administration rights? These systems are usually remote, Security of the network level to see who is connected to your system and if there is an unauthorised person on the system, what measures can be put in place to safeguard access from the network

whether being a local or external network. Malicious software which would require system software or malware which would require the user to log in order to see the people who have logged into your systems”.

Participant 9 also recommended that:

“CHPC should work hard to protect information, we have a facility in the software that we can use to run calculations so that we do not expose our information to hackers”.

Data security seems to be one concern that employees using HPC in an HDI encounter because, it hinders the progress of innovation, there are solutions that they can implement in order to prevent loss of data. This finding supported Venkatesh et al. (2003) findings that showed that the strong effect of facilitating condition on the adoption of innovation is dependent on the environment receiving support from those who are important users (e.g., the teacher to students, the university administration to faculty) and not necessarily the use of technological systems. Ghosh et al. (2023) also stated that HPC system sadly suffered from many issues, such as lack of access and security concerns. HPC security concerns include honesty, integrity, availability, verification, permission, and confidentiality because the cloud storage service is focused on two ways sharing of data between service provider and customer. Consequently, the chance of compromising data is increasing and can be divide into two major groups: essential data and archival data (Ghosh et al., 2023).

4.3.2.3 Lack of resources

Lack of resources as a theme in relation to the impediments of the adoption and continued use of HPC was identified by 50% (N=6) as an impediment to participants towards the adoption and use of HPC. Participants perceive that there are certain software's and equipment that are needed when running certain projects and experiments and these may come quite expensive. The excerpts below attest to this:

Participant 2 states that:

“Looking from a provider perspective, equipment is expensive and for an institution of higher learning you do not always have a limitless budget so you might find that you have to work with whatever that is available and if something breaks, it takes time to get fixed. We use remote data centres and do pay on claim for certain software’s. It is more efficient to use the cloud if you are to run millions of datasets which is also cost effective”.

Another factor that is affected by funds is the license that they subscribe to from the providers, the license provides these employees with access to certain tools in the HPC system to efficiently store, run experiments and take advantage of all our services provided by them.

Participant 5 who works as a principal system scientists explains that:

“Using HPC is much more reasonable, but we would require funding in order to pay monthly subscriptions and they do not come cheap as we also pay for enough storage that runs calculations and experiments for weeks or even months”.

Participant 5 also added by saying:

“The renewal of licenses is also one challenge that takes us a step back because for it to be renewed, a certain amount of money is required and as we know how slow the processes and procedures are when it comes to this institution to process a purchase request, we end up with systems that are unable to run experiments because we are still waiting to finance to pay for the renewal of our licenses”.

Participant 7 statement also adds up to say:

“Money hinders us from a lot of things because HPC systems are quite expensive and not only machines, but all software bought from developers from abroad should be licensed. Also, the time it takes to purchase this software is very longitudinal because it has been approved by the National Reserve Bank so that hinders the progress of our research”.

Participant 8 who is also doing his post-doctoral fellowship attested to say:

“Funding, I wish a budget could be allocated to this centre for a period of 3 – 5 years so that we can take on any projects that we would want to facilitate with having to write a memo and put a lot of attachments on a monthly basis or annually. It discourages a lot of people because you do not even want to initiate a project that could make a significant change in the HPC space mainly because the funding process is really a drag”.

They participants reported that lack of resources prevents them from expanding their knowledge and implement their innovative ideas for the betterment of their performance through the use of HPC.

Participant 1 who works as an ICT technician stated that:

“Working with this institution, resources are really hard to find because of the length process that is required, most of the time we work with what we have because of the limited resources and funding. It is frustrating sometimes but because I love what I do, it doesn't really matter, in as long as I am still able to run calculations and experiments”.

Participant 2 had a different. He explains that:

“Technology is rapidly accelerating, products are there but you may find that the software's that you are using is outdated, compared to the hardware, this then causes a disconnect and you might find that, perhaps if it was advances, it would have been able to take advantage over the new hardware architecture but because you are limited by the developers of the software then it becomes a challenge because you do not have the readiness to make use of the new technology unless if you have a way of advancing the technology yourself”.

Participant 3 also supported the above-mentioned statement by saying:

“I think with every source of support that we need; we always must make an extra effort and explain to management the importance of our resources and why we need them. We really need to motivate a lot, which could be discouraging sometimes because of

how long of a process it is. It would really be great if we had management that is hands on and is involved in the world of HPC, to also understand the latest trends so that we get spontaneous support and be motivated to take on projects that can improve our centre”.

Participant 4 who works as a senior researcher also supported the statement by saying: *“I wish people outside of Physics and Mathematics knew more of HPC systems, how they function and what they could do for this institution, that way whenever we needed certain resources and equipment’s for our experiments, processes would be put in place much quicker, and they would be prioritised because they are then it would yield us effective results that are more research developments”.*

With the evident gathered from the research, participants have greatly expressed that they have feelings of dissatisfaction when it comes to the implementation of certain projects due to the lack of funds and resources. Participants’ responses stipulate that behaviour does not affect the use of HPC technology because behaviour does not necessarily affect how one intent to use technology but rather it depends on the employee’s subjective evaluation of the consequences of using this technology. This is supported by Ajzen and Fishbein’s (1980) that a person’s attitude towards a behaviour indicates an assessment of the behaviour and its result lends credence to this. Additionally, a number of research have discovered that a significant factor influencing behavioural intention to use information technology is the subjective norm (Moore & Benbasat, 1993; Hartwick & Barki, 1994; Fusilier & Durlabhji, 2005; Jong & Wang, 2009).

