Physics Graduate Preparedness for Work and Society

By

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ABSTRACT

Both internationally and in South Africa, there have been renewed debates about the purposes of higher education and the attributes that should be developed in graduates. In the field of physics, many studies have reported that the preparation of physics graduates in the 21st century needs to be broader, to prepare graduates for a range of careers and roles in society. This case-study aims to understand the formation of graduate preparedness and the development of graduate attributes in a Physics Department at a South African university.

A framework of physics graduate attributes was developed, drawing on skills and attributes benchmarked by several international physics bodies, as well as the South African Institute of Physics; the national SAQA critical cross-field outcomes and the UWC Charter of Graduate Attributes were also drawn on. The study adopted a range of research methods: document analysis of physics module descriptors was used to examine the embeddedness of graduate attributes in the physics curriculum; a questionnaire was developed to gauge students' perceptions of their preparedness for work and society; focus group discussions with students, and interviews with graduates, were used to understand the structural and institutional arrangements that enabled or hindered the development of physics graduate attributes.

The theoretical framework for this study is the capability approach, as developed by Amartya Sen and Martha Nussbaum. It offers an enlarged view of the purposes of higher education beyond the development of human capital; it also enabled an analysis of the structural challenges that students faced, while at the same time foregrounding student agency, and the strengths and resources that students bring to higher education.

The findings revealed that the physics graduate attributes were unevenly and mostly scantily embedded as learning outcomes in the physics module descriptors; attributes least embedded in the curriculum were social and environmental awareness, ethical behaviour, and teamwork.

Analysis of questionnaire and focus group discussion data showed that students felt that more could be done in the Physics programme to explicitly develop a wider set of physics graduate attributes to enhance their sense of graduate preparedness. In particular, the development of ICT skills, communication skills, practical skills and social awareness was found to be lacking.

Concepts from the capability approach, including conversion factors, well-being and agency, were used to understand the ways in which the development of students' graduate preparedness and their attainment of academic success and well-being were enabled or hindered by various structural and institutional factors. A range of personal, social and environmental conversion factors was seen to influence students' perceptions of their graduate preparedness and their ability to effectively convert resources on offer at university into capabilities and functionings. Similarly, conversion factors were identified that graduates perceived to have enabled or hindered their preparation for, and entry to, the workplace.

Finally, implications are discussed for undergraduate pedagogical approaches and institutional arrangements that might better support the development of students' graduate preparedness. These include curriculum mapping, creating spaces and a platform for student engagement and affiliation, career exposure and guidance, meeting students' diverse needs, and supporting student agency. Implications and recommendations are also discussed for national stakeholders in the interest of physics graduate preparedness.

***Keywords*:** physics education, graduate preparedness, Benchmark statement, physics graduate attributes, embedded, module descriptor, capability approach, capabilities and functionings, conversion factor, well-being, agency.

DECLARATION

I declare that "Physics Graduate Preparedness for Work and Society" is my own work, that it has not been submitted for any degree or examination in any other university or institute, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Bako Nyikun AUDU Date: January 2023

Signed: 

DEDICATION

To God Almighty.

Itse ‘ru ti.

Ti’ndeya nam ti ati iyenwun nam

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ACRONYMS AND ABBREVIATIONS

AIP:	Australian Institute of Physics
APS:	American Physical Society
CHE:	Council on Higher Education
DEST:	Department of Education Science and Training
ECP:	Physics Extended Curriculum Programme
EPS:	European Physical Society
HESA:	Higher Education South Africa
ICT:	Information and Communications Technology
IOP:	Institute of Physics
PGA:	Physics Graduate Attributes
PGA:	Power for Genetic Association Analyses
PGE:	Post-Graduate Certificate in Education
SAIP:	South Africa Institute of Physics
SAQA:	South African Qualifications Authority
SASSE:	South African Survey of Student Engagement
SKA:	Square Kilometre Array
STEM:	Science Technology Engineering and Mathematics
UK:	United Kingdom
USA:	United States of America
UWC:	University of the Western Cape

CHAPTER ONE

INTRODUCTION TO THE STUDY

Education is not at the root, about the transmission of specific bodies of knowledge and skills. Rather, it is about the development of understanding and the formation of minds and identities: minds that are robust enough and smart enough to engage with the uncertain demands of the future, whatever they may be, and identities that are attuned to the changing communities of which they are members. Minds that are able and willing to participate effectively and responsibly in their activities and thus contribute to, and benefit from, their transformation (Wells & Claxton, 2002)

1.1 Introduction

This study is premised on an expansive view of education (as reflected in the quote above), where education can be considered to be intrinsically, instrumentally and economically valuable for individuals and communities (Dreze & Sen, 1995). The context of this study is higher education – the peak of the education system. The study examines the extent to which physics education prepares students to take up meaningful roles in the workplace and society and to live lives that they value (Sen, 1992). This first chapter reviews the purposes of higher education, the concept of graduate attributes, and their applicability to the discipline of Physics in the South African context. The chapter then provides an overview of the research study and the research questions.

1.2 Purposes of higher education

In these contemporary times, there have been renewed debates on the purposes of higher education, both internationally and in South Africa. In South Africa, the outcry of students during the 2016 "Fees Must Fall" protests challenged notions of access to higher education and the purpose of higher education.

Higher (tertiary) education differs from training; the latter focuses on imparting or transferring a specific set of skills, whereas higher education has broader aims to develop and prepare the individual. For the individual, there is of course, an intrinsic purpose of higher education for personal development, and the development of creativity and aspirations that lead to fulfilment (Fongwa & Walker, 2014; Fongwa, 2018; Boni & Walker, 2016). The other important purpose of higher education for the individual is preparation for employment or work.

At a national level, higher education is linked to the economic development of countries. This is sometimes referred to as 'human capital theory' - it argues that there is a causal link between higher education participation and economic development (Tymon, 2013). Higher education is the central point of innovations, inventions and growth, and the knowledge base for a better competitive environment. It has the potential to create new and better linkage with industries and business enterprises to serve as a catalyst for economic development (Fongwa & Walker, 2014; Boni & Walker 2016). Higher education addresses learning at a high level of complexity and specialization, and in particular is fundamental to the construction of a knowledge economy and knowledge society in all nations.

On account of the above, higher education should be critical for the national interest, especially in the context of the development of scientific and technological advances and equipping graduates with skills needs for the 21st century (Aikman, 2017; Schwab, 2017; Zusman, 2005). Marginson (2006) argues that the human capital conceptualization of higher education is not sufficient and that the public good purposes need to be emphasized. Walker & Fongwa (2014) argue that in a developing country context, like South Africa, university graduates need to be equipped to address inequalities and social justice in society. In the context of professional education, Walker and McLean (2015) explore the potential for higher education to produce 'public good professionals', interested in social justice and poverty reduction.

1.3 Graduate attributes and graduate preparedness

Professional organizations and universities have desired to equip graduate students with the type of education that is relevant to the workplace and society. This graduate preparedness is linked to the concept of graduate employability, termed as the skills and attributes 'that make graduates more likely to gain employment and be successful in their chosen occupations (Yorke, 2004, p.410).

Higher education providers face a very tough challenge as they strive to provide graduates with up-to-date skills and knowledge that are relevant to individual aspirations, workplace and societal needs, while at the same time equipping them with the ability to continue to learn and adapt so that they can adjust effectively as the world and their careers change over time (Kinash et al, 2016; Heron & McNeil, 2016; University of Cork, 2013). Increasingly, higher education also needs to prepare students as critical citizens equipped to deal with societal issues.

The role of universities in shaping the sorts of graduates needed by society has to some extent been taken up by the concept of ‘graduate attributes’ (Barrie 2005; Barrie, 2007), a framework often used by universities for conceptualizing the sort of graduates they aim to produce. Graduate attributes are described as “the qualities, skills and understandings a university community agrees its students should develop during their time with the institution” (Bowden et al., 2000). Graduate attributes are generic and need to be contextualized for specific discipline contexts. In the following section, the development of physics-specific graduate attributes is briefly discussed.

1.4 Graduate attributes – National, institutional and discipline-level adaptations

As noted above graduate attributes can be specified at various levels – a national level, institutional level and discipline level. At the national level, while some graduate attributes are naturally the same for most countries, there still exist explicit inclusions for individual countries as deemed best and as required for work in that society. For example, Australia has defined graduate outcomes as linked to the ‘employability skills’ needed for the workplace (DEST, 2002). There are eight core skills listed: communication, teamwork, problem-solving, self-management, planning and organization, technology, lifelong learning and entrepreneurial skills. In South Africa, the South African Qualifications Authority (SAQA) has outlined some generic outcomes that should inform all teaching and learning in South Africa - in its Critical Cross-Field Outcomes (SAQA, 2011). Many of these are identical to those in the Australian ‘core skills’; however, three additional skills included in the SAQA list reflect specifically national societal needs: social awareness, cultural sensitivity, and environmental awareness.

Graduate attributes are also specified at an institutional level, where universities set out the qualities of graduates they aim to produce. As with the national-level graduate attributes, institution-level graduate attributes would differ for different institutions, often reflecting their individual histories and missions. For example, the Charter of Graduate Attributes of the University of the Western Cape, show a clear commitment to the development of graduates who are agents of social change, able to apply their knowledge in solving diverse problems within the context of the public good role of higher education. Similarly, the graduate attributes of Stellenbosch University include a particular focus on multilingual competence.

Graduate attributes are generic and need to be contextualized for specific discipline contexts. Within a university, the university graduate attributes would then be adapted for specific programmes, at a discipline level. For example, the University of the Western Cape (UWC)

Graduate Attributes could then be applied to diverse disciplines such as physics, philosophy, or law. At a national level, professional bodies and discipline bodies are also able to specify discipline-specific graduate attributes. For professional bodies, this is linked to the accreditation of professional programmes, for example, Engineering and Pharmacy. The next section discusses specifically discipline-level physics graduate attributes that have been adopted by physics bodies internationally and in South Africa.

1.5 Physics graduate preparedness

There is global recognition that physics graduates require a range of physics-specific knowledge and skills, as well as broader generic skills. The international bodies of physicists, such as the United Kingdom's (UK's) Institute of Physics (IOP), the American Physical Society (APS) and the American Association of Physics Teachers (AAPT) in the United States of America (USA), the European Physical Society (EPS) and the Australian Institute of Physics (AIP), have all listed the skills and attributes that physics graduates ought to develop during their physics education. These include problem-solving, investigative skills, analytical skills, communication skills, Information and Communications Technology (ICT) skills, ethical behaviour and personal skills, technology aptitude, etc. (APS-AAPT, 2006; AIP, 2014; Heron & McNeil, 2016; AUTC, 2005; IOP, 2011b; AIP-AAS, 2012; IOP, 2014).

For example, in the UK, the IOP has developed a common Graduate Skills Base for all undergraduate physics programmes, which specifies the physics skills and other transferable skills that all students should acquire (IOP, 2011b). Similarly, in the United States of America (USA), a recent report commissioned by the APS and AAPT entitled *Preparing Physics Students for 21st Century Careers* (Heron & McNeil, 2016) proposed ways to enhance and improve physics programs to better prepare students for the diverse careers into which they progress after graduating from university. Graduate preparedness, according to this report, includes developing skills and attributes such as: working well in teams, understanding how science and technology are used in real-world settings, writing and speaking well, and understanding the context in which work is now done, where the use and value of knowledge and skills that go well beyond their knowledge of physics are often engaged. In Australia, a set of 'threshold learning outcomes' have been developed to describe what a physics graduate at a Bachelor level should know and be able to do (Wegener, 2013).

In South Africa, the South African Institute of Physics (SAIP) has developed a Physics Benchmark Statement of Physics for South Africa (SAIP, 2015a, 2015b), which sets out the core content of an undergraduate physics BSc degree, as well as the sorts of skills and attributes that a physics graduate would be expected to possess. These are divided into three broad categories: Physics skills, Generic skills (including problem-solving, analytical skills, investigative skills, communication skills, ICT skills and personal skills), and Ethical behaviour. The physics graduate attributes specified in the SAIP Benchmark are described more fully in Chapter two.

1.6 Physics graduate preparedness and the capability approach

This study makes use of the capability approach as the theoretical framework to examine the preparedness of physics graduates for work and society. The capability approach is grounded in human development, namely that human development should not have economic growth as an end in itself, but rather the increase in people's real freedoms to do and be what they value (Alkire, 2015). In the context of higher education, the value of the capability approach is that it offers a normative framework for conceptualizing the purposes of higher education, and its role in supporting human well-being and flourishing (Walker & Unterhalter, 2007). Key concepts include capability, functioning, agency, conversion factors, freedom and well-being.

An additional value of the capability approach is that it takes into account individual differences and the role of contextual factors that influence how a person is able to develop their capabilities and functionings (Crocker & Robeyns, 2010). These contextual factors are defined as 'conversion factors', which constitute the personal, social and environmental conditions that enable or constrain the conversion of resources into capabilities and functionings. Applied to higher education, the capability approach can challenge the assumption that all students are equally positioned to benefit from the resources on offer at university and to convert those resources into capabilities and functionings. Similarly, when graduating, graduates would be differently positioned to convert their educational training or degree (a resource, in this case) into desired employment (Fongwa, 2018). The capability approach is discussed in much greater detail in Chapter three.

1.7 Research context

The University of the Western Cape (UWC) is a historically black and disadvantaged university, established in 1960, with a strong anti-apartheid struggle history and commitment to social justice and community engagement. UWC has developed into a strong research-led university, ranked among the top in the country. The Department of Physics and Astronomy is also highly ranked (in 2016, the Department was rated by Nature Index as the top university in Africa for research output published in high-impact journals). The Department excels in the area of research in Astronomy, Nuclear physics, and Solid state physics. In particular, the Department is making a significant research contribution to the Square Kilometre Array (SKA) project, the World's largest astronomy installation. The solid state physics group hosts a chemical deposition system which is unique in the whole of Africa and its nuclear physics research is also world-recognised.

The Department also has a long-standing ethos of commitment to quality undergraduate teaching and it has an active physics education research group. A Physics Extended Curriculum Programme (ECP) is offered in the Department, for students who do not have the required Matric grades to be admitted to the mainstream first-year Physics programme. The ECP physics courses cover the same topics as the mainstream first-year course, over two years, with additional innovative course components, whose purpose is to address the 'articulation gap' (CHE & SAIP, 2013, p.17) between secondary and higher education in South Africa.

The extra time allows more curriculum space for foundational provision, which includes strengthening conceptual understanding, a focus on the nature of physics knowledge, and time spent developing students' mastery of the multiple representations used in ECP physics (for example, graphs, free-body diagrams, mathematical formalism etc), and developing academic literacy skills. The extra time also allows time for the development of students' social capital, exposure to research taking place in the department, and class visits by former students now in industry or research. The teaching of the ECP programme is integrated into the Department of Physics, to reduce the stigma often associated with separate extended (or foundation) curriculum programmes (Pym & Kapp, 2013).

The Department of Physics and Astronomy at UWC provides the setting for a useful case study of a research-led, teaching-focused university catering for a diverse range of students. Within this Department, I worked as a tutor and later teaching assistant in the ECP programme, which triggered my inquiry around physics graduate preparedness. I have an undergraduate degree and a Master's in physics education (from Nigeria) and a Master's in Radiation and Environmental Protection (from the UK). This means that my knowledge and understanding of physics is aligned as a physicist with industry links. This is an advantage for the study as the study brings attention to aspects of preparedness of physics graduates for work and society which may be taken for granted.

Furthermore, although I had not studied in South Africa previously, my experience of other higher education systems in Nigeria and the UK was a benefit, providing me with a more global perspective on higher education.

1.8 Focus of the research and the research questions

As argued earlier, higher education institutions are the right place to effectively develop and prepare graduates for work and society; however, there is also the question of whether these higher education institutions can do so [Council on Higher Education (CHE) & SAIP, 2013, Boni &Walker, 2016]. This research takes the form of a case study of a single Physics Department, to examine the extent to which the Department is successfully developing and preparing graduates for work and society.

The research was conducted in a period after the SAIP Benchmark statement had been adopted (in 2015), and after the UWC Charter of Graduate Attributes had been approved (in 2008). I was interested to ascertain the extent to which these policies had been taken up by the department, and to understand the formation of graduate preparedness (in relation to the attainment of physics graduate attributes) among UWC students and graduates. My research aimed to examine the following:

- firstly, the extent to which these graduate attributes (as specified in the SAIP and UWC graduate documents) had been implemented in the undergraduate physics degree programme;
- secondly, students' perceptions of their preparedness, as well as the perceptions of preparedness of recent graduates;
- thirdly, the personal, social and environmental conversion factors that students perceived to be enabling or hindering the development of graduate attributes during the undergraduate degree programme. These could include students' personal attributes, as well as the institutional and pedagogical arrangements that impacted their perceptions of graduate preparedness.

The research questions for this study are:

- How are the espoused physics graduate attributes (as specified by SAIP and UWC graduate documents) embedded in the UWC physics module descriptors?
- What are students' perceptions of their preparedness in relation to the physics graduate attributes?

- What are the conversion factors that influence students' perceptions of attainment of the physics graduate attributes?
- In relation to physics graduates entering the workplace, what are the conversion factors that influence their preparation for entering the workplace?

1.9 Overview of the thesis structure: Chapter outline

Chapter one has introduced the study. This first chapter has reviewed the purposes of higher education, the concept of graduate attributes, and their applicability to the discipline of Physics in the South African context. The chapter has also provided an overview of the research study and the research questions.

Chapter two provides a review of the literature on graduate attributes and physics graduate preparedness. It reviews policy documents on graduate attributes at a national level (SAQA) and institutional level (the UWC Graduate Attributes). It also provides an overview of the skills and attributes listed by international physics bodies (as well as the South African Institute of Physics). From this overview, a framework of desired physics graduate attributes for UWC is developed.

Chapter three discusses in detail the theoretical framework for the study, the Human Capability Approach. Key concepts are introduced, including the concepts of capabilities, functionings, freedom, agency, well-being and conversion factors.

Chapter four discusses the methodology and methods used in the study and more details about the setting of the study. It outlines the research paradigm, case selection and how data was gathered. It also explains how the analytical tools were developed, and how the data was analysed.

Chapter five addresses research question 1. It presents the findings from document analysis of UWC Physics programme module descriptors, to ascertain the extent to which the desired physics graduate attributes are mapped or embedded in the module descriptors.

Chapter six addresses research question 2. It presents an analysis of the demographics of the students in the study and then discusses the results from a questionnaire gauging students' perceptions of preparedness.

Chapters seven and eight address research questions 3 and 4. It presents an analysis of focus group discussion data with students, and interview data with graduates, to examine the conversion factors that enable or hinder the development of graduate attributes.

Finally, Chapter nine discusses the findings from Chapters 5 to 8 and gives the study conclusion and recommendations for future research.

CHAPTER TWO

GRADUATE ATTRIBUTES AND PHYSICS GRADUATE PREPAREDNESS

2.1 Introduction

In Chapter one, the aims of the study were discussed, which are to investigate the perceptions of preparedness among physics students and graduates and to examine the personal, social and environmental conversion factors that influence these perceptions of preparedness. Chapter one discussed the purposes of higher education. As noted there, the purpose of education is not the maximum storage of facts, optimum scores in examinations or preparation for employment; the most important goal of education is the betterment of the individual and society (Wells & Claxton, 2008). Education needs to equip individuals with relevant skills and sharpen individual's talents so that they can be self-fulfilled, be useful members of society, and be an active players in the knowledge-driven society in a modern 21st century economy (Czujko et al., 2014; McNeil & Heron, 2017).

Chapter one also introduced the concepts of graduate attributes and physics graduate preparedness. Chapter two explores these concepts further by reviewing relevant literature. This chapter then reviews policy documents regarding graduate attributes and outcomes at a national level (e.g. SAQA), as well as at an institutional level (the UWC Graduate Attributes). An overview is also provided of the skills and attributes that various international physics organisations (as well as the national SAIP) feel should be developed during an undergraduate physics degree. From this overview of policy documents, a framework is developed and presented of desired physics graduate attributes for UWC (termed PGAs in this study). This Physics Graduate Attributes framework will be used as an analytical tool in this study.