4.3.2.4 Lack of exposure

Lack of exposure was another theme that emerged in relation to the impediments of the adoption and continued use of HPC. It was identified by 33% (N=4). Participants emphasised that it is it rather difficult to enjoy the benefits of an integration of HPC

because most employees are not exposed to the use of HPC, meaning that they have little or no knowledge about HPC systems. The excerpts below attest to this:

Participant 2 explained that:

“Giving direction helps but it depends on the audience, in order for one to give direction they should be able to understand the standpoint of the audience. It would mean getting a sense of understanding if employees are completely unaware of using HPC computers or they do not know what can be done when the scaling of computing is increased. A system that is able to be integrated. Explain detailed networking and the technology involved and how it integrates, training and workshops. In the institution, we try to bring to a level of our students through such a student cluster competition to make them aware of HPC, so exposure is important”.

Participant 9 also attest that:

“People should be exposed to HPC, but it usually depends on the background that the individual has, it requires dedication and curiosity. The internet is your friend, it will provide you with a lot of information, get yourself into a community, and it will greatly assist”.

Participant 5 also added to say:

“It is very easy to learn HPC. During outreaches and competitions, we can give students access to servers in order for them to be able to do practicals. Employees who also have an interest, can join”.

Participant 7 also emphasised on the fact that:

“I think organisations are already exposed to HPC; the problem is just basic education. Standard bank is moving hybrid, and a lot of organisations are transitioning to HPC. Big companies like SASOL which now has a lab, Nexus and MINTEC are fully transitioning into HPC because HPC is cost effective and will reduce trial and error”.

Participant 8 is of the view that:

“I would rather have people come to the centre to try and expose them to these CHPC. It requires a will from someone to be interested in these things, people have a like and dislike in certain things, so someone’s interest will peak during the little exhibition that we will have”.

Participant 3 also supports by saying that:

“Practical work is really important, having people engaged. People get to be acquainted and experience an application. We go as far as a career exhibition, but I believe that learners from as low as grade 8 should be exposed. It should be added into their curriculum so that we have brilliant minds that are sharpened at a really young age”.

These findings imply that more people needed to be exposed to HPC and that can only happen if people to know and learn about it. Sterling (2017) supports these statements as mentioned that HPC is not a new concept and still needs to be extended to individuals outside of research and science. HPC should be explored by different disciplines.

4.3.4 Integration and continued use of HPC in HDIs

Table 5:

Mechanism for adoption and continued use of HPC

N	%	Theme
4	33%	Education, Training and Development

4.3.4.1 Education, Training and Development

In relation to how the integration and continued use of HPC can be encouraged in HEIs, only one theme emerged, namely, education, training and development. The use of education, training and development programmes to influence the behaviour of

employees to use and continue to HPC. This sub-theme was identified by 33% (N=4) of the participants. These is supported by the following extracts:

Participant 2 explained that:

“Institutions of higher learning should take an initiative into integrating mandatory HPC courses as part of training and development in order to broaden the scope of employees and for them to be able to effectively use HPC in their daily work activities”.

The participants made aware that there is a need for intervention into integrating the right education and knowledge needed for more people to learn the HPC technology and the only way is to start small. Reaching out to students from high school and those in their undergraduate will help grow the interface of more and more people being knowledgeable on the use of HPC for future years to come. Therefore, cognitive needs affect the intention to use HPC because it is important for employees to couple with the necessary cognitive skills in order to be able to use HPC in an HDI. According to research by Nazar (2008), cognitive abilities have an even greater impact on technology use intentions than personality models do. Information systems research has shown that using human variables is crucial for forecasting how people would use and adopt technology (Lucas, 1981; Nazar, 2008).

Participant 7 stated that:

“I form part of the outreach community; the common mistakes that schools make is that they are scared of letting students learn science streams or rather mathematics. They force them to do Mathematics literacy so that passing rates look much better, but quality is compromised on the science side. Automatically you cannot do computer science so we figured, we can work with the undergraduates and make them have an idea so that they move away from traditional careers like medicine and lawyers because HPC has a lot of careers”.

Participant 4 stated:

“High school is where the problem starts. How the curriculum is set is actually wrong because I was only exposed to HPC and had to learn the HPC language as a whole when I was doing my masters. Imagine if I had the knowledge when I was an undergraduate, it would have made a big difference. What we are currently doing together with the school of physics and minerals, we are engaging in changing the curriculum, we are targeting doing a winter school where we will take in the 3rd year who are doing what is in line with computer science which will expose them to HPC because most of them are exposed to HPC when they do their Honours because they have to choose projects”.

Participant 6 is of the opinion that:

“We might need to do outreach, visit schools, invite matriculates and school learners to expose them to HPC and artificial intelligence of some sort because if they are not informed, we will have a lot of people who are not involved which then hinder development. Workshops will enlighten them and do practical’.

The need to revise the curricular by integrating HPC related modules in some of the current formal qualification was emphasised. Thus, Undergraduate degrees containing an introduction module into HPC in order for students to know about Material Modelling and HPC while introducing advanced modules for Postgraduate degrees.

Participant 1 said:

“The government should be the driver of interest so that it is able to incorporate such knowledge into young and upcoming people so that they can be curious into learning HPC. Users are interested in their outcomes. Its outcomes are in research, and perhaps people have been battling with routine mode of operation and are made aware of an acceleration then the interest will change in making use of HPC systems. Only people who know and have learned about HPC can have a reaction to it because of what it is capable of doing. There is potential influence. There is a need for capacitation and change of setting”.

Looking into the perspectives of different participants, the researcher has concluded that exposure and an integration of certain education, training and development needs may assist people to be able to use HPC effectively and thus enjoy the benefits of HPC. If employees and people are not equipped with a certain aspect of technology, there is no fascination or eagerness to learn about. Exposure together with the right amount of knowledge can get other employees interested in integrating HPC Technology. Hence, outreaches and initiative programmes in high schools and tertiary institutions to introduce HPC and to also integrate certain modules were considered important. This supported by Shields (2020) by emphasising that some universities and many HPC centres worldwide promote broad involvement by offering some HPC curricula at undergraduate or graduate levels.

There has also been steady progress in the creation of educational materials and with the formation of a community of educators that can aid future efforts. In particular, the Curriculum Development and Education Resources (CDER) center provides a detailed curriculum and parallel computing undergraduate courses (Hunter, 2019).

4.4 CHAPTER SUMMARY

The above chapter presented data analysis and the presentation of findings. The composition was based on the demographic details of participants who took part in this study. Participants' responses were grouped into themes in line with the research objectives and questions and presented on tables. Two (2) themes, computer language background and continuous learning emerged as determinants of the adoption and continued use of HPC. The following four (4) themes emerged in relation to the benefits of the adoption and continued use of HPC: solving complex problems, cost efficiency, innovation and job opportunities. The themes that emerged in relation to the impediments of the adoption and continued use of HPC are four (4), namely, load shedding, lack of data security, lack of resources and lack of exposure. On the other hand, only one theme, education, training and development emerged with regards to influencing the integration and continued use of HPC can be encouraged in HDIs.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

The chapter provides a summary of the methodology adopted in this study as well as the research findings which were guided by the objectives of the current study. This is followed by the recommendations for this study, the study's contributions, and its limitations as well as future implications.

5.2 METHODOLOGY

This study was based on both the epistemological and ontological stance of the researcher, the interpretivist and constructivist nature of this study. The study adopted interpretivism, which is based on the assumption that the values and dispositions that influence knowledge are constructed through interaction with the phenomenon. Thus, a qualitative research approach was adopted, whereby the constructivist's perspective, which is subjective and multiple, provided for interaction with the different research participants to gather their different viewpoints, opinions and interpretations in order to understand the phenomenon under study. Hence, a qualitative research approach, which is subjective in nature was adopted in this study (Creswell & Clark, 2017).

According to Saunders and Lewis (2012), a qualitative research design allows the researcher to understand why the participants behave in a certain manner. The adoption of a qualitative research approach in this study enabled the researcher to directly get the participants' views and gain new insights about how the HPC affects behaviour in a historically disadvantaged institution. Thus, a qualitative enquiry assisted to explore people's behaviour, perceptions, and experiences by means of a narrative approach through the use of semi-structured interviews (Mohajan, 2018). The study was exploratory in nature, which enabled the researcher to investigate research questions that have not been previously studied.

5.3 SUMMARY OF RESEARCH FINDINGS

The discussion below provides the research findings of existing studies relating to the research questions which are guided by research objectives namely, to determine the perceptions and experiences of employees on the adoption and use of HPC, to explore the benefits and the impediments of using HPC and to establish the determinants of using HPC in a historically disadvantaged institution. Therefore, the preceding chapter discusses the key findings in line with the objectives. The results of this study will be beneficial for understanding the different perceptions and experiences that employees have towards the use of high-performance computing. From the collected data, ten key themes emerged, two from the first objective, seven from the second objective and one from the third objective. These themes answer to the research questions of the study.

5.4 RESEARCH QUESTIONS

5.4.1 The determinants of the adoption and continued use of HPC in HDIs

5.4.1.1 Computer language background

Research participants emphasised the importance of having computer background when dealing with the basis of HPC because of how tricky it can get. Having foundational education and knowledge on programming and computer science serves as a good standard for learning about HPC. Most participants reported that were from the physics and it became difficult to learn coding from the beginning. Duval et al. (2021) questioned, Who Teaches and Who Learns? HPC remains a challenge for both computing employees and researchers. Staff recruitment for HPC courses is a major problem in this field. Employees need to be convinced that the HPC field is important enough to justify taking on extra credit hours in their already challenging programs (Cooper & Cunningham, 2019). As a result, most computing employees do not have sufficient knowledge of parallel computer architecture elements such as an HPC interconnection network, different execution models for various architectural types

(distributed, shared memory, Working Group High Performance Computing Education, common parallel algorithms, and high-performance analysis (Cooper & Cunningham, 2019).