The chapter also reviews international studies on the perceptions of physics graduates and employers regarding graduate preparedness and skills needed in the workplace. Finally, the chapter reviews physics education research on approaches to fostering and developing key graduate attributes and skills during an undergraduate programme.

2.2 Higher education, graduate attributes and graduate preparedness

Universities are increasingly concerned with the quality of graduates they produce and how these graduates are equipped with the skills and attributes that would enable them to be productive at work and be good citizens in society at large (Barrie, 2007; Clegg et al., 2010;

Bitzer & Withering, 2020). Universities and professional organizations have sought to graduate exceptional students by offering the type of education that is relevant to the individual, for the workplace and for the good of society (Lowe & Marshall, 2004; SAIP, 2004). In addition, university education should at the same time equip graduates with the ability to continue to learn and adapt so that they can adjust effectively as the world and their careers change over time (Heron & McNeil, 2016).

Included in the literature on graduate preparedness is the concept of graduate employability, defined as the skills and attributes 'that make graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy' (Yorke, 2004, p.410). Walker and Fongwa (2017) argue for an expanded perspective on employability to include the wider societal benefits of higher education. They argue that higher education also needs to prepare graduates as critical citizens equipped to deal with societal issues:

> *"Graduate education … requires an ethical framework beyond knowledge and skills which aims at improving quality of life not only for graduates but for all in the society who interact with these graduates" (p.154).*

Many universities address the challenge of graduate preparedness by drafting charters of generic attributes which outline the attributes and skills (which transcend disciplinary knowledge) that the institutions expect their students to have acquired upon the completion of their studies. As noted earlier, graduate attributes are often strongly related to universities' particular missions, visions and values. Given the different understandings of graduate attributes, the debate around the use of the correct terminology had continued, but the importance of graduate attributes as an essential outcome of university education seems beyond doubt. Several authors (Bath et al., 2004; Barrie, 2007; Sumsion & Goodfellow, 2004; Cummings et al., 2005; Ducasse, 2009; Sharp & Sparrow, 2014) have used terms such as transferable skills, generic skills, generic capabilities and graduate attributes. A comprehensive and well-used definition of graduate attributes is as follows:

> *"The qualities, skills and understandings a university community agrees its students should develop during their time with the institution. …These attributes include but go beyond the disciplinary expertise or technical knowledge that has traditionally formed the core of most university courses.*

They are qualities that also prepare graduates as agents of social good in an unknown future." (Bowden, Hart, King, Trigwell & Watts, 2000).

Graduate attributes adopted by universities are by nature overarching and generic since they are developed at a university-wide level; they are to be adapted for specific faculties and disciplines.

In South Africa, higher education since 1994 has been framed in terms of its anticipated contribution to the process of societal transformation in the country. The vision of the Education White Paper (DOE, 1997) is of aligning educational programmes and training with the country's societal and economic needs so that undergraduate and graduate programmes are meant to equip undergraduates and postgraduates with graduate skills and attributes for work and further studies. Furthermore, the National Development Plan 2030 has the target of improvement of the quality of education, skills development in education delivery and innovation in the system for the nation.

At a national level, the South African Qualifications Authority (SAQA, 2011) outlines some generic outcomes – termed critical cross-field outcomes - that should be reflected in educational programmes at all levels, including higher education. These include:

- Identifying and solving problems in which responses display that responsible decisions using critical and creative thinking have been made.
- Working effectively with others as a member of a team, group, organisation, or community.
- Organising and managing oneself and one's activities responsibly and effectively.
- Collecting, analysing, organising and critically evaluating information.
- Communicating effectively using visual, mathematical and/or language skills in the modes of oral and/or written persuasion.
- Using science and technology effectively and critically, showing responsibility towards the environment and the health of others.
- Demonstrating an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation (SAQA, 2011, p.22).

Furthermore, the framework argues that learners need to be conscious of the following processes:

- Reflecting on and exploring a variety of strategies to learn more effectively;

- Participating as responsible citizens in the life of local, national and global communities;
- Being culturally and aesthetically sensitive across a range of social contexts;
- Exploring education and career opportunities; and
- Developing entrepreneurial opportunities. (SAQA, 2011; p.23)

These SAQA CCFOs categories informed the development of a framework for Physics Graduate Attributes for UWC (see Section 2.8) and are included in Table 2.3 below.

A Higher Education South Africa (HESA)-commissioned study (Griesel & Parker, 2009) entitled *Graduate attributes: A baseline study on South African graduates from the perspective of employers,* arose out of employers' concern over the quality of graduates exiting universities and the view of higher education that employers are not fully aware of qualities and skills graduates possess. HESA undertook this study to obtain a picture of graduate attributes and the way these were perceived by employers. The study examined employers' perceptions of graduates' strengths or weaknesses in relation to the following four clusters of attributes:

- Basic skills and understanding;
- Knowledge and intellectual ability;
- Workplace skills and applied knowledge; and
- Personal and interactive skills (Griesel & Parker, 2009).

Broadly, the study found that while employers valued the 'conceptual foundation, knowledge and intellectual approach to tasks produced by higher education' (p.20), they perceived several gaps in graduates' preparedness, including the ability to plan and complete tasks proactively and independently, as well as significant gaps regarding communicative competence in English, written and oral communication skills, and ICT skills. On the other hand, graduates were regarded as well-prepared in their "ability to deal with different cultural practices" (p.14), which implied that higher education was successfully exposing students to cultural differences and diversity.

In summary, then, graduate attributes refer to the attributes and skills that graduates should have acquired upon the completion of their studies. These are specified at various levels: at a national level (e.g. SAQA); at university level, reflecting institutional distinctiveness (e.g. UWC Charter of GAs) and then at a disciplinary level, in this case, physics. The discussion of physics graduate attributes at an international and national level is explored in greater detail in Sections 2.5 and 2.6 below.

2.3 Implementation of graduate attributes: Espoused versus enacted graduate attributes

As noted above, graduate attributes can be specified at a national level (e.g. SAQA), at an institutional level, or at a disciplinary level (specified by a national discipline, for example, SAIP (South African Institute of Physics). Graduate attributes can be said to be *espoused* when they are explicitly stated in institutional documents (for example, university graduate attribute lists, or discipline benchmark statements, e.g. SAIP). Moving from espoused graduate attributes to having these attributes *embedded* in modules in a curriculum is a complex process. Some universities go on to set out a process towards the implementation of the Graduate Attributes in the course curriculum and module descriptors (Bath et al., 2004; Lowe & Marshall, 2004) which would help to ensure that 'espoused' graduate attributes are more likely to be 'enacted' (Jones, 2009; Lee, Barker & Mouasher, 2013). The implementation process might include:

- Institutional graduate attributes are 'translated' into discipline-specific descriptions (for example, the attributes of 'problem-solving' or 'being skilled communicators' would be described differently in physics as compared to history).
- These discipline-specific graduate attributes would then be mapped onto each course module in a degree programme. Bath *et al* (2004) refer to this process as `program stocktaking' (Bath et al., 2004, p.318), in other words taking stock of how a degree programme as a whole supports the development of graduate attributes. This is also sometimes referred to as 'graduate attribute mapping' (Lowe & Marshall, 2004)
- The next step would be to review and refine the programme structure to ensure a 'developmental sequence of graduate attributes across courses' (Bath et al 2004, p.319), This is a sort of 'backward design' process (Wiggins & McTighe, 2005) which entails starting with the espoused graduate attributes and then mapping these backwards from final year level modules to 1st-year modules.
- The final step would be to ensure that these espoused graduate attributes are then enacted in the teaching and learning activities, and the assessment.

Studies note several obstacles to the successful embedding of graduate attributes. One is the perception of some academics that the development of skills and attributes, while perhaps seen as valuable, is not their responsibility (Bath et al., 2004; Jones, 2009). In such cases, there is a preference for offering general skills courses (e.g. courses on communication skills or ethical and social issues). This approach is referred to as the `bolt-on approach' (Bowden et al., 2000; Pearson & Brew, 2002, in Bath et al., 2004). In this vein, a South African study with physics lecturers found that some felt that developing students' competence in communication or mathematics needed for physics was not their responsibility (Linder et al., 2014).

Jones' (2009) study found that, not surprisingly, graduate attributes are strongly influenced by the disciplinary culture in which they are taught. Generic attributes such as critical thinking, problem-solving and communication are taken up differently in different disciplines; for example, Jones (2009) found that while physics lecturers claimed to value all three attributes, only problem-solving was explicitly developed in their teaching, whereas in medicine, its problem-based approach meant that all three attributes were more explicit in the teaching.

Graduate attributes can be said to be *embedded* when they are evident in course-level module descriptors. Finally, graduate attributes can be said to be *enacted* when they are embodied in teaching and learning activities and assessments in a module. In other words, sometimes graduate attributes might be espoused in institutional mission statements, without actually being embedded in module descriptors or being enacted in the curriculum. If the actions (enacted) which are to be based upon the espoused are not explicitly formulated for enactment, then what may play out in the teaching or learning of these graduate attributes will not be deliberate, but ad hoc or chanced (Bath et al., 2004; Clegg, Stevenson & Willott, 2010; O'Neill, 2010; Bitzer & Withering, 2020).

In South Africa, there have been some studies done on graduate attributes (for example, Mtawa, Fongwa and Wilson-Strydom (2019) on how community service volunteering enhances graduate employability skills; Bitzer & Withering (2020) on students' understanding of graduate attributes. However, there is not much literature on the embeddedness of graduate attributes in module descriptors, except for Matshiyi, (2015) for an embedding example in commerce context; and Meda and Swart (2017) for an engineering context.

In terms of graduate attribute mapping, this study was designed to ascertain the extent to which espoused graduate attributes (for example, in the SAIP Benchmark statement and the UWC

Charter of Graduate Attributes) were embedded in the module descriptors, and how the development of graduate attributes was experienced by the students.

In the following sections, physics graduate attributes are explored at an international level and national level, and then the institution-specific graduate attributes of UWC are discussed.

2.4 Physics graduate attributes: International context

As noted earlier, graduate attributes are generic and need to be contextualized for specific disciplinary contexts. For example, physics as a discipline has a particular way of approaching problem-solving, or experimentation. Being successful in this endeavour requires one to synthesize and use a broad spectrum of discipline-specific knowledge, discipline skills/attributes and inter-disciplinary skills that enhance the mind to think like a physicist.

Studies focusing on physics as a discipline have increased globally over the past two decades. These have come out of concerns regarding declining student interest in physics, as well as from concerns about the preparedness of physics graduates (for example, in the USA: Heron & McNeil (2017); in Australia: AIP & AAS (2012); in South Africa: SAIP (2015a); and in the UK: Hanson & Overton, 2010).

In the USA, a report commissioned by the APS and AAPT entitled *Preparing Physics Students for 21st-Century Careers* (Heron & McNeil, 2016) presents the need to go 'beyond the "standard model" of preparing majors for physics graduate school' (p.iii), where graduate preparation now is not merely preparation for graduate school, but 'for the diverse careers that our students take, from engineer to entrepreneur to high school physics teacher to physics researcher' (p.iii). Physics graduates surveyed in the study noted that they often needed to use skills in their workplaces beyond their physics knowledge: these included 'Working in teams, technical writing, programming, applying physics to interdisciplinary problems, designing and developing products, and managing complex projects (McNeil & Heron, 2017, p.39). These graduates also noted that developing these skills was not addressed adequately in their physics programmes.

As McNeil and Heron (2017) note, departments that take up this challenge to equip graduates with skills for a wider range of careers will provide the preparation that their graduates need; they will not only better serve their current students, but they are also likely to attract a more diverse set of students with a broader range of career interests:

"Adopting career-preparedness strategies will enhance your department's reputation and attract a talented and diverse group of students" (McNeil & Heron 2017, p.43).

In Physics worldwide, there has been a greater emphasis on defining the specific skills that physics graduates should be able to demonstrate. International physics organisations, such as the Institute of Physics (IOP) in the UK, the American Physical Society (APS) in the USA, the European Physical Society (EPS)[1] and the Australian Institute of Physics (AIP), have listed the skills and attributes that physics graduates should develop during their undergraduate education (SAIP, 2004; CHE & SAIP, 2013; SAIP, 2015b). These are collated in Table 2.1 below.

Table 2.1: Skills and attributes that physics graduates should develop during their undergraduate education (International physics bodies APS, IOP and AIP)

APS (USA)	IOP (UK)	AIP (Australia)
Problem-solving	Problem-solving	Problem-solving
Investigative skills	Investigative skills	Investigative skills
Analytical skills	Analytical skills	Analytical skills
Communication skills	Communication Skills	Communication skills
Ethical behaviour	Ethical behaviour	Ethical behaviour
ICT skills	ICT skills	ICT skills
Computational Skills		Computational Skills
Research Skills		Research Skills
	Personal skills	
Practical skills		Practical skills
Project planning/management		Project planning/management
Teamwork		Teamwork
		Scientific skills
		Social interaction
		Co-curricular activities
		Professional responsibility
Collaboration skills		
Inventiveness skills		
Mechanical aptitude		
Technology aptitude		

While some of these skills and attributes are the same for most countries compared with that of the IOP, as seen in the above lists, there are explicit inclusions for individual countries. It is interesting to note that 'Personal skills' is only mentioned in the IOP list (this category includes

[1] The EPS list of generic skills is identical to those in the IOP list, except for an additional category 'Language', relating to multilingualism for a mobile labour force. Since the EPS was developed from the IOP Benchmark statement, they are not both included in the table.

the ability to work independently as well as a skill in group work, similar to the 'Teamwork' category of APS and AIP).

Computational skills, Practical skills, Project planning/management and Teamwork were mentioned in the APS and AIP lists of skills/attributes but not in the IOP. Also, Collaboration skills, Inventiveness skills, Mechanical aptitude and Technology aptitude are mentioned only in the APS list; and scientific skills, Social interaction, Co-curricular activities and Professional responsibility are mentioned only in the AIP list of skills/attributes.

The benchmark statements for physics degree programmes across countries characterise an international view of the skills and competencies that graduates of physics degrees should have acquired through their studies; there are many such programmes offering degrees, reflecting the varying aspects of physics and different national education policy imperatives, scientific traditions and knowledge perspectives. However, there is an overall agreement on what constitutes the basics of physics, and the skills and attributes that should be developed during the course of a degree in physics and beyond.

2.5 Physics graduate attributes: South African SAIP Benchmark Statement

In South Africa, too, there has been an increased focus on the nature and quality of undergraduate physics education and the preparedness of physics graduates. A report commissioned by the South African Institute of Physics (SAIP), titled *Shaping the Future of Physics in South Africa* (2004), acknowledged the efforts of the South African physics community to address the challenges which were identified in the training and education of physics majors in South Africa. These challenges were grouped into:

- Recruiting students;
- Retaining students; and
- Coping with underprepared students.

A subsequent review of undergraduate physics education in South Africa (CHE & SAIP, 2013) highlights concerns about the under-preparedness of students entering first-year physics and the level of graduate competence with acquired skills when completing their first degree in physics. This in turn yielded the Benchmark Statement of Physics for South Africa, which was published in 2015 (SAIP, 2015a). The SAIP Benchmark Statement sets out the core content aspects of an undergraduate physics BSc degree and acknowledges that 'Physics is a universal discipline: content is largely a 'given' and all universities are more or less aligned with the 'international' curriculum'. However, it then goes on to argue that 'in addition to acquiring insights into the working of the physical world' physics students should also develop 'a wide range of competence in generic and subject-specific skills' (SAIP, 2015a, p.6). The Benchmark statement then characterised the sorts of skills and attributes that a physics graduate would be expected to possess. These are divided into three broad categories: Physics skills, generic skills and ethical behaviour (see Table 2.2.) below:

Table 2.2: SAIP Benchmark Statement: Skills and attributes

SAIP Skills and attributes	
Physics skills	How to tackle problems in physics and formulate an appropriate solution How to use mathematics to describe the physical world How to plan, execute and report the results of an experiment or investigation How to compare results critically with predictions from theory
Generic skills	Problem-solving
	Investigative skills
	Analytical skills
	Communication skills
	ICT skills
	Personal skills (work independently and teamwork)
Ethical behaviour	Recognise that to fabricate, falsify or misrepresent data or to commit plagiarism constitutes unethical scientific behaviour. Be objective, unbiased and truthful in all aspects of their work and recognise the limits of their knowledge.

The details of each of these three broad categories - Physics skills, generic skills and ethical behaviour – are described in more detail in Table 2.5 below. Although the SAIP Benchmark Statement sets out this list of suggested skills to be developed in the BSc Physics degree, the document notes that,

> *'...it is up to each institution to formulate the precise and measurable indicators that apply to its situation in the context of various national policies, including the Higher Education Qualifications Framework, Level Indicators, and the generic Qualification Standard for the Bachelor of Science degree, as well as the respective university rules' (SAIP, 2015a, p.2)*

It is worth noting that the SAIP Benchmark statement is very similar to the IOP benchmark statement in many aspects.

2.6 Institutional graduate attributes: UWC Charter of Graduate attributes

As noted earlier, graduate attributes are specified at an institutional level, where these would be "the qualities, skills and understandings a university community agrees its students should develop during their time with the institution" (Bowden et al., 2000). Institution-level graduate attributes tend to differ for different institutions, often reflecting their individual institutional histories and missions. In South Africa, university graduate attributes may reflect some of the public good and equity aspects evident in higher education policy, for example the SAQA critical cross-field outcomes). Graduate preparedness for the University of the Western Cape is captured in its Charter of Graduate Attributes[2], which reflects its history and clear social justice mission. The Charter consists of three tiers – Scholarship; Critical citizenship and the social good; and Lifelong learning. From these three tiers, six overarching skills and abilities are listed:

- **Inquiry-focused and knowledgeable:** UWC graduates will be able to create new knowledge and understanding through the process of research and inquiry.
- **Critically and relevantly literate:** UWC graduates will be able to seek, discern, use and apply information effectively in a range of contexts.
- **Autonomous and collaborative:** UWC graduates will be able to work independently and in collaboration with others, in a way that is informed by openness, curiosity and a desire to meet new challenges.
- **Ethically, Environmentally and Socially Aware and Active:** UWC graduates should be critical and responsible members of local, national, international and professional communities. They should also demonstrate a thorough knowledge of ethical, social, cultural and environmental issues relating to their disciplines and make professional and leadership decisions in accordance with these principles.
- **Skilled Communicators:** UWC graduates should recognise and value communication as a tool for negotiating and creating new understanding, interacting with diverse others, and furthering their own learning. They should use effective communication as a tool to engage with new forms of complexity in social and working life.

[2] The UWC Charter of Graduate Attributes used for this study is the 2008 version, a new version is being developed.

- **Interpersonal flexibility and confidence to engage across differences**: UWC graduates should be able to interact with people from a variety of backgrounds and have the emotional insight and imagination to understand the viewpoints of others. They should be able to work in a productive team, lead where necessary and contribute their skills as required to solving complex problems.

The Charter of Graduate Attributes shows that the University recognizes its role of producing graduates that can engage in the generation of innovative and relevant knowledge through inquiry, and apply this knowledge in solving diverse problems. Also, the public good role of higher education is emphasized in students' awareness of social justice in the context of appreciating the complexity of historical contexts in their roles as professionals and as members of local and global communities. Lastly, graduates are expected to move on into life beyond university with the confidence of lifelong learners. From these categories in the UWC Charter of Graduate Attributes, I extracted a list of skills and attributes which are included in Table 2.3 below.

2.7 Developing a framework for Physics Graduate Attributes (PGA) for UWC

As noted above, the purpose of higher education is to equip graduates with relevant discipline knowledge and skills, as well as wider attributes, in preparation for the workplace and their role in society. The sections above have described lists of relevant skills/attributes developed at a national level, by SAQA (section 2.2); by international physics organisations, such as the IOP, AIP and APS (section 2.4); by the South African Institute of Physics (SAIP) as captured in the SAIP Physics Benchmark Statement (section 2.5); and, at an institutional level, through UWC's Charter of Graduate Attributes (section 2.6).