Participants proposed that enrolling into initiative coding programmes and workshops assist in keeping up with the upgraded computer language and features that are included when working with HPC.

5.4.1.2 Continuous learning

Participants emphasised on how constantly the programming language changes that they must keep up with the changes, which is normally not easy. Kumar et al. (2020) attests that interdisciplinary area for non-computing majors can come across extensive. Computational science creates advanced models that require a mixture of knowledge of mathematics, computing, and domain science and engineering expertise. Many of the curriculum changes occur regularly at graduate levels where the students have the appropriate disciplinary background to understand the systems being modelled and the challenge of advancing research in their own disciplines (Theis & Wong, 2019). It is not uncommon for employees and researchers to learn important skills and techniques through less formal means, such as workshops and training sessions provided by HPC research centres (Hazzen, 2020).

Several graduate interdisciplinary programs in computational science have emerged in the physical sciences, materials science, atmospheric science, biological sciences, and earth science. Although somewhat unique, each program generally provides advanced work in the research challenges within the discipline, along with courses on the application of HPC to those challenges (Ben-Ari, 2023).

5.4.2 The benefits of the adoption and continued use of HPC in HDI

5.4.2.1 Solving complex problems

The participants mentioned how beneficial it is to use HPC rather than super computers because of how easy it is to run multiple simulations at a time. That way, the participants can upload multiple experiments and calculations on the server. Reed and Dongarra (2015) emphasised that HPC is mainly about lightning-fast processing, which means HPC systems can perform massive amounts of calculations very quickly. In comparison, regular processors and computing systems would take longer – days, weeks or even months – to perform these same calculations (McCurry, 2020). High Performance Computing assists in processing larger amounts of data, running analytics, and other applications. In many ways, HPC provides the framework and performs the background work that allows Artificial Intelligence (AI) to make sense of all data available and present it in a way that is easy to understand and utilise (Gangman & Vincenzo, 2019).

Naps et al. (2022) support that High Performance Computing is a technology that uses parallel processing to process data and perform complicated calculations efficiently and reliably at high speeds. This solution provides the computing power and performance needed for running advanced applications and solving complex problems. Marco et al. (2018) state that HPC is made possible through the convergence of different technologies under one system, such as computer architecture, algorithms, system software, programs, and electronics. This technology was initially a use case for scientific research by academic institutions to assist with processing, storing, and reporting on large amounts of data (Gordon & Cahill, 2020).

5.4.2.2 Cost efficiency

HPC efficiency relies mostly on software rather than the hardware. Findings showed that participants relied mostly on using HPC because simulations and experiments are run on the cloud. They emphasised that it saves more money, than buying actual

hardware supercomputer. They rely on renewing their licences. Little et al. (2019) mention that HPC system can process faster, applications can run faster and yield answers quickly, saving time or money. Moreover, many such systems are available in “pay as you go” modes and can scale up or down as needed, further improving their cost-effectiveness. HPC can be more cost-effective than on-premises HPC (Little et al., 2019).

Cloud HPC is more reliable than on-premises HPC. HPC systems can process massive volumes of data and execute simulations and other activities faster than ordinary computers, increasing the efficiency of commercial processes significantly. This can result in cost savings and allow firms to accomplish more in less time (Harvey et al., 2022). HPC systems can assist businesses in cutting costs in addition to boosting efficiency. Businesses can cut down on the demand for human labour and streamline their operations by automating procedures and tasks (Wilson, 2021). Over time, this may result in considerable cost saving (Rodger, 2022).

5.4.2.3 Innovation

The study showed how participants are of the notion of innovation. Most innovation that participants are mostly focused on are machine learning and alloy batteries to reduce the effects that come with load-shedding. A study by Pfothenauer et al. (2019) showed how an obscure association uses HPC technology to remain remarkably flexible in work settings. Automation and technological innovation have increased productivity over time, decreased effort required to perform jobs, and positively impacted how personnel respond to new innovations (Acemoglu & Restrepo, 2019). Innovation will bring about revolutionary changes and an improved working environment for employees, according to research on the relationship between technology and innovation (Kourtit & Nijkamp, 2012). However, according to predictions made by Monterio (2018), it is said that the effects of technological innovation on the workforce have usually been gradual, giving workers time to adjust to new developments.

According to Rogers (2020), use of highly new technologies like HPC may foster differentiation, provide the employees with considerably greater benefits for their daily activities, and lead to competitive advantages and more efficiency in HDI's. Sometimes, O'Connor (2008) technological change can induce a new value proposition that has not existed before. Even if old employees might not appreciate this new functionality, this can open opportunities for fringe and new advancement and growth (Christensen, 2019). Therefore, higher technological innovativeness will induce higher market innovativeness in tertiary institutions and better the work of employees in the research and academic space (Page & Shirr, 2018).

5.4.2.4 Job opportunities

Participants working with HPC explained how HPC has diverse opportunities of employment that individuals require accessible information for them to know about opportunities in HPC. Studies support the notion of HPC technology being a more innovative technology in the success of HDI's for the development of more career choices. Venkatesh (2013) findings showed that the strong effect of facilitating conditions on the adoption of innovation is dependent on the environment receiving support from staff that are users and makes it easily effective for the creation of more job opportunities (e.g., the teacher to students, the university administration to faculty members). In the case of a school environment, support services are always available to assist, this then assist students to pick more specific career choices based of the information they find (Wang, 2016). Zhou et al. (2009) found that highly innovative products that incorporate radically new technological knowledge offer higher product quality and value to employees in an HDI.

5.4.3 The impediments of the adoption and continued use of HPC in HDIs

5.4.3.1 Lack of data security

Findings show that, because HPC is ran on the cloud using a server, it is prone to hackers and cybercrime. Participants also supported the statement as they stated that it is difficult to run multiple simulations at once because most users log on to the users and can see what other users are doing. An experiment or a study can easily be stolen if simulations are not encrypted. Brett et al. (2019) note that a common concern when migrating HPC workloads to the cloud revolves around data security and compliance. Cloud providers, cognizant of these concerns, offer robust security measures and compliance certifications. While these offerings address most challenges, organisation must still assess their specific regulatory requirements before making the transition (Levy, 2023). Data security is important in order for organisation to keep their HPC servers secure while running experiments or simulations. Cloud providers have a vested interest in keeping their infrastructure secure, but businesses need to make sure that their data is protected in the cloud. This includes using strong passwords and encryption and being careful about who has access to the data (Chen et al., 2020).

Additionally, businesses need to be aware of compliance issues related to regulations that restrict the use of HPC services. Businesses need to verify that they are compliant with all applicable regulations before they migrate to the HPC.

5.4.3.2 Lack of resources

Beaumont et al. (2019) state that HPC potential is enormous, but challenges remain. A key challenge is to close the investment gap in HPC facilities and resources and to ensure that businesses, public sector authorities and researchers have equal access to HPC facilities and services. In fact, while a third of the global demand for HPC capabilities comes from computation industry, SMEs and researchers, currently only 5% of the HPC capabilities are being provided by HPC centres (Castellana et al., 2019). To

close the investment gap, significant investments in infrastructure, access to Big Data, the development of tailor-made complex software solutions, as well as investment in new business development are needed (Matthews, 2020). As we understand both the unique opportunities and the important challenging funding conditions supercomputing projects are facing in the Africa continent (Sterling, 2017).

Andrew (2020) clearly lays out the steps and actions needed to improve access-to-finance conditions for supporting the growth of this strategic sector in HPC. This study demonstrates that, in addition to the continuous use of grants, more advisory support is required to strengthen the HPC ecosystem and establish the building blocks for enhancing funding models in this sector. The combination of grants with financial instruments will unlock the unprecedented opportunities offered by the next generation of supercomputers.

Harvey et al. (2022) explained that in HPC, there is a limitation of practice environments. Unlike multicore parallelisation, HPC presents unique problems of large-scale parallel systems such as scalability, parallel efficiency, heterogeneous computing, parallel storage systems and energy efficiency. These components require space and support (Anderson & Taylor, 2021). HPC education should reproduce these unique problems; however, the current practice environment, resources and support does not provide an immersive experience. Besides, effective practical exercises from real application cases are also essential for an immersive practical environment. Most of the real application cases cannot be directly used for teaching content because they tend to be too complex for people's understanding (Joel et al., 2018). Researchers and employee must be able to decompose real-world complex problems into smaller detailed forms so that they can understand how HPC can be applied.

5.4.3.3 Lack of exposure

In recent years, cloud computing privacy and security issues have been a popular topic (Mullen, 2021). Data privacy, data protection, data availability, data location, and secure

transmission are the most pressing concerns in cloud data security. Threats, data loss, service disruption, outside malicious assaults, and multi-tenancy difficulties are among the security challenges in the cloud (Mullen, 2021). Users of this technology outsource their data to a cloud provider's server located outside of their premises (Neelima, 2018). Memory, processor, bandwidth, and storage are also visible and accessible via the Internet by a client. By focusing on privacy protection, data segregation, and cloud security. Chen et al. (2018) investigated privacy and data security challenges in cloud computing. Data security issues are primarily at SPI (SaaS, PaaS, and IaaS) level and the major challenge in cloud computing is data sharing (Ponce, 2019).

This paradigm shift that comes with cloud computing usage is increasingly causing security and privacy concerns about aspects of cloud computing such multi-tenancy, trust, loss of control, and accountability (Asif, 2023). Before consumers and businesses use cloud computing, users' security concerns must be addressed in order for the cloud environment to be trusted. The trustworthy environment is the basic prerequisite to win confidence of users to adopt such a technology. The assessment of cloud computing hazards was examined by Latif et al. (2020). In other research, cloud infrastructures are combined with unique services aimed at specific businesses. To put it another way, the cloud is designed to provide specific services to clients, such as cloud computing for manufacturing or cloud computing for health care (Meier, 2014).