These lists are synthesised and summarised in Table 2.3 below. This summary was created by careful examination of documents from the international physics bodies that specified the sorts of capabilities, skills and attributes to be developed in physics graduates (as referenced in the above sections), as well as documents from SAQA and UWC. Table 2.3 shows the commonalities and differences between the skills listed (from left to right): the national physics body (SAIP); the various international physics bodies (IOP, AIP, APS); the national qualifications agency (SAQA), and UWC's Charter of Graduate Attributes.

Table 2.3: Transferable Skills and Graduate Attributes as captured across international physics bodies (SAIP, IOP, AIP, and APS), SAQA and the UWC Charter of Graduate Attributes

SAIP	IOP	AIP	APS	SAQA	UWC
Personal skills	Personal skills				Personal skills
				Aesthetically sensitive	
			Collaboration skills		Collaboration skills
Problem-solving skills	Problem-solving skills	Problem-solving skills	Problem-solving skills	Problem-solving skills	Problem-solving skills
Communication skills	Communication skills	Communication skills	Communication skills	Communication skills	Communication skills
Investigative skills	Investigative skills	Investigative skills	Investigative skills		
				Environmental Awareness	Environmental Awareness
Analytical skills	Analytical skills	Analytical skills	Analytical skills		
				Critical Thinking skills	Critical Thinking skills
Ethical Behaviour	Ethical Behaviour	Ethical Behaviour	Ethical Behaviour		
ICT skills	ICT skills	ICT skills	ICT skills		
		Teamwork	Teamwork	Teamwork	Teamwork
		Research skills	Research skills	Research skills	Research skills
		Social Awareness		Social Awareness	Social Awareness
		Computational skills	Computational skills		
		Project Planning /management	Project Planning /management		
		Practical skills	Practical skills		
				Life Long Learning	Life Long Learning
			Technology Aptitude	Technology Aptitude	
		Co-Curricular Activities			Co-Curricular Activities
				Culturally Sensitive	Culturally Sensitive
			Inventiveness skills		
			Mechanical Aptitude		
			Leadership skills		Leadership skills
		Professional Responsibility			

From this Table 2.3, the next step was to filter the attributes to come up with a framework of desired physics graduate attributes for UWC (termed PGAs in this study). The SAIP generic attributes were used as the basis for this framework, and then other relevant attributes contained in AIP and APS documents, as well as SAQA and the UWC Charter were included. This framework of Physics Graduate Attributes (PGAs) is used as an analytical tool in this study (see Table 2.4 below).

Table 2.4: Framework for physics graduate attributes (PGAs) for UWC

Physics Graduate Attribute	
Generic skills	Problem-solving skills
	Investigative skills
	Analytical skills
	Communication skills
	ICT skills
	Personal skills
	Ethical behaviour
	Practical skills
	Teamwork
	Technology aptitude
Citizen skills	Social/Civic awareness
	Environment awareness

These categories in Table 2.4 are described in greater detail in Table 2.5 below. What is worth noting is that this framework of PGAs is more comprehensive than the list of skills and attributes contained in the SAIP Benchmark Statement (the attributes included in the SAIP Benchmark Statement are indicated in grey shading in Table 2.4 above). The most striking addition is the inclusion of *'Practical skills'* (which are mentioned in the preamble to the SAIP Benchmark Statement, but not mentioned explicitly in the list of attributes, but included in AIP and APS lists).

In addition, the SAIP Benchmark statement includes *'Personal skills'* – which encompasses independent learning and group work; however, this category did not sufficiently focus on working with diversity in groups; therefore, a separate category *'Teamwork'* was added which includes aspects foregrounded in the SAQA and UWC documents – 'cultural sensitivity' and 'working with people from diverse backgrounds'[3]. These were seen to be important for inclusion in a framework for graduate preparedness in the context of South Africa.

'Technology aptitude' was also not included in the SAIP Benchmark statement (but adapted from APS and SAQA). '*Environmental awareness'* and *'Social/civic awareness'* were also

[3] The HESA study (Griesel & Parker, 2009) also noted the importance of graduates' "ability to deal with different cultural practices" (p.14)

absent from the SAIP Benchmark statement but were crucial and were included (these were included in AIP, SAQA and UWC documents).

The final SAIP Benchmark category *'Ethical behaviour'* is extended from its narrow focus on the ethics of data handling and plagiarism to include a wider focus on the ethical implications of the applications of physics, and ethical professional decision-making.

Table 2.5: Basic definition of terms listed as physics graduate attributes (generic skills and citizen skills) as used in this study

Physics Graduate Attribute		Definition[4]
1	***Problem-solving skills***	This is core, it should involve students in solving problems with well-defined solutions, as well as experience in tackling open-ended problems. Develop the ability to formulate problems in precise terms, identify key issues; develop the confidence to try different approaches to make progress on challenging problems and develop one or more strategies to solve a problem and iteratively refine the approach.
2	***Investigative/Independent research skills***	Students should be able to develop their skills of independent investigation. By using textbooks and other available literature, searching databases and the Internet, and interacting with colleagues to derive important information. Identify resources needed for solving a problem or to make decisions or recommendations for a research project.
3	***Communication skills***	Physics deals with unexpected ideas and difficult concepts; good communication is essential. Students should develop the ability to listen carefully, read demanding texts, and present complex information clearly and concisely – both orally and in written format. Be able to obtain information and evaluate its accuracy and relevance; be able to construct logical arguments.
4	***Analytical thinking skills***	Students should be able to pay attention to detail and develop their ability to manipulate precise and intricate ideas, construct logical and reasoned arguments, critically think and use technical language correctly. Be able to sieve a problem down to its basic elements.
5	***ICT skills***	Students should develop their computing and ICT skills in a variety of ways; for information searches, document preparation and numerical calculations, including the ability to use appropriate software such as programming languages, and analysis packages.
6	***Personal skills***	Students should develop their ability to work independently, use their initiative, organise themselves to meet deadlines, gain experience in group work and be able to interact constructively.
7	***Teamwork***	Students should be able to work in various groups and across groups, and work with people from diverse backgrounds to

[4] Many of the definitions in Table 2.3 are based on definitions in the SAIP/IOP Benchmark Statements; 'Technology aptitude' is based on definitions from the APS and SAQA; 'Teamwork' is based on definitions from the UWC Charter; 'Social and civic awareness' and 'Environmental awareness definitions are based on UWC Charter and SAQA definitions. Interestingly, the category 'Practical skills' is absent in both the SAIP and IOP Benchmark statements but is described in AIP and APS documents.

		contribute to knowledge construction; should be able to work in a productive team and lead where necessary.
8	***Environmental Awareness***	Students should have a preservation attitude to the environment within the context of ethical issues relating to the discipline and show responsibility with regard to environmental sustainability.
9	***Social and civic awareness***	Students should be critical and responsible members of their local, national, global and professional communities; be engaging, committed and accountable agents for the good of society.
10	***Technology aptitude***	Students should be able to operate and manipulate devices and applicable technologies and foster their use and applications.
11	***Practical skills***	Students should be able to design an experiment and set up and perform an experiment with the intent and purpose to collate data. Students should be able to use appropriate methods to analyse their data and to evaluate the level of uncertainty. Also, students should be able to relate conclusions they make to current theories of physics involved.
12	***Ethical behaviour***	Students should gain an appreciation of what constitutes unethical scientific behaviour. That to fabricate, falsify or misrepresent data or to plagiarism is unethical scientific behaviour. They should recognise the limits of their knowledge and demonstrate awareness of the wider ethical issues relating to physics and make ethical professional decisions.

In summary, this section has given an overview of the sort of attributes physics graduates should possess upon graduating and a Framework for Physics Graduate Attributes was developed for UWC. In the next section, some research is reviewed which examines international studies on graduate preparedness and the extent to which physics graduates possess the desired graduate attributes.

2.8 Research on the status of physics graduate preparedness

There has been much research into the general perceptions of Science graduates and employers regarding the employability skills needed in the workplace (Rayner & Papakonstantinou, 2016; Sarkar et al., 2017; Smith and Reid, 2018; Zegward & Hodges, 2003; Assamoi, 2015). These studies indicate that generic skills are valued by both science graduates and employers from science-based sectors and suggest implications for how the university could do more in preparing its graduates for employment.

Regarding physics graduates in particular, studies related to physics graduates' perception of their preparedness have included those from Australia (Sharma et al., 2008; Mendez et al., 2008; O'Byrne et al., 2008), from the UK (Hanson & Overton, 2010; University College Cork, 2013; IOP Ireland, 2011; Queen Mary & IOP, 2014) and the USA (APS and AAPT, 2013;

Mulvey & Nicholson, 2011; AIP, 2014; Arbor, 2015; Ive & Stowe, 2002). In some studies, survey methods were used as students had to rate how the undergraduate education prepared them, while others used a structured/open-ended interview method to generate data. These studies have recognised that a strong disciplinary knowledge base does not guarantee graduate work in most instances, but the ability to transfer and apply knowledge and skills learned at university into the workplace is becoming more important. For example, a survey of 171 physics graduates across a number of Australian universities (O'Byrne et al., 2008) offered these graduates a list of graduate attributes and asked respondents to rate the extent that felt these attributes had been developed in their undergraduate studies.

Graduates rated problem-solving as the most developed attribute, followed by practical skills and computational skills; in contrast, graduate responses indicated that ethical and social issues were scarcely given attention in undergraduate physics, and that oral communication was also poorly developed. When graduates were asked which graduate attributes needed to be further developed, oral communication was the attribute most mentioned, followed by written communication, project planning and experimental design. Graduates also commented on the lack of useful career guidance provided during their undergraduate studies (Sharma et al., 2008).

In the UK, a study of employers' views of physics graduates (Jagger et al., 2001) found that while employers ranked graduates' problem-solving highly, their communication and teamwork skills were perceived as lacking. A study in the USA (Porter, 2019) on physics PhD graduates ten years on from graduating found that these graduates more frequently attributed their career success to the following skills: problem-solving, research and analytical skills, and interpersonal skills.

The South African studies (SAIP, 2011; SAIP, 2015; SAIP, 2004) documented reports of skills shortages in several parts of all prospective graduate workspaces; the efforts of universities in addressing the scarce skills demands did not translate to an appreciable increase in physics graduates in South Africa.

2.9 Physics education research on approaches to developing physics graduate preparedness

The previous section discussed graduates' and employers' perceptions of graduate preparedness. This section reviews some physics education studies and teaching interventions which have been conducted to enhance students' learning of physics and develop a range of skills and graduate attributes, to reflect those possessed by expert physicists.

Some of these studies have been framed by sociocultural perspectives on learning: learning physics is viewed not only as the learning of content but also as developing the social practices of being a physicist (in other words, taking on the disciplinary ways of solving problems, reading, talking, writing, using laboratory apparatus etc.) (Airey & Linder, 2008; Volkwyn et al., 2008). For example, van Heuvelen has designed curriculum interventions which focus on helping students to 'think like physicists' in all aspects of their studies (tackling problems, communicating and conducting experimental work) (van Heuvelen, 1991a; Rosengrant, van Heuvelen & Etkina, 2009).

Not surprisingly, since problem-solving is central to physics, much of the physics education research has been on examining students' approaches to problem-solving and developing students' representational competence in problem-solving (for example, Rosengrant et al. (2009). Other studies have focused on students' skills in the laboratory, with a focus on experimental design skills, measurement and data analysis skills (Karelina & Etkina, 2007); Volkwyn et al., 2008). Yet others have focused on how to foster and support students working in groups and develop their co-operative learning skills (Johnson & Johnson, 1991) or fostering student engagement (Deslauriers, Schelew & Wieman, 2011). In terms of graduate preparedness, these various studies and interventions can be viewed as developing the graduate attributes of physics students in line with the practices of expert physicists. As Wieman and Perkins (2005) argue, 'effective' physics teaching is teaching that 'changes the way students think about physics and physics problem-solving and causes them to think more like experts – like practicing physicists' (p.36**).**

In the following sections, some of these research studies relating to developing particular physics graduate attributes are discussed (in particular, problem-solving, teamwork, and practical skills).

2.9.1 Representational competence and developing 'Problem-solving skills' as a physics graduate attribute

One of the key studies on physics problem-solving (Van Heuvelen, 1991a) noted that expert physicists and students approach physics problems in very different ways. While the experts start with qualitative analysis (thinking about the relevant physics principles) and use qualitative representations (for example, sketches and diagrams) to understand a physical process, the typical student approach is different: students tend to move directly to mathematical equations, viewing problem-solving as ‘almost entirely formula-centred – devoid of qualitative sketches and diagrams that contribute to understanding’ (Van Heuvelen, 1991b, p.891).

To address this ‘formula-centred’ approach to problem-solving, several physics education reform initiatives have been developed. Van Heuvelen (1991a) argues that, since students are beginners in the field, they have to learn to ‘think like a physicist’, by learning to explain physical processes and to represent these using ‘multiple representations’. Van Heuvelen (1991b) and Etkina and Van Heuvelen (2007) have developed physics curricula that centre on the use of representations (these curricula are Overview Case-Study Physics and more recently, the ISLE project). These curricula help students to:

- Construct *qualitative representations* of physical processes and problems,
- Reason about the process using these *qualitative representations*,
- Construct mathematical representations with the help of qualitative representations, and
- Solve the problem *quantitatively* (Van Heuvelen, 1991b, p.892).

Furthermore, van Heuvelen (1991b) explains the sorts of representations typically used in tackling a problem:

- The *verbal* representation of the process (describe in words);
- A *pictorial* representation (draw a sketch or a picture) to represent the process;
- A *physical* representation that involves quantities and descriptions (draw a free body diagram or a graph); and
- The *mathematical* representation to describe the process by using basic physics principles (laws and equations)

As Rosengrant et al. (2009) note, many students avoid the use of qualitative representations when they solve physics problems and move directly to equations (the mathematical representation). To address this equation-based approach, they argue for the importance of creating a ‘representation-rich learning environment, which helps students learn how to use different representations’ (p. 010108-2) and therefore to develop what Airey and Linder (2008) term ‘discursive fluency’ (p.13) in moving between representations. Physics education studies have examined students’ representational competence with a range of physics representations, including graphs (Volkwyn, et al, 2020), verbal representations (Brookes, 2006), work-energy bar charts (Van Heuvelen & Zou, 2001) and free body diagrams (Rosengrant, van Heuvelen & Etkina, 2009).

These studies show that competence and confidence in using representations in tackling problems take time to develop, and this is why studies suggest that explicit focus on representations needed to be sustained in undergraduate courses over an extended period (Etkina & van Heuvelen, 2007; Eriksson et al., 2014).

Another aspect of undergraduate teaching that hinders the development of problem-solving skills is that typical physics problems are already rather abstracted from real-world contexts (e.g. blocks on inclined planes) and are idealised (e.g. frictionless, no air resistance). Furthermore, if a problem is found at the end of a particular textbook chapter, that tends to show which physics concepts are relevant to the problem. To counter this, context-rich problems (Heller & Hollabaugh, 1992) have been developed that require that students solve problems in a more real-world context: students are expected to figure out what physics principles apply to messy real-world situations given and need to figure out which given information is useful and which is extraneous and to make simplifying assumptions.

This progression towards more open-ended questions is captured in the SAIP Benchmark Statement which notes that students should solve not only 'problems with well-defined solutions' but also 'gain experience in tackling open-ended problems (SAIP, 2015a, p.7). Similarly, the Benchmark statement also alludes to the qualitative analysis involved in tackling problems: students should 'learn how to identify the appropriate physical principles, how to use special and limiting cases and order-of-magnitude estimates to guide their thinking about a problem and how to present the solution, making their assumptions and approximations explicit (SAIP, 2015a, p.6). The USA APS-AAPT report (Heron & McNeil, 2016; Mc Neil & Heron, 2017) also points to the need to prepare students for the "challenge of solving complex, ambiguous problems in real-world contexts" (McNeil & Heron, 2017, p.41).

2.9.2 Student engagement, co-operative learning and developing 'Teamwork' as a physics graduate attribute

In undergraduate physics education, there has been a shift over many decades from the traditional lecture format towards more interactive engagement modes of teaching, partly in response to physics education research that has shown how student engagement in classrooms enhances learning outcomes: Hake's seminal study on interactive engagement showed that in undergraduate physics classes with more interactive engagement, the development of students' understanding of concepts was significantly improved (Hake, 1998).

Physics education researchers have used different terms to describe various forms of student engagement. One form of interactive engagement in lectures is termed 'Peer Instruction' (Mazur, 2007), also referred to as the 'convince your neighbour discussion' (Mazur, 1997, p.12); with the use of electronic voting or what are termed 'clicker questions' (Mazur, 2009). Another form of interactive engagement is a more formalised form of group work, termed 'co-operative learning' (Johnson & Johnson, 1991), defined as the process whereby students work together in small groups to maximise their own learning and that of their peers in the group. In co-operative learning, students are each assigned roles in the group and there is a clear awareness of group processes. (Lindstrøm & Sharma, 2011) refers to 'peer collaboration' where students work on a challenging physics task that they would find difficult to complete individually, without collaboration.

In the context of this study, interactive engagement activities were viewed as helpful for developing students' confidence in oral communication, personal skills (taking initiative as an individual while working in a group), and teamwork skills (working constructively with diverse groups).

2.9.3 Developing 'Practical' skills and related physics graduate attributes

Undergraduate physics laboratories play an important role in helping students to develop a diverse range of skills needed for graduate research and the workplace. One undergraduate programme that has done excellent work in this regard is the ISLE (Investigative Science Learning Environment) project. The ISLE laboratory tasks are more open-ended than traditional 'cookbook'-style laboratories and require students to work in groups to design their own experiments. The ISLE approach aims to develop scientific abilities such as experimental design skills, the ability to collect and analyze data, the ability to evaluate assumptions and uncertainties, and communication skills (Karelina & Etkina, 2007). Other studies have examined the development of students' measurement and data analysis skills (Volkwyn et al., 2008).

2.10 Physics education research (PER)-based teaching practices at UWC

The design of the first-year introductory courses at UWC has been informed by some of the research reviewed above on representational competence in problem-solving, teamwork and experimental skills. The first-year mainstream and ECP courses focus on the use of multiple representations in learning physics. Here, the focus is on developing students' mastery of the multiple representations used in physics, including oral and written language, graphs, diagrams, mathematics etc. (for further details on developing representational competence, see (Van Heuvelen, 1991; Rosengrant, Van Heuvelen & Etkina, 2009). In tackling physics problems, students are expected to start with qualitative analysis of a problem situation (modelling the situation, articulating relevant physics principles and making assumptions and approximations explicit etc.), then use qualitative representations, before moving to mathematical representations. In both mainstream and ECP courses, classes are held in a flat-space venue, conducive to group work and enabling interactive engagement between lecturers and students.

The ECP physics courses cover the same topics as the mainstream first-year course but are spread over two years. The extra time allows more curriculum space for foundational provision, which includes strengthening conceptual understanding, a focus on the nature of physics knowledge, and time spent developing students' mastery of multiple representations (van Heuvelen, 1991; Etkina & van Heuvelen, 2007). The ECP courses have also moved towards 'design-based' laboratory activities (drawing on the ISLE approach). The extra time also allows time for the development of students' social capital, exposure to research taking place in the department, and class visits by former students now in industry or research.

2.11 Conclusion

This study focuses on the preparedness of UWC physics graduates and their level in meeting internationally acknowledged standards in skills and attributes that graduate physics students should possess. This chapter has explored concepts of graduate attributes and physics graduate preparedness. It has reviewed policy documents from international physics organisations in the UK (IOP), USA (APS), Europe (EPS) and Australia (AIP) to identify the skills and attributes that these physics organisations feel should be developed during an undergraduate physics degree. Graduate attribute documents from SAQA and UWC were also reviewed. From this overview of policy documents, a framework was developed for desired physics graduate attributes for UWC (termed Physics Graduate Attributes (PGAs) in this study). This PGA framework will be used as an analytical tool in this study.