5.4.4 The integration of HPC in HDIs

5.4.4.1 Education, Training and Development

Educational tools are lacking, according to Wienke et al. (2019). Teaching loads are a problem for institutions. Teaching HPC courses has traditionally been the domain of one or a small number of courses, whose instructors also have to manage teaching responsibilities for important departmental courses or, in the case of research, grant work and the department's overarching research initiative. Although academic HPC researchers have extensive backgrounds in HPC engineering, they frequently

concentrate on their own work because they understand how important it is to produce graduates with a wide range of talents in HPC (Sterling, 2017). Because of the rapid development of HPC technologies and the limited availability training and developmental tools, the average employee lacks the vision and HPC knowledge to learn and teach on HPC for both students and to employees, but more will be able to do so if course materials are provided and readily available for use in an average lab (Duval et al., 2021).

5.5 RECOMMENDATIONS

Based on the results, the following recommendation were made:

- The key to successful engagement with HPC for nontraditional users is to start early to create fluency, expectation and to provide the opportunity to support innovation and new discoveries. Therefore, it is recommended for the embedding of HPC in the university curriculum in different programmes and over different years of study to allow for the building of a relationship with employees on the timeline needed to foster mentoring and coaching for those who wish to explore the area further and facilitates diversity.
- It is recommended that the public sector initiate for the development of strategic and enabling HPC infrastructure. The availability of high-end and best in class HPC systems (such as exascale supercomputers) is a key building block for the next wave of digital innovation based on Deep Tech. Public investments in this area have the potential to generate significant public value in the form of economic and societal benefits and returns.
- It is recommended that the institution should comprehend how anticipated developments in HPC technology could affect workers in various departments. The organisation should develop a change management and communication strategy that capitalises on the employees' present perspective of the future after the future state has been established.

- The study's findings highlight the significance of paying attention to workers' cognitive requirements in the HPC industry. This is recommended because it will lead to more HPC technology being used inside the organisation, not just in one department. McConnell et.al (2017) also supported that other staff members in the organisation can be taught to HPC technology using active learning techniques like programming and machine learning.
- It is recommended that since a large part of the scientific endeavour is currently heading towards handling massive amounts of data, institutions and countries who wish to stay ahead must invest not just in HPC infrastructure, but also into enabling researchers to actively apply HPC to their research. Thus, the researcher believes that more effort needs to be put into developing best practices for integrating learning HPC as part technical skills for those who are in computer science and IT.
- When equipment and training is provided, the attendance of employees on HPC technology often gives sub-optimal results, in which it does not lead to improvements in employees' skills and does not bridge the gap between the attitude and the intention to adopt the technology, hence it is recommended that employees inhouse training is provided to all employees working on HPC facilities (OECD, 2015; Pérez-Sanagustín et al., 2017).
- Arguably, adoption of HPC and its optimal use in historically disadvantaged institutions requires an investment in technical equipment and training, but also an investment in the tools of the mind that practitioners in this occupation use. Most commonly employees who make use of HPC systems refer to external barriers such as insufficient equipment, lack of software/hardware training or insufficient class time to adopt fully HPC (Pelgrum, 2018). Hence, it is recommended that staff members actively participate in the creation of HPC learning resources rather than just performing pre-made assignments.

- The TPB theory also has provided useful insights into predicting the intention of HPC in an education sector used for academic purposes among employees. Such a finding has important practical implications for enhancing employees' learning processes with the use of the HPC technology. It is recommended that the implementation institutions to be equipped with resources that will help employees use HPC more effectively.
- Furthermore, since our turnout for participants who were knowledgeable about HPC was low, it is recommended that the setup needs to be repeated with several other groups of researchers in different institutions, to achieve a higher sample overall sample size.
- It is recommended that faculty, staff, and other university personnel should foster an atmosphere that encourages a positive attitude and perception of using HPC technology for research, administration, and academic purposes. This is because these attitudes will translate into positive learning behaviours and, ultimately, positive outcomes (Fusilier & Durlabhji, 2005).
- Positive learning experiences in higher education institutions require creating and putting into place the learning HPC infrastructures required to improve and enable HPC's perceived utility and simplicity of use at historically underprivileged institutions.
- Furthermore, it is recommended that employees should be offered short term programming and HPC courses or workshops to those eager on the use of HPC in order to develop their sense of self efficacy and ease of use. By doing so, their attitudes toward technology will be positive.

5.6 CONTRIBUTIONS TO THE STUDY

This study contributes to the existing body of knowledge in different areas of research, for people to understand that adoption and use of HPC does not only apply to certain sections in higher education institutions such as Physics and Mathematics but also in areas of Human Resource, Agriculture and Mining. This study contributed by means of explaining the perceptions and experiences that employees have when using HPC, supported by the theories and the existing empirical research.

Observation on universities, there seems to be a few studies relating to the use of HPC in a lot of disciplines. Especially when looking into the exploring behaviour and how people can use knowledge and experience to better use HPC on work activities. The exploratory nature of the research design and methodology adopted in this study assisted to provide findings in relation to how people can use their experiences on HPC and how their perceptions towards HPC can influence them into the adoption of HPC moving forward.

The integration of HPC into different sectors and industries of research is still a very grey area, so this study will opened up more conversations on the interaction of HPC not only in research but also in other industries, which will also assist employees and employers in the institutions and organisations to better understand the association between computation and behaviour and how it is imperative, moving forward to integrate HPC in our daily work lives. This study and future research will assist not only the employees who work with the HPC directly but also other institutions of higher learning in being able to take the initiative into the transition from the traditional way of technology into the artificial intelligence, machine learning and the fourth industrial revolution, moving into the future integration of the fifth industrial revolution.

5.7 LIMITATIONS TO THE STUDY

This study was not exempt from the flaws that the literature suggests are inherent to qualitative research. Because the researcher was instrumental in the study's conduct, analysis, and interpretation, the results may have been directly or indirectly impacted by the researcher's subjectivity, which was determined by her experiences, background, education, and other factors.

This study was only limited to employees who worked or had knowledge of HPC systems, which were people from the material modelling centre and only two individuals outside the centre, one being in the school of accounting and one at ICT. Purposive sampling was used to include participants within the study. The study was only conducted at the University of Limpopo; therefore, the findings cannot be generalised to all institutions that make use of HPC systems. The researcher also noted that some participants, as limited as they were, did not want to participate in the study.

The centre had quite a limited number of people so those were the only individuals who had any knowledge of operating HPC systems. Few problems were encountered since they had little to no knowledge about HPC. Some participants did not have extensive knowledge of some of the questions that were asked, resulting in very brief to no answers. With regards the rest of the staff members outside the departments, the study was only limited to a certain number of people in the physics department. They must also learn certain things from scratch. They must mostly rely on their colleagues with background information and those with expertise to guide them through certain projects and systems which then hinders innovativeness and creativity because calculation and experiments fail when there is no theoretical background. Data was only collected from those few who willingly participated in the study.

In this study, the questions were not strictly structured as respondents were given greater freedom to completely express themselves. When compared to structured interviews, semi-structured interviews are less objective and more difficult to justify

legally (Smith, 2019). Semi-structured interviews limit the interviewee's ability to speak freely, which lowers the interview's overall potential. As a result, they may be administered quickly and easily. They can be especially helpful when asking clarifying questions or when there is a chance that the respondents will struggle with reading or numeracy (Westby, 2019).

5.8 FUTURE IMPLICATIONS

University staff, especially those working in ICT and those in the computer science department should really take the initiative in learning and being knowledgeable on HPC. They seem to have little to no knowledge about it and because of the constant updating of technology, automation, artificial intelligence and the fourth industrial revolution, it is of utmost importance that employees who deal with computers daily, know how to operate a supercomputer and how to run an HPC system.

HPC systems already exist in the latest models of our cell phones, but people do not know that. Learning on HPC systems will make it easier for them to implement better, fast, and efficient ways of solving problems, building software that can work effectively within their departments to update the University enrolment, course systems and other systems that the employees in the institution need to deliver objectives. The transition from traditional work to remote will be in full effect and will work efficiently for a lot of people and future generations to come. We need to pave the way for the incoming generation so that we are not left behind.

This study mainly focused on the perceptions and experiences of employees on the use of HPC but, studies should be conducted on how effectively employees or personnel can use the computation knowledge that they have to improve the systems software, hardware, learning and upgrades in institutions. Manufacturers will need to enhance the design, development, and distribution of next product generations, product technologies, equipment, and processes in order to sustain excellence in the highly competitive global economies of the future decades. Using computer modelling,

simulation, and analytical technologies, High Performance Computing (HPC) addresses the application of major difficulties. Products will be produced more swiftly thanks to HPC technology, which will also reduce the time and costs associated with developing high-value innovations and creating and testing prototypes.

Educational programs are strongly encouraged to develop a set of competencies needed for their programs to enable high performance computing education. Recent efforts in the academic community have proposed competencies as a core set of knowledge, skills, and dispositions that need to be attained. While many programs focus on the knowledge and skills alone, the dispositions that prescribe a requisite character or quality in task performance are very much lacking in the specification of academic programs. Programs need to be alerted to providing students with an experiential environment for students to immerse themselves in a hands-on setting.

The greater adoption of HPC systems by the scientific community will raise the prospect of establishing coursework in the subject, which is currently limited to electives in computer science in a handful of universities, with one well-known postgraduate level degree at the University of Edinburgh, although there is continuing research journals and conferences on the subject, with strong industry support. Whilst the lack of coursework may seem to be a surprising result for what is the provision of the world's most powerful computer systems, it is an understandable result when viewed as a highly specialised sub-discipline. Only when there is mass adaption of HPC systems by scientific researchers will there be the need for additional HPC systems and system engineers, and only then will there be the opportunity to conduct extensive coursework in the subject. This possibility is therefore a future elaboration dependent on how institutions continue to integrate HPC in years to come.