The chapter has also reviewed international studies that surveyed graduates' perceptions of their graduate preparedness. However, few in-depth studies focus on the perceptions of physics graduates from the perspective of preparedness, and relatively little has been reported on the knowledge and skills that physics graduates have found of value when they enter the workplace. This study aims to contribute to the literature and make a case for further research on physics graduate preparedness in South Africa.

In the following chapter, the capabilities approach is introduced; it will be used as a lens for examining physics preparedness in this study.

CHAPTER THREE

THE CAPABILITY APPROACH

3.1 Introduction

In the previous chapter, the concepts of graduate attributes and physics graduate preparedness were discussed. In this chapter, the capabilities approach is introduced; it will be used as the theoretical framework for this study, as a theoretical lens for examining physics preparedness and the development of physics graduate attributes. The capability approach is used in this study because its concepts of agency and human development fit well with the focus of this study on the development of physics graduates for work and society. In addition, the capability approach provides a normative view of what comprises a good life and offers an enlarged view of the purposes of education - moving beyond the development of human capital to encompass the development of human capabilities and freedoms.

The first section of this chapter introduces the capabilities approach in higher education. The next section explores key concepts from the capabilities approach that are used in this study including the concepts of capabilities, functionings, freedom, agency well-being, and conversion factors.

3.2 The capability approach

The capability approach (CA) theory was first introduced in 1979 by Amartya Sen, a Nobel Prize Laureate and economist. In his article 'Equality of What?' (Sen, 1979), he focused on the freedom people have to conduct their lives in ways that they have reason to value. In this view, human development is viewed as not just about poverty reduction but the expansion of people's 'capabilities' (Sen, 1999). Sen (1993) articulates this approach as follows:

> *"The capability approach is concerned primarily with the identification of value-objects, and sees the evaluative space in terms of functionings and capabilities to function (p.32) …Capability is not an awfully attractive word, perhaps a nicer word could have been chosen when some years ago I tried to explore a particular approach to well-being and advantage in terms of a person's ability to do valuable acts or reach valuable states of being. The expression was picked to represent the alternative combinations of things a*

person is able to do or be - the various 'functionings' he or she can achieve." (p.30).

The capabilities approach was further developed and promoted by Martha Nussbaum (2000; 2011), a feminist philosopher. The approach has been developed for over three decades now by numerous scholars, including Ingrid Robeyns, Des Gasper, and Sabine Alkire. The central message of the capability approach concerns the objective of human development, namely, that it should not be economic growth as an end-in-itself, but rather it should be the increase of people's real freedoms to do and be what they value (Alkire, 2015). Robyens (2006) describes the capability approach as

> *"a broad normative framework for the evaluation and assessment of individual well-being and social arrangements, the design of policies, and proposals about social changes" (Robeyns, 2006, p.78)*

This view was furthered by authors such as Alkire, Black and Gasper who see capabilities as assets of human functionings that afford individuals as autonomous agents opportunities to acquire knowledge, skills and perspectives that enable them to pursue personal well-being in their unique ways (Alkire & Black, 1997; Gasper, 1997). The capabilities approach is concerned with the real opportunities the individual has to lead a valued life, or the freedoms he or she has to achieve the particular existence they have chosen and have reason to value (Sen, 1999; Nussbaum, 2011).

According to Alkire and Black (1997) and Alkire (2015), a key aspect of exercising such freedom is the mental act of deliberation, defined as the critical assessment of ends and means available in respect of a person's well-being (Alkire & Black, 1997; Alkire, 2015). The capabilities approach moreover takes into consideration the role of institutions. As Sen remarked:

> *'We individuals live and operate in a world of institutions, of which we are not always aware, many of which transcend national boundaries today. Our opportunities and prospects largely depend on existing institutions and how they operate. Institutions do not only contribute to our freedoms but must be assessed according to their contribution to our freedoms' (Sen, 1999, p.142).*

3.3 The capability approach and education

As noted earlier, the capability approach is about creating an environment in which people can develop their full potential and lead productive, creative lives in accord with their needs and interests. Marovah (2013) puts it this way,

> *"The emphasis is on cultivating an environment or a context in which human beings realise their maximum possibilities and also realise useful or beneficial, and inventive lives in alignment with their valued necessities and well-beings." (Marovah, 1990, p.1) cited in Marovah (2013, p.599)*

As such, the capabilities approach is seen to offer a critical perspective from which to consider and evaluate what is of value in education, beyond a narrow focus on skills acquisition for the workplace and not ignoring the many other components of the education system that come into play, such as developing individual agency, well-being and citizenship (Nussbaum, 1997; Lozano et al., 2012; Hart & Brando, 2018).

Sen singles out education as one of 'a relatively small number of centrally important beings and doings that are crucial to well-being' (Sen, 1992, p.44). The capability approach seeks to engage and encourages reflection and dialogue about educational aims, which go beyond the instrumental aims of a human capital approach (Sen, 1979).

Sen acknowledges that education has an instrumental role (for example, employability, or in this case, in enabling graduates to access the workplace and economic opportunities). However, besides this *instrumental personal role* of education, Dreze and Sen (1995) characterise four other ways in which education is intrinsically, instrumentally and socially valuable for individuals and society.

The first is the *intrinsic importance* and value of education in itself in contributing to 'a flourishing life'; being educated is a valuable achievement in itself, for its own sake (Sen, 1979; Dreze & Sen, 1995). As expressed by Walker and Fongwa (2017),

> *"being educated is valuable in itself in enabling persons to flourish by enabling imagination and love of knowledge and ideas (which need to have no other purposes beyond this)" (p.60).*

There may be other arguments, but the intrinsic nature of education is the major drive that helps individuals to flourish. This relates directly to human development and the individual's choice to value the education received – Freedom. Therefore, to be educated is to have gained something of value in the process and at the end of the process.

In the same vein, education has benefits to society that cannot be quantified in economic terms and calculations (Dreze & Sen, 1995, Hart, 2012, Walker et al., 2017). Dreze and Sen refer to this as education’s *instrumental social role* in equipping people to contribute to public discussions as informed and active citizens. For example, a better-educated population might be easier to communicate to and to get feedback, they might understand human rights better with its implications, and they are likely to be nutritionally and health conscious and conservationally inclined (UN_GA, 2013; Sen, 1999).

Other ways in which education benefits society include the *instrumental process role* of education (Dreze & Sen, 1995) whereby young people engage with diversity and have their perspectives broadened and challenged. Lastly, there is the *empowerment and distributive role of education*: education can promote a more equitable society, by reducing gender and race inequalities and ‘open opportunities for others … and interrupt intergenerational inequalities (Walker & Fongwa, 2017, p. 10).

The application of the capability approach to higher education has given rise to studies examining issues of social justice in higher education. Walker has used the capabilities approach to discuss higher education pedagogies that improve student learning and support first-generation students (Walker, 2006). This research on pedagogies has also extended to professional education and the role of universities in developing public good professionals (Walker & McLean, 2015).

Other studies in South Africa have used a capability approach to evaluate and address unequal access to higher education (Wilson-Strydom, 2015a; Wilson-Strydom, 2015b), participation in undergraduate studies (Calitz, 2015; Calitz, 2017; Calitz, 2019; Calitz et al., 2016), and graduate outcomes and employability (Walker & Fongwa, 2017). Yet other studies have used the capabilities approach to examine undergraduate engineering education for sustainable human development (Hoppener, 2016), and the experiences of low-income students in higher education (Walker et al., 2022).

Within the context of this study, the capability approach is applied to the educational experiences of physics undergraduate and postgraduate students to examine their perceptions of preparedness and the extent to which a physics education can enhance the choices that physics students and graduates have to lead lives that they value.

3.4 Key concepts of the capability approach

3.4.1 Capabilities and functionings

Capabilities and functionings are two important and interrelated concepts in the capability approach. Capabilities refer to what people can do and be (Sen, 1992; Dreze & Sen, 1995). For example, people could have the opportunities (also called 'freedoms') to be healthy, have positive relationships and be well educated; these opportunities are termed 'capabilities' (Sen, 1993). In this regard, capability can be seen as an individual's ability to perform important acts or attain states of being. It can also be the utilization of different combinations of things an individual can do or be able to attain, such as being able to read, write and communicate well, take part in the activities of the community and be confident to get involved in teamwork (Berges, 2007; Gasper, 1997; McLean & Walker, 2010)**.** Sen explains capabilities as,

> *"the alternative combination of functionings that are feasible for [a person] to achieve well-being; they are 'the substantive freedom' a person has 'to lead the kind of life he or she has reason to value" (Sen, 1999, p.87).*

A capability is a potential functioning, but not all capabilities are translated into functionings. As Sen notes, "A functioning is an achievement [outcome], whereas a capability is an ability to achieve [potential]" (Sen, 1985b, p.48). So that it can be said that functionings are a subset of the capability set. It is the actualized options or chances of an individual. Calitz (2016) illustrates this point with an example of a student who develops the capability to express her voice; she then has the choice of whether (or not) to realise this capability as a functioning, through speaking out confidently in a class situation. Walker (2006), similarly, notes how higher education can offer students the opportunity to develop capabilities such as analytical thinking or citizenship, but a student may choose whether (or not) to function as analytical young people and engaged citizens.

As Walker (2006) notes, in education it is important to consider students' functionings (what they achieve) and not just their capabilities (what they are free to be or do). Often, what is assessed in higher education are students' functionings (for example, if a student is functioning as a poor communicator in written practical reports, then that indicates that their capability as a skilled communicator has not been developed in their studies).

As noted above, functioning is an achieved capability. Functionings, according to Sen, are the various things a person may value doing or the things a person is substantively free to do. Lozano et al. (2012) articulated the following examples,

> *An important category in the capabilities approach is 'functionings'. 'Functionings' can be (1) activities like reading or writing; (2) physical states, such as being able to be well-nourished and healthy; (3) mental situations, like being happy, or (4) social functioning, such as being integrated into society. When people have managed to perform a set of functionings, it seems logical to think that they have faced a number of possibilities and opted for those that they considered to be the most appropriate for their well-being (Lozano, Boni, Peris, & Hueso, 2012, p.134).*

Functionings are likened to beings and doings (Orton, 2011; Robeyns, 2006), such as being confident of one's self or being able to take part in group decisions and activities, being literate, being able to work, being healthy, being an active part of a community, being respected, and playing an active civil role etc.

Functioning is the transformation of one's opportunities, freedoms and choices - to do and be what one values – into concrete achievements. These concrete achievements could include being well-educated, having paid professional work, being respected, being scientifically literate and so on (Marovah, 2013). In the capability approach, the outcomes of education are understood as 'achieved functionings': that is, what graduates actually do and are actually, in ways they value and choose. So, in the undergraduate physics context, the achieved functionings could be viewed as the physics graduate attributes that a student has developed, for example, being able to solve physics problems, design and conduct experiments, work well with others, to be able to communicate scientific understandings etc.

In summary, it can be said that capabilities are potential functionings not necessarily achieved by the individual and not necessarily put into practice. Capabilities do not necessarily have to be expressed as a functioning in order to exist. Opportunities (linked to 'freedoms') such as eating, being healthy, having supportive relationships, being well educated etc, are termed ‘capabilities’. While the realised states of being and doing, that is, the actual practices of the individuals in their everyday lives are called ‘*functionings*’. Individuals flourish when they are free to choose how they want to function in all areas of life. So, the capability approach promotes *agency* whereby individuals are free to choose lives (beings and doings) that express their values and objectives.

3.4.2 Capabilities sets for higher education

Studies in the context of education have developed sets of educationally-based capabilities and associated functionings (Calitz, 2016; Crosbie, 2014; Flores-Crespo; 2007; Walker, 2006; Walker & Fongwa, 2017; Wilson-Strydom, 2015). These sets of educationally-based capabilities and associated functionings are produced by exploring student perspectives through in-depth participatory research methods (Bridges, 2015; Calitz, 2016; Crosbie, 2014; Flores-Crespo, 2007; Walker, 2006; Walker & Fongwa, 2017; Wilson-Strydom, 2015a&b). In considering the transition to university studies, Wilson-Strydom (2015a) argues that opportunities to develop certain capabilities should be developed in high school and during the first year of university study. Her list of capabilities for university readiness includes,

> *(1) Decision-making, 2) Knowledge and imagination, 3) Approach to learning, 4) Social relations and social networks, 5) Respect, dignity and recognition, 6) Emotional health, and 7) Language competence and confidence*

Walker (2006) lists the following capabilities that ought to be fostered in higher education:

> *(1) Practical reason, (2) Educational resilience, (3) Knowledge and imagination, (4) Learning disposition, (5) Social relations and social networks, (6) Respect, dignity and recognition, (7) Emotional integrity, and (8) Bodily integrity.*

In relation to professional education, Walker et al (2010) list the following set of capabilities:

> *(1) Informed vision, 2) Affiliation, 3) Resilience, 4) Social and collective struggle, 5) Emotional awareness, 6) Integrity, 7) Assurance and confidence, and 8) Knowledge, imagination and practical skills*

For graduates leaving higher education, Walker and Fongwa (2017) list the capabilities which graduates should possess if they are to be considered ‘employable-capable’:

> *1) Subject knowledge, critical thinking and autonomy, 2) Economic opportunities, 3) Affiliation, and 4) Thick’ aspiration (i.e. career aspirations and imagine future possibilities)*

As is evident from these capabilities sets, there is quite a bit of overlap in the capabilities that higher education should expand; common capabilities include:

- **Knowledge and imagination:** Gaining knowledge of a field – for personal development, career, and social action; using critical thinking and imagination. Being aware of wider ethical and moral debates in the knowledge field
- **Practical reason**: Being free to make well-informed, independent choices about one’s life
- **Affiliation:** Having the opportunities to develop social relationships and connections with peers and lecturers; working well collaboratively with others in groups
- **Respect and dignity**: Being treated with respect and dignity and treating others likewise
- **Emotional integrity**: Being free from fear or anxiety that might constrain learning; the ability for understanding and empathy
- **Educational resilience**: To be able to navigate challenging life and academic circumstances
- **Learning disposition**: Possessing a desire to learn and be curious

The capabilities sets above tend to have been developed through in-depth, participatory methods. The aim of this study is not to develop capabilities set for physics graduates, but to use a capability lens to look at physics graduate preparedness. In this study, a framework of physics graduate attributes is developed, not through participatory methods, but through analysis of documentation (from physics bodies, including the SAIP Benchmark statement, and the UWC Charter of Graduate Attributes). The aim of the study then is to use the capability approach to examine what enables or hinders the development of PGAs.

3.4.3 Graduate attributes versus capabilities

In Chapter two, the concepts of graduate attributes and graduate preparedness were explored in relation to the individual student or graduate. This section will aim at answering the following question ‘How does a set of higher education capabilities differ from a set of graduate attributes?’ Bozalek (2013) answers this question in relation to the development of the Charter of Graduate Attributes for the University of the Western Cape, as a historically disadvantaged university. She argues that the capability approach offers an enlarged view of the purpose of university education, with a broader conception of the graduate’s ‘good life’, pointing out that it has at its heart the understanding of the ‘social good’ contribution of university education, whereas graduate attributes might or might not be focused specifically for the workplace. In other words, in some instances, graduate attributes could be oriented more towards a human capital development perspective, whereas capabilities would be framed more by a human capability development perspective, with a focus on social justice.

It is interesting to note that the ‘social good’ contribution of university education is evident in the UWC Charter of graduate attributes, reflecting some of the capabilities for higher education identified above in section 3.4.2. For example, the capabilities of ‘affiliation’ and ‘respect and dignity’ are reflected in the UWC graduate attributes relating to collaboration and the ability to ‘interact with people from a variety of backgrounds and have the emotional insight and imagination to understand the viewpoints of others’. Similarly, the UWC graduate attribute of being ‘Ethically, Environmentally and Socially Aware and Active’ is reflected in the ’knowledge and imagination’ capability (which encompasses knowledge for social action, and being aware of wider ethical and moral debates in the knowledge field).

However, as noted in Chapter two, not all universities would necessarily have graduate attribute documents with such a clear ‘social good’ orientation; this focus on UWC’s graduate attributes reflects its particular history and institutional mission. Moreover, as also noted in Chapter two, it is clear that the SAIP Benchmark Statement (introduced in Chapter two) is more narrowly focused on a disciplinary context, and does not include wider ethical, environmental or social dimensions. Also, the SAIP 'ethics' category is limited as it does not encompass wider ethical issues in science, as it focuses only on data ethics and nothing is said about the fact that knowledge could be harnessed for the public good or ‘public bad’ (East, Stokes & Walker, 2014, p.1629).

3.4.4 Freedom

Sen relates capability to freedom as the range of alternatives a person has in choosing what kind of life to live (Sen, 2004; Saito, 2003). Freedom is about the alternative options or combinations of functionings from which a person can choose and freedom makes sense when combined with the individual abilities to make good choices and not one which the person is forced or coerced into. For example, a student who chooses to study physics for his/her degree and progresses in that course of choice will do better than a student that is forced to study physics. Freedom is valued by all. Without freedom, an individual may not claim increased functionings such as agency and well-being, because an individual's achieved functionings at any given time are the identified beings or doings the individual enjoys in freedom (Alkire & Black 1997; Alkire 2015).

> *"The basis of capability development is guided by the exercise of individual freedom to choose and develop the desired lifestyle, and therefore the values individuals consider to be desirable and appropriate. Capability, therefore, responds to an individual's internal demand to freely choose his or her own way of life. Here Freedom is understood as autonomy to be and to do the things someone has reason to value" (Lozano et al., 2012, p.140).*

Here, the process of expanding freedom is present everywhere and the individual's development is an expression of freedom.

> *"Freedom can be valued for the substantive opportunity it gives to the pursuit of our objectives and goals. In assessing opportunities, attention has to be paid to the actual ability of a person to achieve those things that she has reason to value" (Walker & Fongwa 2017, p. 61).*

Therefore, freedom has an intrinsic value obtainable both from the choices made and the process of making these choices, such as the choice of studying physics amidst the likes of Mathematics, Statistics, Engineering and the Medical sciences. Freedom to make choices does not guarantee human well-being. Sen stated that a person could have freedom without achieving much in life. This low achievement level could happen even if an individual has the capacity to achieve a functioning, that is because the capability of an individual is high but, for some reason, the individual may choose not to actualize it or the individual may choose to have more from a set of freedom than from another (Nussbaum, 2007; Nussbaum, 2011; Orton 2011;

Powell & McGrath, 2014). Freedom could have both good and bad dimensions. Freedom leading to bad actions is not of value, as explained by Sen: “It is odd to conclude that the freedom of a person is no less when she has to choose between three alternatives which she sees respectively as 'bad', 'awful', and 'gruesome' than when she has the choice between three alternatives which she assesses as 'good', 'excellent' (Sen, 1993, p.34). Positive freedom is what people can do or be. Freedom is an end in itself, and not only a means for another type of utility (Gasper, 1997).

3.4.5 Agency

In the capability approach, agency is one of the key functionings of human life (Sen, 1992). Agency encompasses the ability of the individual to pursue goals that they value, and which are valuable for the life they wish to lead. Sen’s concept of ‘agency freedom’ entails the person having the freedom to achieve whatever goals they regard as valuable (Sen, 1992). Sen argues that people “have to be seen … as being actively involved – given the opportunity - in shaping their own destiny” (Sen, 1999, p.53). This is further articulated by Marovah (2013),

> *“… the concept of agency advances the notion that it is the stimulation and commitment of the individual learner (agency) which makes ‘functionings’ ’important in securing human freedoms, choices and opportunities to do and to be what they value. In other words, the will to be or not to be will make a difference in the way a student advances or regresses. For this reason, Nussbaum (2000) argues that citizens must be left to determine what they make of the capabilities that are granted them” (Marovah, 2013, p. 604).*

Being agentic involves making choices. For example, a student would have the agency to choose between studying physics or biotechnology; to choose whether (or not) to take up opportunities such as student union activities, volunteering, internships, industrial attachments, etc. As physics graduates, they would have the agency freedom to choose whether to work as a data analyst in industry or to become a science teacher. In this way, individuals should be seen as being able to act or add a voice to bring about desired change (Alkire 2015). Thus, participation in community affairs where members freely do something they value for others is an expression of agency. From the foregoing, it can be said that the process of obtaining freedom to make choices which involves the beneficiaries of that process as actors (free agents) is agency.

The capability approach encourages the individual to be the ones in charge of their own lives by allowing people to exercise agency towards achieving goals that they value. In this regard, O'Meara (2013) in her work on graduate student agency notes that '*Agentic action is discrete from, but often closely follows, and is related to agentic perspective*' (O'Meara, 2013, p.3). O'Meara (2013) explains that '*Agency is always enacted in relationship to something and individuals can display agency in one area but not in another*' (p.2). As an example, she notes that a student may exercise agency to balance family commitments with thesis-completion demands, but not experience agency in terms of the freedom to determine the direction of her research agenda.

Walker (2006) argues that student agency can be fostered or restricted by pedagogical practices. Walker and Fongwa (2017) note how universities can do their best to expand students' capabilities and functionings, but ultimately student agency also plays a role:

> *At the core is expanding students' human capabilities and agency freedoms by addressing educational conversion factors in intersection with personal biographies, while also expecting students to be responsible as individuals for their learning once conditions are in place to fully support them. (p. 105)*

3.4.6 Well-being

Well-being is constituted by all the capabilities of a person and what he/she can then do and be (his/her functionings) including his/her agency so well-being is multidimensional with many valuable dimensions. The fostering of students' well-being (their capabilities and functionings) and their agency – together enables students to reason about and make choices about the life they have reason to value. Sen (1993) relates well-being to the standard of living of an individual, not merely wealth or income. He explains that it has a personal dimension and relates to one's life. Gasper notes that "well-being will reflect (mainly) [an individual's] actual functionings" (p.283) and not just what makes the individual happy or what the individual does that brings fulfilment (because, as an example, he includes the fulfilment felt by a drug addict). Walker and Fongwa, in their study on graduate pathways, highlight the importance of work for well-being and human flourishing:

> *"Work then matters for flourishing lives and social well-being and for our identities and relationships. ... aspirations for what work can do in our lives, and social and educational arrangements should enable the translation of*

employability into meaningful, decent work and fulfilling graduate careers"(Walker& Fongwa, 2017, p.55).

The individual's freedom may go beyond the capabilities of personal existence and may relate to the individual's other objectives/goals, such as social goals not directly related to the individual's own life. In many settings for some individuals, these goals/objectives may include the consideration of the overall choice of having or not having to choose among a whole lot of relatively trivial alternatives. An individual may feel happy because he has helped another person solve a problem and, as such, well-being could be related to the freedom that individuals have to achieve this outcome, such that Sen wasn't hesitant to say that,

"In this approach, functionings are seen as central to the nature of well-being, even though the sources of well-being could easily be external to the person" (Sen, 2003, p.36).

Well-being is seen in the abundance of the means of livelihoods of people. It involves the presence of necessities of material well-being and opportunities for living a good life (Nussbaum, 2011; Orton, 2011; Alkire, 2015). Education (in whatever form) enables individuals to acquire knowledge, but at a higher level such as university education in the context of this study, it contributes to well-being through capability development (such as the PGAs) which physics graduates can develop and use for benefit of studies, career or work and a fulfilling life in the society.

3.4.7 Conversion factors

The capability approach is based on the notion that individuals are fundamentally diverse, and that there are *personal, social and environmental conditions* at different geographical locations which are the reasons for this fundamental diversity (Sen, 1979). That is to say that because humans are not the same, they will require different resources/commodities to achieve the same functionings. For example, Sen (1979, 1993) notes that a person in a wheelchair will require more resources to achieve the same level of personal mobility than will able-bodied people.

As Nussbaum notes, the development of capabilities is closely tied to the wider environment in which individuals find themselves:

In the capabilities approach, capabilities 'are not just abilities residing inside a person but also the freedom or opportunities created by a *combination of personal abilities and the political, social, and economic environment' (Nussbaum, 2011, p. 20).*

Sen's concept of conversion factors is aimed to evaluate how each person is able to convert his/her bundle of goods (resources) into capabilities (Sen, 1999). Within the capability approach, conversion factors are personal, social and environmental differences that explain why individuals benefit differently from the same resources (Robeyns, 2005a). Conversion factors constitute the personal, environmental and social situations or conditions of each individual as a unit of interest. Sen (1993) and Robeyns (2005b) see these conversion factors as the basic influencers that play a major shaping role for the individual. In the capability approach literature, the example of a bicycle is often used to illustrate the concept of conversion factors. The usefulness of a bicycle in enhancing a person's mobility could depend on the person's level of fitness (a personal conversion factor), on social norms, for example, whether women are allowed to ride bicycles (a social conversion factor), or on the availability of suitable cycle-paths (an environmental conversion factor) (Robeyns, 2017).

In the context of higher education, Walker and Fongwa (2017) describe conversion factors as follows:

> *"Conversion factors encompass intersecting personal, social, environmental, relational and family factors (although the latter two could arguably be subsumed into the social). Students, for example, could differ: (1) along a personal axis (e.g. gender, age, class, family structure, etc.); (2) along an external environmental axis (climate, geography, prevalence of diseases in the region, etc.) and (3) along an interindividual or social axis" (Walker and Fongwa, 2017, p. 65).*

Bozalek (2013) notes the usefulness of the concept of conversion factors in foregrounding how each student is differently placed in terms of being able to convert his/her bundle of goods (education resources on offer in a university) into capabilities:

> *'The [capability approach] offers a way of taking into account where students and institutions are positioned and what they are able to do with personal, material and social resources, rather than merely looking at what resources people have and assuming that people are equally placed in relation to these resources' (ibid. p.74).*

Calitz (2015) provides a useful illustration of this: some students are more able to make use of the university library and computer labs after hours than other students, due to it being unsafe for some students to commute home after hours. Because of this environmental factor, students are differently positioned in being able to convert educational resources (like books or internet access) into educational functionings.

Thus, for any educational context (such as the undergraduate physics programme in this study), there are institutional arrangements (which are social or environmental in nature) that enable or hinder the conversion of resources into capabilities and functionings attained. Graduate skills and attributes can be viewed as functionings that in turn expand capabilities for an outcome that enhances well-being. For example, a graduate who leaves university with functionings such as communication or computational skills would be able more easily to develop further capabilities in the workplace or life beyond university.

Conversion factors include the external structures of the social world or the relevant policies that shape the conditions under which individuals can (or cannot) capitalise on their resources to enhance or expand their capabilities. This includes all accounts of personal, environmental and social conversion factors for the individuals. Thus, it can be stated that the capability approach allows us to

> *"Acknowledge structures that influence and shape education but also draws our attention firmly to an education space of capability possibility and agency freedoms. It provides us with a rich approach to investigating advantage and disadvantage in education as capability expansion or capability deprivation. A more socially just education would need to demonstrate that it is advancing the capabilities and secure functionings of all students", Walker & Fongwa (2017, p. 64)*.

In other words, the capability approach allows us to identify conversion factors that enable or hinder educational processes, and in doing so, highlight changes needed to societal and institutional arrangements to ensure more equitable outcomes. For example, Calitz's study on students' participation in higher education found enabling social/institutional conversion factors that included 'affiliation with lecturers' and 'creating platforms for students' voice'. Social/institutional conversion factors that hindered student participation included 'individualising failure' and 'alienation from lecturers' (Calitz, 2015). Walker and Fongwa's study (2017) examined the conversion factors that shape graduates' conversion of education resources into capabilities and functionings (in this case, gaining employment). Personal conversion factors included race and social class (including social networks for entry to the workplace); social-university conversion factors included university reputation, the field of study, and career advice on offer. The environmental conversion factor of the location of the university (urban or rural) also played a role. Walker and McLean (2015)**,** in their study of professionals and public good capabilities, identified conversion factors such as 'lack of resources', 'understaffed services' and 'inappropriate government attitudes' amongst others.

3.5 Theoretical relevance of the capability approach

Sen argues that the capability approach must be practical in the sense of being usable for assessments of the living standard of individuals, where the implications of the capability approach have practical importance in the real world (Dreze & Sen, 1995; Alkire & Black, 1997; Nussbaum, 1997). The capability approach replaces the traditional concern of resources, utilities or income with an intrinsic concern of what people can be or can do; what people do or be and choose to like amidst alternatives (Gasper, 1997; Nussbaum, 2011). This is expressed by Gasper,

> *"Each person's inheritance and situation provides them with a distinctive set of capabilities. In Sen's usage… the consumer's capabilities (or capability set) means this particular set of options, where each option is an alternative package of doings or more broadly speaking, of functionings, i.e. `doings and beings from which she chooses" (Gasper, 1997, p.283).*

Therefore, the capability approach can be applied to the analysis of phenomena such as university education, the educational pathways that students follow through courses or programmes, and the graduate outcomes of these pathways. In its application to this study, the capability approach *encompasses the identification and weighting of valuable things* that people can be or do, in this case, physics students and physics graduates. The flexibility of the capability approach allows for adjustment to different situations and Sen advises the use in line with observations of personal status as the main focus as it pertains to data. Sen clarifies that the extent of application of the capability approach depends on the practical considerations regarding what data can be accessed and what cannot (Sen 2004). Whereas the capability approach can take stock of the full extent of freedom to choose between functioning bundles, there may exist limits of practicality which may force analysis to be confined to examining the achieved functionings only. For example, as noted by Walker (2006) earlier (see section 3.4.1), in higher education it is often more practical to assess students' achieved functionings, rather than their capabilities.

The strength of the capability approach is that it does not only focus on the individual's characteristics (for example, abilities, knowledge, motivation etc.), as is sometimes the case with 'deficit' perspectives in higher education that position student success as individually-determined and disregard the impact of structural constraints (Bozalek & Boughey, 2012; Pym & Kapp, 2013). Instead, the capabilities approach is focused on the entire process that leads the individual to acquire a particular set of capabilities, and how institutional and social arrangements can enable or hinder this process.

3.6 Conceptual framework: Capability approach and physics graduate preparedness

This chapter has presented the capability approach as the main theoretical framework for guiding the current study. University education may appear to avail every student equal opportunity; however, only certain social groups with the same attributes as the educational system might excel. Similarly, when graduates enter the workplace or society, personally linked or held social or economic capital may turn out to be the influencing factor in the face of certificates/qualifications of equal worth for the same opportunity. Thus, the conversion factors will influence the individual's work, professional opportunities and identities in different ways, depending on whether the individual has more, less, or no social or economic capital. This may have a far-reaching impact as noted by Walker and McLean,

> *"The positive impact of higher education, therefore, is not restricted to those who directly study there, but can potentially permeate through the whole of society" (Walker & McLean, 2015, p.61).*

The impact of preparedness of physics students and graduates is linked to well-being; where well-being is possible as is in this case, education enables individuals to acquire knowledge and at this level, it contributes to well-being through capability development. The conceptual framework for this study is a synthesis of the capability approach as it relates to physics graduate preparedness. Figure 3.1 provides a visualisation of the application of the capability approach for understanding and analysing physics graduate preparedness for work and society.

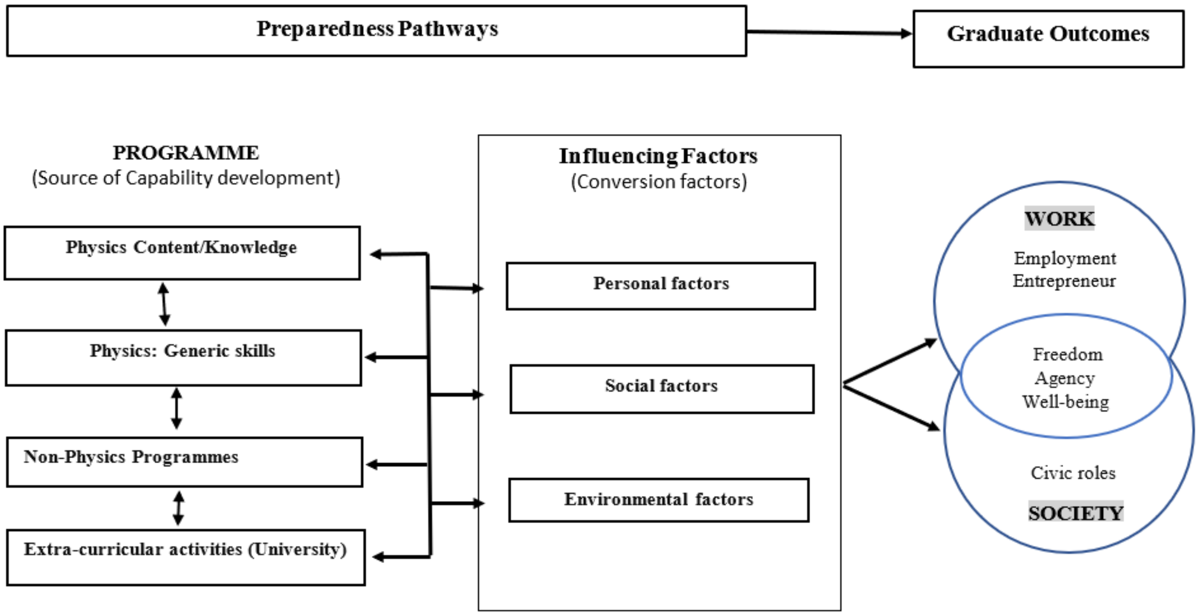

Figure. 3.1: Visualisation of a capabilities framework for understanding physics graduate preparedness for work and society (adapted from Robeyns, 2006; Fongwa, 2018)

3.7 Conclusion

In this chapter, the capability approach, used as the theoretical framework for this study, was introduced. Its application to education, and in particular, higher education, was discussed, and key concepts from the capability approach used in this study are described, including the concepts of capabilities, functionings, freedom, agency, well-being, and conversion factors.

The value of the capability approach was discussed in relation to the enlarged view of the purposes of education that it offers - moving beyond the development of human capital to encompass the development of human capabilities and freedoms. In the context of this study, the capability approach fits well with the focus of this study on the preparedness of physics graduates for work and society. An additional value of the capability approach is its focus on the entire process that leads the individual to acquire a particular set of capabilities, and how personal, social and environmental factors can enable or hinder this process.

In the next chapter, the research methodology and research methods used to examine physics graduate preparedness are discussed.

CHAPTER FOUR

RESEARCH DESIGN: METHODOLOGY AND METHODS

4.1 Introduction

This chapter outlines the methodology and research methods used to design and conduct this study. As discussed in Chapter one (section 1.8), the study aimed to examine the following:

- firstly, the extent to which the graduate attributes (as specified in the SAIP and UWC graduate documents) had been implemented in the undergraduate physics degree programme;

- secondly, students' perceptions of their preparedness, as well as the perceptions of preparedness of recent graduates;

- thirdly, the personal, social and environmental conversion factors that students perceived to be enabling or hindering the development of graduate attributes during the undergraduate degree programme. These could include students' personal attributes, as well as the institutional and pedagogical arrangements that impacted their perceptions of graduate preparedness.

As discussed in Chapter three, the capabilities approach is used as a normative framework and a lens to examine physics graduate preparedness (in relation to the attainment of physics graduate attributes).

It is worth stating again the research questions for the study:

- How are the espoused physics graduate attributes (as specified by SAIP and UWC graduate documents) embedded in the UWC undergraduate physics curriculum?
- What are students' perceptions of their preparedness in relation to the physics graduate attributes?
- What are the conversion factors that influence students' perceptions of the attainment of the physics graduate attributes?
- In relation to physics graduates entering the workplace, what are the conversion factors that influence their preparation for entering the workplace?

This chapter describes the research paradigm, and methodology and explains the steps and procedures taken to design the research study and to select suitable data collection methods to address the research questions of this study. A brief overview is provided of how the data was collected and analysed, as well as consideration of the ethical clearance process and my position as a researcher.

4.2 Research paradigm/theoretical perspective

In the literature on research methodology, the terms ‘research paradigm’ and ‘theoretical perspective’ are often used interchangeably. In discussing the research paradigm/theoretical perspective, methodology and research methods of this study, Crotty‘s (1998) framework is useful for conceptualising the four key elements of the research process:

- *Methods*: Techniques or procedures used to gather and analyse data related to some research question or hypothesis.
- *Methodology*: Strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes.
- *Theoretical perspective*: Philosophical stance informing the methodology and thus providing a context for the process and grounding its logic and criteria.
- *Epistemology*: Theory of knowledge embedded in the theoretical perspective and thereby in the methodology (p.3).

This framework emphasises that the methodology and research methods of a study are underpinned by the theoretical perspective (or research paradigm) and its associated epistemological commitments.

Research paradigms/theoretical perspectives are characterised in various ways. A common approach is to classify research paradigms into three philosophically distinct categories: positivism, interpretivism and critical theory. Each of these research paradigms has different aims or purposes:

- *Positivism*, with its association with the natural sciences, is hypothesis-driven, focusing on prediction and establishing cause-and-effect relationships;
- *Interpretivism* has a focus on interpretation and aims to provide insight into people’s subjective experiences and how they make sense of phenomena;
- *Critical theory* tends to have emancipatory purposes, focussed on a critique of inequalities and power relationships to bring about social change (Paterson and Higgs, 2005; Maree, 2007; Case and Light, 2011).

For this study, an interpretivist paradigm is well suited, as the study seeks to provide insight and understanding of students' and graduates' perceptions and experiences of graduate preparedness and the development of their capabilities and functionings (i.e. the physics graduate attributes developed) through their university education.

It is worth noting, that although the capabilities approach is a normative framework oriented towards social change, this study itself did not set out to effect change through the research process itself (unlike other capabilities approach studies which adopt a more critical participatory research approach (for example, Calitz, 2015).

4.3 Research methodology

The research paradigms/theoretical perspectives outlined above are characterized by particular methodological approaches to research, methods of data collection, as well as analysis of data. Crotty (1998) characterises the methodology as 'the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes' (p.3).

It is often argued that quantitative studies and qualitative studies differ in their approaches with respect to their epistemology (the ways of knowing and enquiry into the nature of reality) and ontology (that is, what is to be known and assumptions about the nature of reality). Thus, in epistemological orientation, quantitative researchers are often viewed as objectivists and positivists in their research approach while qualitative researchers are subjectivists and anti-positivists in their research approach (Creswell, 2009; Tubey et al., 2015; Flick, 2009).

However, this dichotomy between quantitative and qualitative research is not very useful. As Case & Light (2011) note, a more significant distinction to be made is "between the different theoretical perspectives which are marshalled to justify both the methodologies and methods employed" (p.189). In this regard, it is important to note that although research from an interpretivist perspective would tend to adopt qualitative approaches (for example, interviews) to better understand participants' experiences of phenomena, quantitative methods could also play a role in such an interpretivist study.

This study was framed by an interpretivist paradigm; the methodology adopted was a qualitative inquiry, which poses questions that emphasise the why and how of human interactions and experiences (Agee, 2009), with the goal of understanding the lived experiences of the individuals or groups. Hesse-Biber (2010) notes that a qualitative approach to research:

> *"…aims to understand how individuals make meaning of their social world. The social world is not something independent of individual perceptions but is created through social interactions of individuals with the world around them. … [An]interpretative approach assumes a subjective reality that consists of stories or meanings grounded in natural settings" (p.455).*

The research objectives of this study can best be explored through this approach – the study posed research questions that could not be experimentally examined or measured in terms of descriptive statistics (Denzin, Lincoln & Giardina, 2006; Creswell, 2013). Furthermore, the purpose of the study was not aimed at comparing or generalising findings, but to help widen our understanding of the development of physics graduate preparedness in the specific context of a South African university. Nevertheless, as noted earlier, quantitative research methods can play a role in qualitative inquiry, in providing background information or providing an overview which can be explored in finer detail qualitatively.