5.9 CONCLUSIONS

In this study, the perceptions and experiences of employees on the adoption and continued use of HPC in an HDI were investigated. The research findings show that

employees have different perceptions and experiences with regards to the adoption and continued use of HPC, both positive and negative. The next technological revolution, Industry 5.0, may catch people off guard if the rate of change in technology accelerates from a gradual, adaptive pace to a more transformative pace. Employee skills and some positions may become obsolete because of this technological disruption. Organisations contemplating investments in further automation of HPC technology possess a chance to capitalise on employees' mind sets and anticipate possible disruptions in the workforce. To be more precise, the study suggests that organisations should comprehend how anticipated developments in HPC technology could affect workers in various departments. The organisations and institutions should develop a change management and communication strategy that capitalises on the employees' present perspective of the future after the future state has been established.

Increasing competition is already taking place between universities, research groups, and between academics and other staff members in terms of the integration of advanced technology. Research capacity of a university is related to individuals' cognitive skills in continuing professional development on HPC which will be based on learning new competencies, especially from the field of computer science and information technology, which can provide efficiency and ensure the competitive edge of adopting HPC in the long run. Therefore, it is vital that universities and other organisations jump on HPC technology.

In addition, the research believes that by implementing shared leadership, updating rewards and recognition programmes and performance management processes to align with future business objectives, and—more urgently—developing employee training programmes so they are adaptable even as change accelerates, the institution can improve employee mentality and increase institutional effectiveness. Employees have the mentality that, although they are receptive to learning and have witnessed the benefits of HPC technology, developments in the field have only slightly affected their jobs and duties in the past.

In conclusion, it is critical for employers to ensure that HPC benefit employees' learning outcomes and to provide more excellent HDI techniques for greater success. This can be achieved by understanding the strong determinants of employees' behaviour to use HPC in order to positively influence employees' adoption and continued use of HPC.

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APPENDICES

APPENDIX A: INFORMED CONSENT

Consent to take part in research.

- I..... willingly accept to engage in this research study.
- I realize that, even if I agree to participate right now, I can withdraw at any point or refuse to answer any question without any repercussions.
- I accept that I have two weeks to withdraw consent to utilize data from my survey or interview, after which the case material will be erased.
- I was given written explanations of the study's objective and nature, as well as the opportunity to ask questions about it.
- I am aware that I will not benefit immediately from my participation in this study.
- I consent to having my interview audio recorded.
- I am aware that any information I provide for this study will be kept private.
- I accept that my identity will be kept anonymous in any report based on the findings of this study. This will be accomplished by altering my name and concealing any aspects of my interview that could disclose my identity or the identities of others I discuss.
- I understand that if I advise the researcher that I or someone else is in danger, they may be required to report it to the appropriate authorities - they will consult with me first, but they may be required to report with or without my agreement.
- I accept that I am free to contact any of the research participants for additional clarity and information.
- I understand that, under freedom of information legislation, I have the right to access the information I've provided at any time while it's being stored as described above, and that signed consent forms and original audio recordings will be kept in a secure location.

Signature of research participant

.....

Signature of participant

.....

Date

I believe that the participant is giving informed consent to the participant in this study.

.....

Signature of researcher

.....

Date

APPENDIX B: SEMI STRUCTURED INTERVIEW QUESTIONS

Biographic Details

Race:

Age:

Occupation:

Gender:

HIGH PERFORMANCE COMPUTING

1. How familiar are you with HPC? Please substantiate with your experience.
2. Have you fully adopted the use of HPC systems in your daily work? Please substantiate.
3. Which factors influence a decision to use HPC systems in your work setting? Please substantiate.
4. What are the benefits of using HPC systems in your daily work? Please substantiate.
5. What are the benefits of using HPC systems for societies? Please substantiate.
6. What are the impediments of using HPC? Please substantiate.
7. What do you think Higher Education Institutions should do influence employees' adoption and continued use of HPC successfully?

APPENDIX C: REQUEST LETTER



University of Limpopo

Faculty of Management and Law

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Tel: (015) 268 3947, Email: lethabo.ledwaba@ul.ac.za

REQUEST LETTER

Greetings,

I Lethabo Ledwaba, Student no. 201700524, a Master's student with the University of Limpopo would like to formally request permission to conduct study research relating to my topic "PERCEPTIONS AND EXPERIENCES OF EMPLOYEES ON THE ADOPTION AND CONTINUED USE OF HIGH-PERFORMANCE COMPUTING SYSTEMS AT A SELECTED HISTORICALLY DISADVANTAGED INSTITUTION, SOUTH AFRICA' in your institution.

The study will be of qualitative, comprising of interviews conducted within your Physics and Mathematics Department and Computer Science department. Only a number of 12 will be selected within, mainly those who are involved with the HPC.

Please find the attached Proposal for your perusal.

Kind Regards.

Lethabo Ledwaba