4.4 Research design

As noted, this study is interpretivist in nature, aiming to understand students' perceptions and experiences, and therefore the research design is largely qualitative. However, the study also employed quantitative methods for the earlier part for two main purposes: to gather demographic details of the student cohort, and to survey the cohort for their perceptions of preparedness in relation to the Physics Graduate Attributes framework (as described in Chapter two). This was done using a questionnaire which was developed in this study, referred to as the Physics Graduate Preparedness Questionnaire.

From the overall cohort of students who completed the questionnaire, a sub-group formed the first part of the qualitative aspect of the study, which required rich descriptive data that pertains to individual experiences (Sinclair, 2002; Creswell, 2013). Here, focus group discussions and open-ended interviews were used to examine critical issues in the overall concept of physics graduate preparedness for work and society; where the physics graduates would need to re-live their experiences in the narrative stories they tell.

In-depth, open-ended interviews were conducted with individual students since the background of an individual plays an important role in his/her experience. So also, the experiences of higher education have diverse impacts on people, so human capabilities and functionings are perceived subjectively. For example, the undergraduate students were all registered for the same programme, but came to university with different backgrounds and social capital, and so what they valued, and the professional capabilities and functionings that they developed during their programmes, varied for each student. The same applies to the post-graduate students, some of whom joined UWC at the Honours level, bringing different undergraduate experiences.

In addition, each graduate has a distinctive set of experiences as a student and unique circumstances and motivations for choosing physics as a discipline. This study, therefore, employs qualitative research as its final method to gather descriptions, which are not aimed at comparing or generalising findings.

4.4.1 Locating narrative inquiry in this research

Narrative inquiry is based on the premise that when participants are provided with opportunities to narrate and share their own stories, they try to effectively make sense of their experiences; human experience lends itself to be shared in narrative form (Clandinin & Connelly, 1998). Narrative researchers, in turn, seek to understand and then present human experiences through the stories of the research participants (Creswell, 2005). In writing about narrative inquiry, Polkinghorne (1995) distinguishes between 'narrative analyses' and 'analysis of narratives'. In a 'narrative analysis' approach, each narrative needs to be dealt with on its own terms, to maintain the coherence and logic of the story it contains. The next stage is to look across the narratives for similarities and commonalities while keeping the integrity of each individual narrative. Polkingthone describes this process of examining the narrative data for the emergence of common themes or "paradigmatic typologies and categories" (p. 5) as an 'analysis of narrative'. This is similar to the common approach to analysing qualitative data, often termed 'thematic analysis'.

In this study, a narrative inquiry approach is adopted with the physics graduates, who were first interviewed in their final year of study and then again the following year, once in the workplace. The graduates narrated their experiences of getting to university, their experiences while at university, and the pathway beyond university into the workplace. Several other studies framed by the capability approach have also adopted a narrative inquiry approach: these include Mkwananzi and Wilson-Strydom (2018) who adopt narrative inquiry to gain insight into the lives and educational aspirations of migrant youth; Calitz (2015; 2019) who uses narrative inquiry to explore students' experiences of participation in higher education, and Walker and

Fongwa (2017) and Walker et al. (2022) who analyse the narratives of students' aspirational pathways through university and beyond.

4.5 Case selection and the participant sample

The higher education institution selected for this study is the University of the Western Cape. The Department of Physics and Astronomy at the university is well-regarded for its Astronomy, Nuclear Physics and Material Science programmes. The selection of this research site was influenced majorly by the fact that it is the institution where I am studying for my PhD.

The study population was the 3rd year undergraduate, Honours and master's students in the department. That is because they are in the final year of their studies in their various programmes (i.e. completing 3rd year, the one-year Honours programme, or in the process of completing their Master's). These senior-level students were chosen because they are likely to have a wider range of experiences from which to draw and formulate their perceptions of how their education has prepared them for work and society.

The quantitative aspect of this study focused on gathering data from a large, representative sample of 3rd year, Honours and Master's students. From this larger cohort, a smaller cohort of students was chosen for a follow-up focus group discussion as part of the qualitative aspect of the study, to examine students' perceptions of the 'preparedness' of physics graduates in detail. The goal is not to provide a broad, generalizable description that is representative of most situations, but instead to describe a particular context in depth (Borrego, Douglas & Amelink, 2009; Trevelyan, 2016). By assessing the rich contextual descriptions afforded by focusing on only a few participants it is possible to recognize and understand some nuances about the practices and situations that occur within the university system which may have been overlooked.

Table 4.1 below outlines the phases of the research and details about the sample. In the first phase, questionnaires were administered to 3rd year, Honours and Master's students in the Department (52 students completed the questionnaire, representing 70% of students enrolled in the Department in those year levels). Eleven students took part in focus group discussions; of these students, four were interviewed the following year, as graduates now working in various job capacities.

Table 4.1: Summary of the phases of the research study

Research question addressed	Phase of the research study	Source of data/sample	Data collection	Data analysis
RQ1 How are the espoused physics graduate attributes embedded in the UWC undergraduate physics curriculum?	***Phase 1*** (August 2017)	UWC Science Faculty Yearbook	Module descriptors	Document analysis
RQ2 What are students' perceptions of their preparedness in relation to the physics graduate attributes?		3rd year, Honours & Master's students (52 students)	Quantitative - Demographic data - PGP Questionnaire data - Short Ranking list of attributes[5]	Descriptive statistics
RQ3 What are the conversion factors that influence students' perceptions of attainment of the physics graduate attributes?	***Phase 2*** (Oct. – Nov. 2017)	Sub-section of the cohort 11 students: - five 3rd years - six Honours and Masters	Qualitative - focus group discussions with students	Thematic analysis
RQ4[6] In relation to physics graduates entering the workplace, what are the conversion factors that influence their preparation for entering the workplace?	***Phase 3*** (Oct. – Dec. 2018)	Four graduates from the student cohort who had graduated the previous year	Qualitative - open-ended interviews with graduates	Thematic analysis and narrative analysis

4.6 Data Collection

For this study, I employed both quantitative and qualitative research tools. This enabled me to get to look at the research situation from different perspectives. The quantitative and qualitative tools that were employed in this research are:

- Analysis of module descriptors;
- Questionnaire (Physics Graduate Preparedness Questionnaire) and short Ranking list;

[5] This simple Ranking list (based on Sharma et al (2008) was given to the students at the start of the focus group interviews in Phase 2
[6] Phase 3 also addresses RQ3, since the graduates described not only their pathways into the workplace, but also shared their stories about getting access to university, and navigating through university.

- Semi-structured focused group discussion with physics students; and
- Open-ended interview with physics graduates who were working six months after graduating.

Each of the data collection tools is discussed below.

4.6.1 Document analysis

To explore what was already being done in the university to prepare physics graduates, I obtained the 2017 Faculty of Natural Science yearbook, which contains module descriptors for each module offered. The module descriptors include details such as the module credit value, module content and learning outcomes, methods of assessment and learning hours. The learning outcomes for each module descriptor were analysed, to gauge the extent to which the Physics Graduate Attributes (PGAs) were evident in the listed learning outcomes. In some cases, the PGAs were directly listed, in other cases, they could be inferred (this is discussed in greater detail in Chapter five).

4.6.2 Development of the Questionnaire (Physics Graduate Preparedness Questionnaire)

In Chapter two, the development of a framework for Physics Graduate Attributes for UWC was described, based on the benchmark statements and reports from international and national bodies (SAIP, IOP, AAPT, AIP), as well as SAQA and the UWC Charter of Graduate Attributes (see Table 2.3).

From this framework of physics graduate attributes, and based on approaches and formats of other studies, the Physics Graduates' Preparedness Questionnaire was designed. It was designed to gauge students' perceptions of their current level of preparedness in each of these skills/attributes, as well as the extent to which these skills/attributes were developed during their undergraduate studies (see Appendix D)[7].

As noted in Chapter two, many physics graduate attribute studies use a survey that is a list of attributes and then graduates indicate (on a Lickert scale) the extent to which they believed these attributes had been developed in their undergraduate and postgraduate degrees (Shin & Phang, 2012; Byrne & Mendez, 2012). The limitation of such an approach could be that

[7] This was done to distinguish between skills that students had developed *prior* to coming to UWC and skills that were further enhanced during their studies at UWC

respondents may have their understanding of terms such as ‘lifelong learning’ or ‘teamwork skills’ (Shin & Phang, 2012). To address this, in some cases, the questionnaires included an information sheet with a description for each of the attributes listed to clarify any student misunderstanding of the terms (Assamoi, 2015; Zegwaard & Hodges, 2003).

In this study, instead of simply giving respondents a list of the 12 graduate attributes in the PGA Framework, the Physics Graduates’ Preparedness Questionnaire was developed, consisting of 36 items which are statements about the 12 graduate attributes in the PGA Framework (and 8 items which are statements about extra-curricular activities, career guidance, and UWC graduate attributes awareness). In the case of some graduate attributes, the attribute comprised various aspects. For example, the definition of ‘Teamwork’ included working in teams and collaborating with others, and being able to work constructively across differences, with a diverse range of people. In these cases, several items were developed on the questionnaire to reflect the various aspects comprising a single attribute[8].

Overall, the Physics Graduates’ Preparedness Questionnaire comprised 44 items and respondents were asked to rate the extent to which they agreed with each statement (using a 7-point Likert scale, 1 = lowest agreement and 7 = highest agreement).

Section A of the questionnaire contained questions about students’ biographical details. The questionnaire items in Section B were developed based on descriptions of the Physics graduate attributes from the SAIP benchmark statement and other physics bodies (IOP, AIP and APS), as well as from the UWC Charter of Graduate Attributes (for teamwork, ethical behaviour) and items from the graduate survey used by Walker and Fongwa (2017).

The questionnaire items in Section C were developed taking into account the social and environmental awareness aspects of the UWC Charter for Graduate Attributes, as well as building on the findings of Walker and Fongwa (2017) who noted the importance of extra-curricular activities and career guidance in developing some of the graduate attributes. Similarly, literature on STEM undergraduate education in the USA shows that extracurricular and co-curricular activities are important for student retention and academic success (Figueroa et al., 2013), as well as for increasing job prospects after graduating (Sagen et al., 2000).

[8] `For example, Teamwork items on the questionnaire included: ‘I am capable of collaboration and teamwork’; ‘I am equipped to interact with people from diverse background’.

Therefore, in Section C, items related to extra-curricular activities such as volunteering roles, tutoring, sports activities, community groups or clubs and social engagements were seen as important and included in the questionnaire.

4.6.3 Semi-structured Focus Group Discussions

One of the qualitative data collection methods used in this study is the focus group discussion. This method involves a semi-structured discussion about a specific topic (Maree, 2007; Creswell, 2013), in this case, a discussion about physics students' 'preparedness' among a small group of selected individuals. Focus group discussions do not aim to reach a consensus on the discussed issues; rather, they encourage a range of responses which provide a greater understanding of the attitudes, behaviour, opinions or perceptions of participants on the research issues (Hennink, 2007; Creswell, 2013). For this study, the students were selected based on the following criteria:

- They must be in the final year of their various programmes (i.e. 3rd year undergraduate, completing the one-year Honours programme, or completing their Master's degree)
- They had volunteered to participate in the research.

The focus group discussion took place in a venue where participants felt comfortable enough to engage in a lively discussion for over one hour (Liamputtong, 2011). The researcher created a space for the participants to feel comfortable discussing their opinions and experiences without fear that they would be judged or made fun of by others in the group. The focus group discussions for undergraduate and postgraduate students took place in the same venue on a separate day; this was to ensure that the focus group interview questions could be adapted for each specific group (undergraduate and postgraduate).

It is worth noting that as a research method, focus groups do not suit all research. That is because focus groups may not be sufficiently in-depth to allow the researcher to get a complete understanding of the participants' experiences, especially because there are other participants during the discussion. The purpose of the focus group discussions in this research was to understand how participants view the purposes of their studies, why they wanted to become physicists and what participants felt they needed to find fulfilment. The first section of the discussion focused on talking about the students' motivation to study Physics. Then, the discussion focused on students' perceptions of learning the generic skills, questions about the programme, career information and fulfilment in taking the path of Physics.

To set the context for the focus-group discussion, each participant was given a simple Ranking list just before the focus-group discussions; this was a list of 11 graduate attributes (adapted from the Sharma et al. (2008) Australian study, which asked participants to rank the extent to which each skill had been developed in their undergraduate studies (on a scale of ‘A little’, ‘Some’ and ‘A lot’).

The semi-structured interview protocol for the focus groups was developed by the researcher who was the interviewer and focuses group facilitator (see Appendix D).

4.6.4 Open-ended interviews with graduates

According to Maree (2007) and Creswell (2013), open-ended interviews allow the researcher to best define the line of inquiry, but at the same time provide room to identify emerging lines of inquiry that are related to the study objectives, which can further be explored and probed.

The interview was to elicit the physics graduates’ perceptions of their preparedness for the workplace and life beyond university. The open-ended narrative approach enabled them to tell their stories of coming to university, their experiences while at university, and the pathway beyond university into the workplace. The interview was intended to stimulate the interviewees’ critical reflection and at the same time lead the conversation without deviating too much from the purposes as stated by the research questions.

The open-ended interview allowed me to follow up on each participant on what is narrated (which was informed by literature, my conceptual framework, and most importantly the research questions) and allowed room to ask probing questions that were born out of some curiosities triggered during the conversations. Each interview lasted between one and two hours – three interviews were conducted via telephone (since the graduates were elsewhere in the country) and one face-to-face (with a graduate working locally).

4.7 Transcribing the interview and focus group data

The focus group discussions and interviews were audio and video recorded and transcribed directly, that is verbatim. There were two focus group discussions (one with undergraduate students and one with postgraduate students), and four interviews with graduates. All focus group discussions and interviews were conducted in English. I did the transcribing myself and it was crosschecked by physics colleagues for any inaccuracies. All deviations, sounds or exclamations (such as sighing) and gestures, were ordinarily ignored.

4.8 Data analysis

For the quantitative aspect of this study, descriptive statistics were used. For the qualitative aspect of the study, thematic analysis was applied to reveal nuances to enable the researcher to draw out the themes relating to aspects of the context that enabled or hindered students' perceptions of their preparedness. The process of thematic analysis in qualitative research involves working with and searching for patterns in the raw data, to simplify it to see what is important and what is to be learned and deciding what is significant in the data. In this study, the data consisted of focus group discussions and interview transcripts, and the analysis process is to identify themes that are important to the research questions.

Thematic analysis was therefore applied in a line-by-line manner. I started in an open coding manner, annotating printed copies of the transcripts, and noting aspects in the interview data that related to the development of physics graduate attributes. I then used the software ATLAS.ti to draw out the themes and create categories and sub-categories; this was an iterative process of creating and merging categories and codes (See Appendix F for an example of the coding process). The development of categories was, of course, influenced by the literature on higher education in South Africa. As a participant in a UWC-wide qualitative research development programme, I participated in workshops on qualitative data analysis using ATLAS.ti. I presented the coding of my data and received feedback and recommendations from the programme facilitators and participants.

For the open-ended graduate interviews, a narrative analysis approach (Polkinghorne, 1995) was adopted. Instead of the thematic analysis described above, each narrative is treated on its own terms, so maintaining the coherence and logic of the story it contains. The next stage is to look across narratives for commonalities while keeping the integrity of each individual narrative. As such, narrative analysis is an appropriate method to be used to understand how participants make sense of the phenomenon under study (Flick, 2009; Hesse-Biber, 2010).

Furthermore, the interpretations of the data were achieved by illustrating findings with quotes from the raw data which shows the participants' reflections conveyed in their own words. This aspect strengthened the face validity and credibility of the research (Fereday and Muir-Cochrane, 2006; Creswell, 2013). It is acknowledged that the highlighted themes and conversion factors may not be the only exact likeness to be represented about the experiences of the group. The researcher acknowledges that for the same work, another researcher may highlight different themes or conversion factors, depending on the lens through which the researcher views the respondents and their responses.

4.9 Validity and reliability

The concepts of validity and reliability in qualitative research need to be conceptualised in different ways to the way they are viewed in quantitative research (Lincoln & Guba, 1985). This section will discuss issues of validity and reliability in relation to the questionnaire data collection and analysis, and then in relation to the focus groups and open-ended interviews.

4.9.1 Validity and reliability of the questionnaire

Validity expresses the degree to which a measurement measures what it purports to measure. The Physics Graduate Preparedness Questionnaire was intended to give a broad overview of perceptions of preparedness among the cohort of participants in the study. Since the sample size is small (n = 52), there was no intention to apply complex statistical analysis to this data. The questionnaire was constructed taking into account the structure of similar surveys, (for example, Sharma et al. (2008), Shin & Phang (2012) Mendez et al., 2008), the descriptions of the SAIP Benchmark skills and UWC graduate attributes and the wording of similar surveys (for example, Walker & Fongwa, 2017).

A questionnaire is said to have validity if the questions or statements measure what they are intended to measure. Some of the statements in this questionnaire were borrowed directly from other validated surveys; in other cases, I requested physics colleagues to read through the questionnaire and give feedback on whether the statements adequately captured the PGAs. They also checked for any confusing wording or sentence construction or confusing instructions, which can limit the content validity of a survey instrument (Fraenkel & Wallen, 2003).

Furthermore, each participant was given the chance to acquaint themselves with the questionnaire and had a chance to ask for relevant explanations before completing the questionnaire. The terms used in the questionnaire were familiar to all participants since all of them had spent more than 2 years in the university, and some had progressed to be tutors or teaching assistants; this familiarity with terms in the questionnaire strengthened the validity of the questionnaire. The validity of the questionnaire, in turn, strengthens its reliability, which is the extent to which a research instrument would produce the same results if it was administered to the same respondent under the same conditions (Maree and Fraser, 2004).

Nevertheless, it should be noted that even responses from well-validated questionnaires may sometimes not reflect the respondents' actual perceptions, since the response to a questionnaire statement may be influenced by a particular interpretation of that questionnaire item or confusion at the wording of the statement (Mogashana et al., 2012).

4.9.2 Validity, reliability and generalisability of qualitative research

In qualitative research, there is no categorical statement of replication as in the case of quantitative research. Qualitative research uses terms such as quality, rigour, trustworthiness and credibility in place of validity. In addition, it uses dependability for reliability, and transferability for generalisability (Lincoln & Guba, 1985). This section outlines the rigour and the integrity (trustworthiness) in which the study is conducted and ensures the credibility of findings in qualitative research.

In this study, interviews were used to uncover students' perceptions of graduate preparedness and their experiences of undergraduate study. To maximise the credibility (validity) of the data elicited, it was important for the interviewer to have a good rapport with students, and to emphasise that the study placed value on the participants' own experiences. Furthermore, the strategy of 'expert review' was used: the interview protocols were given to expert colleagues for feedback before the focus group and individual interviews.

Triangulation (getting information from different sources) is another method to ensure the trustworthiness of research. For example, in this study, students' questionnaire responses on their perceptions of their preparedness were compared to the more detailed accounts given in the focus group interviews[9].

Another approach to strengthening dependability is to provide a detailed description of the data collection process and an 'audit trail' (Lincoln & Guba, 1985) of the analysis. It is required that the researcher show clearly how interpretations of the data have been achieved and illustrate findings with quotes from the raw data which shows the participants' reflections, conveyed in their own words. This aspect strengthens the validity and credibility of the research (Fereday & Muir-Cochrane, 2006; Creswell, 2013).

In qualitative research, the construct of generalisability is replaced by that of transferability – the degree to which the results can be transferred to other contexts or settings. In this case,

[9] Notwithstanding the awareness that interviews may in fact clarify apparent lack of triangulation between questionnaire and interview data (see Mogashana, 2012)

providing a ‘thick description’ (Lincoln & Guba, 1985) of the wider context of the research and the undergraduate situation allows readers to discern what aspects of the research might apply to their contexts.

4.10 Researcher positionality

As noted earlier in section 1.7, I worked as a tutor and teaching assistant in the UWC Department of Physics and Astronomy while conducting this study. My interest in physics education and physics graduate preparedness is informed by my educational background and experiences. Before coming to South Africa, I completed a Master’s degree in physics education in Nigeria and then a Master’s degree in Radiation and Environmental Protection in the UK. My Master’s in physics education grew my awareness of the role of an educator in growing and nurturing students, and how positive learning experiences in learning physics are vital and can make a difference in students’ lives. My Master’s in Radiation and Environmental Protection was a programme closely linked to industry in the UK, and my experience in this programme led me to a greater awareness of the broader generic skills (e.g. ICT skills, data analysis) that one acquired through such a programme.

On a more personal level, I experienced first-hand entering a graduate programme less well-prepared than many of my classmates. While the UK students arrived with excellent Excel skills and familiarity with many of the software packages used in the experiments, a student like myself from a non-EU country was less prepared. This experience has inevitably influenced my sensitivity towards similar stories recounted by students in this study. My experience in two other higher education systems Nigeria (College of Education and a university) has provided me with different perspectives from which to examine the South Africa higher education system.

Even though I had not studied in South Africa before, the knowledge gained from this research (through engaging with South Africa literature and attending seminars and conferences) as well as my interactions with students, graduates, lecturers and experts (in physics education and the capability approach) has deepened my understanding and perspectives of what it means to study physics in a particular university in South Africa.

4.11 Ethical considerations

The principles of ethical consideration which guided this research include concerns for confidentiality, the protection of research participant’s identities, respecting their privacy rights, ensuring informed consent and the right to voluntary participation or withdrawal (Denzin et al., 2006; Piper & Simons, 2005; Maree, 2007). These principles informed the drafting of both the information letter and informed consent form, which were sent to the participants before meeting them for completing the questionnaire, the focus group discussions and the interviews. The informed consent form translates to mean that those participating in the study have full knowledge of the research and the consequences of their participation.

The data obtained was treated anonymously with the utmost confidentiality. Also, voluntary informed consent was obtained. This entails the protection and respect of research subjects (Johnson, 2011). An information page stating everything about the research project and its purposes was given to all participants before the first meeting. The participants who were informed about the research and agreed to participate in the research also agreed to the conditions stipulated in the informed consent form. The conditions included that participants willingly accepted to be involved in the research and that they had been informed about its purposes. Additionally, the consent form informed the participants that the questionnaire, focus group discussions and interview would be recorded and that extracts of the transcripts would be cited in the thesis.

Research ethical clearance is about social responsibility and a standard of regulation within which the researcher ought to operate. It is to raise awareness of ethical principles in research, like the protection of research participants' rights to privacy, confidentiality and voluntary participation and making researchers consider the ethical dimension of their work. (See Appendix A for the ethics clearance letter and Appendix B for participants' information sheet and informed consent documents)

4.12 Conclusion

In this chapter, I have discussed the methodological decisions that have guided the research design to address the four research questions for the study. In the following four chapters (Chapters five, six, seven, and eight), I present the research findings that address the research questions of the study.

Chapter five presents document analysis of module descriptors to address RQ1: *How are intended physics graduate attributes embedded in the UWC undergraduate physics curriculum?*

Chapter six presents an analysis of the data from the Physics Graduate Preparedness Questionnaire to address RQ2: *What are students' perceptions of their preparedness in relation to the physics graduate attributes?*

Chapter seven presents an analysis of data from student focus group discussions to address RQ3: *What are the conversion factors that influence students' perceptions of attainment of the physics graduate attributes*?

Finally, Chapter eight presents an analysis of data from interviews with graduates who have entered the workplace to address RQ4: *In relation to physics graduates entering the workplace, what are the conversion factors that influence their preparation for entering the workplace?*

CHAPTER FIVE

ANALYSIS OF GRADUATE ATTRIBUTES IN UWC PHYSICS MODULE DESCRIPTORS

5.1 Introduction

In Chapter two, the framework for physics graduate attributes was presented (incorporating the attributes identified by international physics bodies and SAIP, as well as SAQA and UWC Charter of Graduate Attributes). This chapter discusses the findings from a document analysis of UWC Physics programme module descriptors (using the Physics Graduate Attributes framework as an analytical tool). The analysis examines how the physics graduate attributes were mapped in the module descriptors. As such, the research question addressed in this chapter is research question one (RQ-1):

> *How are espoused physics graduate attributes (as specified by SAIP and UWC graduate documents) embedded in the UWC undergraduate physics module descriptors?*

The discussion at the end of the chapter examines the extent of embeddedness of graduate attributes in the UWC undergraduate and Honours curriculum, and the implications of this for the development of graduate preparedness.

5.2 The framework for physics graduate attributes

As discussed in Chapter two (section 2.8), a framework of desired physics graduate attributes was developed by examining documents from international physics bodies that specified the sorts of capabilities, skills and attributes to be developed in physics graduates (for example, from IOP (UK), AIP (Australia) and AAPT (USA)). The South African Quality Assurance (SAQA) Critical cross-field outcomes for South African higher education and the UWC Charter of graduate attributes were also drawn on.

The findings from the document analysis pointed to an understanding that Physics education at UWC should also entail the development of a range of skills/attributes. This could be linked to a collection of skills and attributes which I referred to in this study as the "Physics Graduate Attributes" or the PGAs attributes to come up with a framework of desired physics graduate attributes for UWC (termed PGAs in this study). As noted in Chapter two (section 2.8), these PGAs would be the generic skills and attributes that physics graduates from UWC need to develop during their engagement as students of the Department of Physics and Astronomy. This Framework for physics graduate attributes was presented in Chapter two (Table 2.4) and is reproduced in Table 5.1 below, to remind the reader. This framework of physics graduate attributes (PGAs) becomes the lens through which the researcher analysed the module descriptors of the UWC physics degrees (B.Sc and B.Sc (Hons)) programmes.

Table 5.1: Framework for physics graduate attributes (PGAs)

Physics Graduate Attribute	
Category	Specific Skill
Generic skills	Problem-solving skills
	Investigative skills
	Analytical skills
	Technology aptitude
	ICT skills
	Practical skills
	Ethical behaviour
	Personal skills
	Teamwork
	Communication skills
Citizen skills (Graduate Attributes)	Social/Civic awareness
	Environment awareness

These categories in Table 5.1 are described in greater detail in Table 5.2 below (which is a reproduction of Table 2.5 presented in Chapter two). As noted, this framework of physics graduate attributes (PGA) is based largely on attributes included in the SAIP Benchmark Statement, but with additional attributes included which are present in the lists from other physics bodies, as well as attributes foregrounded by SAQA and the UWC Charter of graduate attributes.

Table 5.2: Basic definition of terms listed as physics graduate attributes (generic skills and citizen skills) as used in this study

Physics Graduate Attribute		**Explanation**
1	***Problem-solving skills***	This is core, it should involve students in solving problems with well-defined solutions, and gain experience in tackling open-ended problems. Develop the ability to formulate problems in precise terms, identify key issues, develop the confidence to try different approaches to make progress on challenging problems and develop one or more strategies to solve a problem and iteratively refine the approach.
2	***Investigative skills***	Students should be able to develop their skills of independent investigation. By using textbooks and other available literature,

		searching databases and the Internet, and interacting with colleagues to derive important information. Identify resources needed for solving a problem or to make decisions or recommendations for a research project.
3	***Communication skills***	Physics deals with unexpected ideas and difficult concepts; good communication is essential. Students should develop an ability to listen carefully, read demanding texts, and present complex information clearly and concisely – both orally and in written format. Be able to obtain information and evaluate its accuracy and relevance; be able to construct logical arguments.
4	***Analytical skills***	Students should be able to pay attention to detail and develop their ability to manipulate precise and intricate ideas, construct logical and reasoned arguments, critically think and use technical language correctly. Be able to sieve a problem down to its basic elements.
5	***ICT skills***	Students should develop their computing and ICT skills in a variety of ways; for information searches, document preparation and numerical calculations, including the ability to use appropriate software such as programming languages, and analysis packages.
6	***Personal skills***	Students should develop their ability to work independently, use their initiative, organise themselves to meet deadlines, gain experience in group work and be able to interact constructively.
7	***Teamwork***	Students should be able to work in various groups and across groups and work with diversity to contribute to knowledge construction; should be able to work in a productive team and lead where necessary.
8	***Environmental Awareness***	Students should have a preservation attitude to the environment within the context of ethical issues relating to the discipline and show responsibility with regard to environmental sustainability.
9	***Social and civic awareness***	Students should be critical and responsible members of their local, global and professional communities; be engaging, committed and accountable agents for the good of society.
10	***Technology aptitude***	Students should be able to operate and manipulate devices and applicable technologies and foster their use and applications.
11	***Practical skills***	Students should be able to design an experiment, set up an experiment with the intent and purpose to collate results, and data and verifying claims. Students should be able to use appropriate methods to analyse their data and to evaluate the level of uncertainty. Also, students should be able to relate conclusions they make to current theories of physics involved.
12	***Ethical behaviour***	Students should gain an appreciation of what constitutes unethical scientific behaviour. That to fabricate, falsify or misrepresent data or to plagiarism is unethical scientific behaviour. They should recognise the limits of their knowledge, demonstrate awareness of the wider ethical issues relating to physics and make ethical professional decisions

5.3 Result from the document analysis - Physics graduate attributes *embedded* in the UWC physics module descriptors

As noted in Chapter two (section 2.3), the embedding of graduate attributes into modules in a curriculum is a complex process, which entails a mapping of graduate attributes across module descriptors in a curriculum, and then ensuring that these graduate attributes are *enacted* in the teaching and learning activities, and the assessment of each module.

This part of the study was designed to ascertain the extent to which *espoused* graduate attributes (for example, those espoused by the SAIP Benchmark statement and the UWC Charter of graduate attributes) were embedded in the module descriptors[10].

In this study, we use the term *'embedded'* to indicate when graduate attributes are evident in course-level module descriptors. Graduate attributes can then be said to be *enacted* when they are embodied in teaching and learning activities and assessments in a module.

Document analysis was undertaken of learning outcomes stated in the UWC Physics programme module descriptors of the undergraduate and Honour levels, using the Physics Graduate Attributes framework as an analytical tool (Audu & Marshall, 2021). A total of 18 physics modules were examined; physics service modules (physics modules meant for pharmacy, education etc.) were not included. The ECP (Extended Curriculum Programme modules PHY 151 and PHY 152) are captured as one module and the First year modules (PHY 111 and PHY 121) are captured as one module because the stated module learning outcomes were the same, even though the physics content varied between the modules.

Table 5.3a and 5.3b (below) shows the embeddedness of these PGAs. The first table (Table 5.3a) maps out the PGAs across all modules showing where and how *stated* or *inferred* attributes are evident in the module descriptor. By 'stated' it is meant that a particular PGA is evident in the module descriptor. For example, the PHY151 descriptor has as a main learning outcome that students will be able to 'apply introductory kinematics and dynamics principles to solve problems'. Here, 'problem-solving' is a *stated* PGA. Another module, for example, PHY111, has no explicit mention of problem-solving as a stated learning outcome, although it can be *inferred* from the learning outcome 'be able to apply mechanics theory in everyday life situations'. Here, 'problem-solving' is an i*nferred* PGA. Similarly with 'communication

[10] This study did not examine whether the graduate attributes stated in the module descriptors were actually embodied in teaching and learning activities and assessment in a module.

skills': PHY212 has this explicitly stated as a learning outcome 'Demonstrate writing and presentation skills', so this is considered to be *stated*; on the other hand, PHY327 has as an outcome 'explain advanced astronomical ideas to a wider audience', so this is considered to be *inferred*. The second table (Table 5.3b) maps out the PGAs across all modules showing only the physics graduate attributes that were *stated* in the module descriptor. See Appendix G for a sample analysis of a physics module descriptor.

Table 5.3a: The physics graduate attributes as identified in physics module descriptors (*stated* or *inferred*)

Category	**Specific Skill**	Undergraduate										Hons								
Physics Graduate Attributes	**Modules: PHY**	151/152	111/121	212	222	217	227	312	322	317	327	709	720	721	722	723	724	725	726	**Total (number)**
Generic skills	**Problem-solving skills**	√	√*	√	√			√	√*				√	√		√				**9**
	Investigative skills								√*											**1**
	Analytical skills	√*		√*				√*	√*						√*		√*	√*	√*	**8**
	Communication skills	√		√	√	√*	√	√		√*	√*	√	√*	√*	√*		√*		√*	**14**
	ICT skills	√	√	√	√			√*	√		√	√	√				√		√	**11**
	Practical skills	√	√	√	√		√	√		√			√			√	√		√	**11**
	Ethical behaviour	√														√				**2**
	Personal skills																			**0**
	Teamwork																			**0**
	Technology aptitude	√									√		√						√	**4**
Citizen skills	**Social/Civic awareness**	√																		**1**
	Environment awareness	√					√			√*										**3**
Range of PGAs per module		**9**	3	5	4	1	**3**	5	4	3	3	2	5	2	2	3	4	1	5	

Where: √ represents a *stated* attribute/skill in the module descriptor

√* represents an *inferred* attribute/skill in the module descriptor.

Table 5.3b: The physics graduate attributes as identified in module descriptors (*stated*)

Category	Specific Skill	Undergraduate										Hons								
Physics Graduate Attributes	**Modules: PHY**	151/ 152	111/ 121	212	222	217	227	312	322	317	327	709	720	721	722	723	724	725	726	***Stated* in the module descriptors (number)**
Generic skills	**Problem-solving skills**	√		√	√			√					√	√		√				7
	Investigative skills																			
	Analytical skills																			0
	Communication skills	√		√	√		√	√				√								**6**
	ICT skills	√	√	√	√				√		√	√	√				√		√	**10**
	Practical skills	√	√	√	√		√	√		√			√			√	√		√	**11**
	Ethical behaviour	√														√				2
	Personal skills																			0
	Teamwork																			0
	Technology aptitude	√									√		√						√	**4**
Citizen skills	**Social/Civic awareness**	√																		1
	Environment awareness	√					√													2
Range of PGAs per module		**8**	2	4	4	0	**3**	3	1	1	2	2	4	1	0	3	2	0	3	

Tables 5.3a and b display the extent to which physics graduate attributes are *embedded* in the module descriptors (which act as a guide or compass for both lecturers and other team players for framing an undergraduate physics programme). If we analyze only modules in which the PGAs are *explicitly* stated (see Table 5.3b), then the furthest right-hand column indicates the number of times a physics graduate attribute (PGA) is *stated* in module descriptors over the undergraduate and Honours modules. Out of the 12 PGAs, only ICT skills (10 indicators) and Practical Skills (11 indicators) were *stated* frequently in the module descriptors and followed by Problem-solving skills (6) and Communication skills (6). Broadly, the following trend was evident:

- **Most *embedded*:** ICT skills, Practical skills
- **Somewhat *embedded*:** Problem-solving, Communication skills
- **Scantily *embedded***: Ethical behaviour, Technology aptitude, Social awareness, Environmental awareness
- **Absent/not *embedded***: Analytical Skills, Investigative skills, Teamwork, Personal skills

The bottom row of Table 5.3b indicates the *range* of PGAs evident in the module descriptor of each module. There is only one module, PHY151/152 that had a significant range of PGAs *stated* in the module descriptor (eight physics graduate attributes), followed by three other modules with 4 stated PGAs. In summary, of a total of 18 modules, all but one could be said to have a scanty range of PGAs listed in the module descriptors.

In summary, this curriculum mapping gives a reflection of how the *espoused* physics graduate attributes (PGAs) are *embedded* in the module descriptors of the UWC undergraduate and Honours physics modules. The analysis shows that there are gaps in the physics graduate attributes and skills *embedded*, with skills such as investigative skills, analytical skills, teamwork, personal skills, **e**thical behaviour, technology aptitude social and environmental awareness not explicitly *embedded* in the module descriptors.

It is important to note that this does not imply that a pedagogical focus on these attributes and skills is absent from these modules; rather, it shows that these are not explicitly *embedded* in the module descriptors as learning outcomes of these focus modules. These skills and attributes could nevertheless be present in the teaching and assessment of these modules, though in an ad hoc fashion.

5.4 Discussion

The SAIP Benchmark Statement arose out of concerns about the quality and skills of physics graduates, and how to best prepare students for the changing world of work and society. As the SAIP (2015) notes, it envisions the training system within the broader South African context should be aligned to provide skilled personnel required for the mainstream economy and social transformation. The Physics Benchmark statement for undergraduate training will enhance the quality of physics training itself and the achievement of aims of the various physics undergraduate and honours programmes. This would guarantee the meeting of the expectations of students, academic staff, employers and the general public (SAIP, 2015b).

To address this 'meeting of expectations' of various stakeholders, the SAIP Benchmark Statement identified important skills for physics graduates in South Africa. As recognised in SAIP Comments (2018), the standards and indicators in the Benchmark statement serve as 'a point of reference against which programmes may be compared', but SAIP sees it as 'up to each institution to formulate the precise measurable indicators that apply to its situation'(SAIP, 2015; p.2). That means no base mark or level is required by the Benchmark for implementation in the various institutions.

Despite the UWC Charter of Graduate Attributes being adopted in 2009 and the SAIP Benchmark statement being published in 2015, the Faculty of Natural Sciences Calendar published for 2020 did not show any changes in the module descriptors regarding either the UWC graduate attributes or the SAIP transferable skills (SAIP, 2015; UWC, 2017; 2020). This indicates that there was no evidence of new efforts at embedding the UWC graduate attributes or the SAIP transferable skills into the UWC Physics undergraduate curriculum.

The paucity of embeddedness of PGAs in the module descriptors is not to suggest that the publication of the SAIP Benchmark statement had not impacted the actual teaching and assessment in undergraduate physics modules. Indeed, after the SAIP Benchmark statement was published, the Department did run a workshop which discussed the UWC Charter for Graduate Attributes alongside the SAIP Benchmark statement. However, an analysis of the module descriptors in the University Calendar found no evidence of changes having been made at this level. As noted earlier, the absence of PGAs explicitly stated in module descriptors does not mean that there was no pedagogical focus on these attributes and skills in these modules; rather, it shows that these PGAs are not explicitly *embedded* in the module descriptors as learning outcomes of the modules. In this case, their presence or absence could be lecturer-dependent and therefore vary from year to year.

5.5 Implications for the Department

The document analysis has implications for the undergraduate physics curriculum at UWC.

While the development of standards by SAIP was noted earlier, the implementation of the SAIP Benchmark statement was left up to each department, and there were no implementation standards or processes specified (SAIP, 2015a). The embedding of the PGAs in several modules at various stages of the undergraduate programme is important, because skills take time to develop, across years of study, and require explicit attention over an extended period (Bath et al., 2004; Wiggins & McTighe, 2005); skills cannot adequately be developed in once-off courses, adopting a `bolt-on approach' (Bowden et al., 2000).

Turning now specifically to the UWC undergraduate physics curriculum, the findings from this study suggest that a ‘graduate attribute mapping’ (Lowe & Marshall, 2004) or ‘backward design’ process (Wiggins & McTighe, 2005) might be useful. This would entail starting with the skills and attributes required in a physics graduate (as specified in the SAIP Benchmark statement and UWC framework) and then mapping these backwards from the Honours level modules, into 3rd year, 2nd year and 1st-year modules. A further step for implementation and research would be to examine how *espoused* graduate attributes are *enacted* in the curriculum through teaching activities and assessment. However, as a start, the focus would be on *espoused* physics graduate attributes, because if these attributes are not explicitly reflected in module learning outcomes, then constructive alignment (Jones et al., 2007) of classroom activities and assessment with learning outcomes - to develop those attributes - will be difficult to achieve.

5.6 Conclusion

This chapter has examined the extent to which espoused physics graduate attributes (as specified by SAIP and UWC graduate documents) are embedded in the UWC undergraduate physics module descriptors. The study found that only practical skills, ICT skills, problem-solving skills and communication skills were well-embedded, with skills such as investigative skills, analytical skills, teamwork, personal skills, social awareness, environmental awareness, personal skills and ethical behaviour largely absent. Implications of this for departmental curriculum renewal efforts were discussed.

In the next chapter, students' perceptions of their preparedness in relation to the GPAs are examined, as gauged by their responses to the Physics Graduate Preparedness Questionnaire.

CHAPTER SIX

STUDENTS' PERCEPTIONS OF PREPAREDNESS

6.1 Introduction

This chapter explores students' perceptions of their preparedness during their physics studies (3^{rd} year BSc, BSc (Hons) and Master's). Higher education institutions, such as UWC, aim to prepare students for work and society. However, the development of students' abilities and capabilities depends on the extent to which they are able to explore and utilise the opportunities available in the institution. As such, the influence of university education on students is conditioned by their preceding experiences in family circles, primary and high school education and everyday experiences in their environment.

In this chapter, the results from the Physics Graduate Preparedness Questionnaire are discussed. In this way Research Question 2 is addressed:

RQ2: What are students' perceptions of their preparedness in relation to the Physics Graduate Attributes?

As emphasised in the capability approach, each student will be differently positioned (based on personal social and environmental conversion factors) to convert the resources in an undergraduate or a postgraduate programme into functionings and capabilities. Therefore, it is important to get to know the students in this study (in terms of family background, high school experiences and resources etc.). For this reason, the chapter starts by introducing the demographics of the students in the study. After this introduction to the students in the study, the results from the Physics Graduate Preparedness Questionnaire are discussed.

6.2 The participants' demographics

The undergraduate and postgraduate students who were part of this research will be referred to as 'participants'. The participants in this study come from different backgrounds. Table 6.1a below shows that, of the 52 physics students (final year of BSc, BSc (Hons), and Master's studies) who participated in the research, 81% were males and 19% were females. This is a reflection of the demographics in the department where female students are generally under-represented (and a reflection of female representation in the discipline of physics, more broadly). Looking at Table 6.1b, 67% of the students are within the age bracket (21-25), 27%

are between the ages 26 to 30 and 6% are 31 years old and above. This puts the majority of the students at the stage of life where choices and decisions for well-being are important.

Table 6.1a: Gender of participants

Gender		
	Count	%
Female	10	19.2
Male	42	80.8
Total	52	100

Table 6.1b: Age bracket of participants

Age Bracket		
	Count	%
21 - 25	35	67.3
26 - 30	14	26.9
31 & above	3	5.8
Total	52	100

Figures 6.2a & 6.2b below indicate that students self-identified their 'family's income/status' as 38% for low-income, 56% for middle-income and 6% for high-income. Regarding their home environment, 54% of the respondents grew up in an urban environment while 46% grew up in a rural environment.

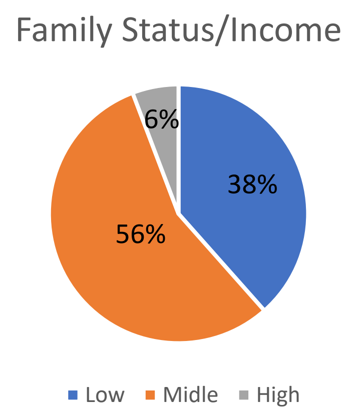

Figure 6.2a: Participants' family income

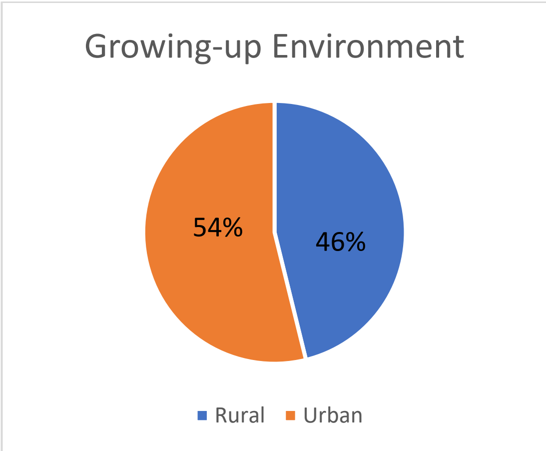

Figure 6.2b: Participants' growing-up environment

Figure 6.3 below shows how the participants self-identified their race, according to the South African race categories used[11]. During Apartheid times, UWC and other universities were established along racial lines as historically black institutions (UWC was initially designated

[11] As noted in Chapter 2, South Africa continues to the use the Apartheid era race-based classifications (black African, coloured, white, Indian/Asian) as a means to track social transformation.

for so-called 'coloured' students); this explains why the students in this study are mostly black and coloured.

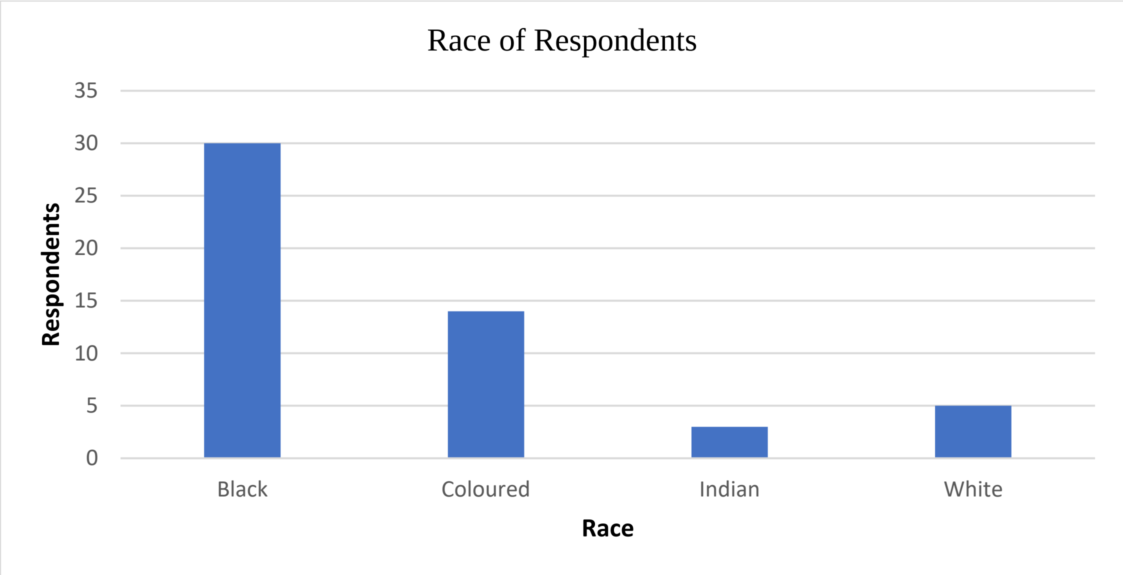

Figure 6.3: Self-identified race of participants

The following table 6.4 brings together the data on race, family income and growing up environment.

Table 6.4: Relating 'race', 'family income' and 'growing up environment'

Race	Gender		Age Brackets			Growing-up Environment		Family Income		
	Female	Male	21- 25	26 - 30	31 and above	Rural	Urban	Low	Middle	High
Black	6	24	19	9	2	23 (77%)	7 (23%)	17 (57%)	11 (36%)	2 (7%)
Coloured	2	12	12	2	0	0	14 (100%)	3 (21%)	11 (79%)	0
Indian	2	1	1	2	0	0	3 (100%)	0	3 (100%)	0
White	0	5	3	1	1	1 (20%)	4 (80%)	0	4 (80%)	1 (20%)

The above data shows disparity along the lines of race, 'growing up environment' and family income of respondents and the disadvantaged background of some respondents. In terms of family income, 57% (17/30) of the black participants and 21% (3/14) of the coloured participants are from low-income families, while 100% of the Indian and white participants are from middle and high-income families. As noted in Table 6.2b above on home environment data, 54% of the respondents grew up in an urban environment while 46% grew up in a rural environment. From Table 6.4, we can see that 77% of the black participants are from a rural background, while all the coloured and Indian participants are from urban areas. This proportion of black students from rural environments is significant since South African studies indicate that rural students face greater challenges when entering higher education (Timmis et al., 2019; Walker et al., 2022). Table 6.4 shows that there is also a strong correlation in this data between students coming from a rural environment and those with low family income (Walker et al., 2022).

Data was also gathered in this study on the education level of participants' parents or guardians. This is because research worldwide and nationally shows that parental education and social and cultural capital are important factors influencing access to, and success in, higher education (for example, in the UK, Bathmaker et al., 2016; Reay et al 2001; in Australia, Threadgold et al., 2018). Table 6.5 below shows that only 25% of parent/guardian 1 and 17% of parent/guardian 2 have a Bachelor's degree or higher. This shows that most of the participants in this study are first-generation university[12] students.

Table 6.5: Participants' Parent/Guardian's highest educational qualification

Highest Educational Status				
	Parent/Guardian-1		Parent/Guardian-2	
	Count	%	Count	%
No-Schooling	2	3,8	1	1,9
No-Matr	14	26,9	15	28,8
Matric	8	15,4	16	30,8
Diploma	15	28,8	11	21,2
Degree	6	11,5	6	11,5
Higher Degree	7	13,5	3	5,8
Total	52	100,0	52	100,0

Students come from a range of differently-resourced high schools. Table 6.6a below shows the responses of participants with respect to the resources available at the high school they attended (a library, access to computers and science laboratories).

[12] 'First generation students' are those students whose parents do not have degrees (but they may have siblings at university or who have graduated); on the other hand 'first in family' students would literally be the first to enter higher education.

Table 6.6a: Participants' high school facilities

Did your High School have the following:						
	Library		**Computers**		**Laboratories**	
	Count	%	Count	%	Count	%
No	15	28.8	12	23.1	18	34.6
Yes	37	71.2	40	76.9	34	65.4
Total	52	100.0	52	100.0	52	100.0

The data in table 6.6a indicates that about 30% of the students did not have access to a library, 23% did not have access to computers, and about 35% attended high schools without a science laboratory. Table 6.6b drills down more deeply into the data on access to science laboratories, in relation to race and family income.

Table 6.6b: Race, family income and availably of high school laboratory

Race	**Family Income**	**Did your High School have Science Laboratories?** No	Yes
Black	Low	6	11
	Middle	2	9
	High	1	1
Coloured	Low	2	1
	Middle	6	5
	High	0	0
Indian	Low	0	0
	Middle	1	2
	High	0	0
White	Low	0	0
	Middle	0	4
	High	0	1

The data shows that 28% of the black low and middle-income participants did not have a science laboratory at high school, 57% of coloured low and middle-income participants did not have a science laboratory at high school, while all the white students had a science laboratory at high school. This data on resources available at high school is significant since it highlights that students come to the university from different experiences of access to resources, yet often universities assume all science students have had the same level of exposure to computers, science laboratories and familiarity with using a library. What was unexpected in this data was that the black students (77% of whom were from rural backgrounds) had attended better-resourced schools (in terms of science laboratories) than the coloured students (all of whom were from urban high schools)[13].

Other resources on offer at some high schools include extra-curricular activities. These are useful to consider because graduate preparedness is a process and may involve participation in other activities at university which inspire the individual to take up roles and lead where necessary. Participants were asked which extra-curricular activities they had been involved in at high school sports, clubs and societies, etc. Table 6.7 indicates that about 31% were involved in clubs and societies at school, while about 77% were involved in sports activities.

Table 6.7: Participants' involvement in extra-curricular activities

	Sport		Clubs & Societies	
	Count	%	Count	%
Not Involve	12	23,1	36	69,2
Involve	40	76,9	16	30,8
Total	52	100,0	52	100,0

The data shows that, although involvement in sport was prevalent, there was limited exposure to other forms of extra-curricular activities, such as clubs and societies. Wilson-Strydom's study noted how involvement in extra-curricular activities was linked to socio-economic status and type of school, with learners from township schools less likely to be engaged in extra-curricular activities, and more likely to be tied up with household commitments after school (Wilson-Strydom, 2015a). This background data on students' prior experience of extra-curricular activities at high school proved to be useful later in this study when examining students' engagement with extra-curricular activities on campus (see section 6.5).

6.3 The participants' demographics and conversion factors

In Chapter three, the concept of conversion factors was introduced. Within the capability approach, conversion factors are personal, social and environmental differences that explain why individuals benefit differently from the same resources (Robeyns, 2005). In the context of education, these are the personal characteristics of individuals as well as institutional

[13] One possible explanation for this might be that the existence of science labs in the rural schools might have been the reason students had developed an interest in science at high school. Some rural schools have been the recipients of development projects, though sometimes the presence of a science laboratory does not necessarily mean that it is used for that purpose.

arrangements (which are social or environmental in nature) that enable or hinder the conversion of resources into capabilities and functionings attained**.**

Central to the capability approach is the need to take account of the lives of individuals, rather than to consider aggregate groups only. Each student is unique so that for each student their pathway through undergraduate studies will be influenced by personal, social and environmental factors originating from the participant's interaction with the environment, which is further influenced by socio-economic factors.

The background demographics of the students are useful because they indicate factors that research studies show influence the successful transition to university – these include the type of school attended, socio-economic status, and level of education of parents (see, for example, Wilson-Strydom, 2015). The demographics of the students in this study show the intersection of race, rurality, family income and parental qualification: of the 30 black students in the study, 17 (56%) self-identified as being from low family economic status, and of these 17 students, 15 (88%) were from rural areas. For more than half of 17 low-income black students, neither parent/guardian had completed Matric, and only one of these 17 student had parent/guardian with a university degree.

As observed from the demographics, the social capital or resources available to each of the participants will likely be influencers of physics graduate preparedness because of these personal, social and environmental conversion factors which originate from the student's home background and previous educational context. These demographic details will become important for the next two chapters, in which we encounter students and graduates from rural areas, low-income families, and from less educated parents, in other words, with fewer material resources or cultural capital to support their transition, and pathway through, university.

6.4 Perception of preparedness by students

As noted in Chapter two, a 'framework of physics graduate attributes (PGAs)' was developed listing the skills and attributes that physics graduates from UWC ought to develop and be equipped with during their engagement as students. This was developed from an overview of policy documents, including physics benchmark statements, SAQA, and the UWC Charter of Graduate Attributes. See Table 5.1 below for a reminder of these Physics Graduate Attributes**.**

Table 5.1: Framework for physics graduate attributes for UWC

Physics Graduate Attribute	
Generic skills	Problem-solving skills
	Investigative skills
	Analytical skills
	Technology aptitude
	ICT skills
	Practical skills
	Ethical behaviour
	Personal skills
	Teamwork
	Communication skills
Citizen skills	Social/Civic awareness
	Environment awareness

As noted in Chapter four (section 4.6.2), the Physics Graduate Preparedness Questionnaire was developed based on items in previous graduate surveys and questionnaires, as well as on the SAIP and UWC descriptions of graduate attributes. The Physics Graduate Preparedness Questionnaire consisted of three parts: Part A focused on biographical data; Part B on generic skills, and Part C on citizenship skills (social/civic/environmental awareness) and students' familiarity with the UWC Graduate Attributes.

The Questionnaire asked participants to indicate their level of agreement with questionnaire statements relating to the physics graduate attributes (using a 7- point Likert scale, 1 = lowest agreement and 7 = highest agreement). The intention of developing the PGA questionnaire was not to develop a robust statistical tool but rather to provide broad preliminary data for the focus group and interview data collection. The results in figure 6.1 express a summary of participants' responses for each item on perceptions of PGA preparedness (on a scale of 1-7).

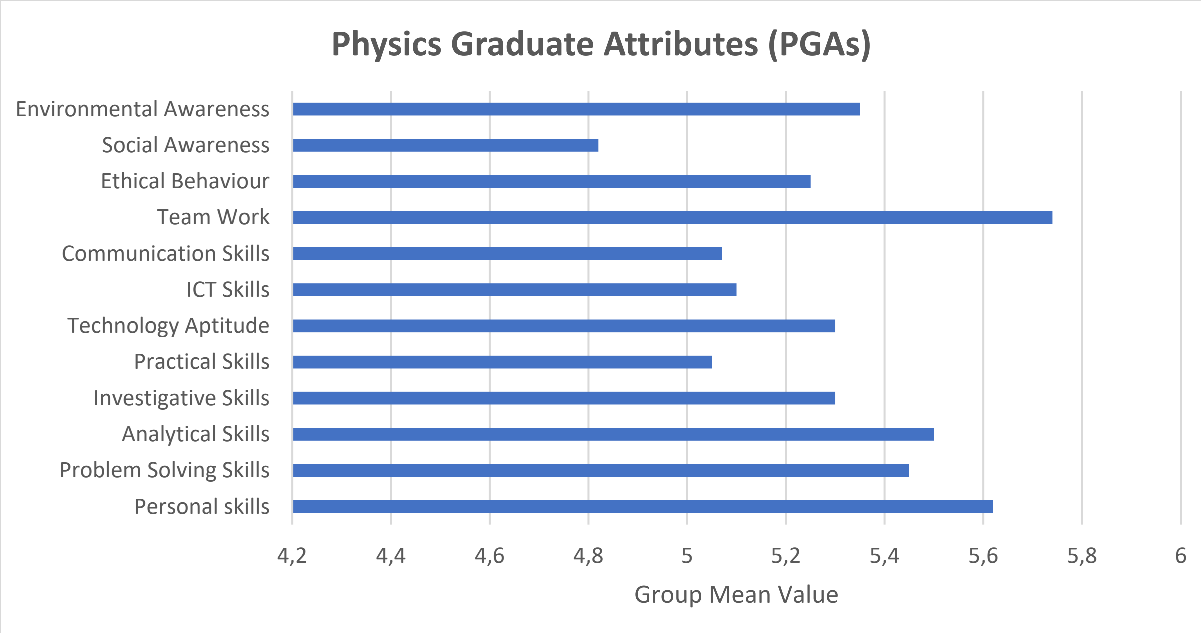

Figure 6.1: Respondent perception of PGAs preparedness as students

The results in figure 6.1 are not meant to be statistically rigorous but to give a broad indication of respondents' perceptions of preparedness. The data showed that students overall rated the graduate attributes positively[14]. Overall, the analysis showed that participants perceived the following skills to be most developed: teamwork, analytical skills, problem-solving skills and personal skills. Skills perceived to be least developed were social awareness, communication skills, ICT skills, and practical skills as compared to other PGAs. This is summarised in Table 6.7 below.

[14] It is worth noting that these are students' *perceptions*, and there may well be a tendency for students to overestimate their competencies

Table 6.7 Participants' perception of PGAs development in regard to preparedness

Perceived to be most developed:
Teamwork
Personal skills
Analytical skills
Problem-solving skills
Perceived to be developed:
Environmental awareness
Investigative skills
Technological Aptitude
Ethical behaviour
Perceived to be somewhat developed:
ICT skills
Communication skills
Practical skills
Less perceived to be developed:
Social awareness

Each of these graduate attributes is briefly discussed below. For most attributes, the overall PGA category is discussed, and not the items or statements within each category in the Questionnaire. However, in two cases, where there was a large variation in the responses to the different items within one PGA category, the ratings on the individual items are discussed (this was the case for the PGA categories 'Teamwork' and Communication skills).

'Problem-solving skills' are rated highly by the participants; this is to be expected since problem-solving is integral to physics learning. Problem-solving skills are developed along with other associated skills for problem-solving such as *'Analytical skills'*, which also score highly.

'*Teamwork'* was another of the skills rated highly by participants. Figure 6.10 shows that there was a large variation in the responses to the different items within the category 'Teamwork'. Interestingly, the statements 'I am equipped to interact with people from diverse backgrounds' and 'I am able to respect and value other people's views' were the most highly rated statements for this construct. This may be related to the diverse backgrounds of students who study at UWC and how engaging with students, scholars and researchers from all over the world has impacted them. The statement 'Physics at UWC developed my ability to work in teams' was the lowest rated, reflecting perhaps that it was *not the physics programme itself* that had developed teamwork skills. It might also reflect the perspective that more attention was needed on the group processes involved in working as a team (this is a theme which arises later in Chapters seven and eight in focus group discussions and interviews).

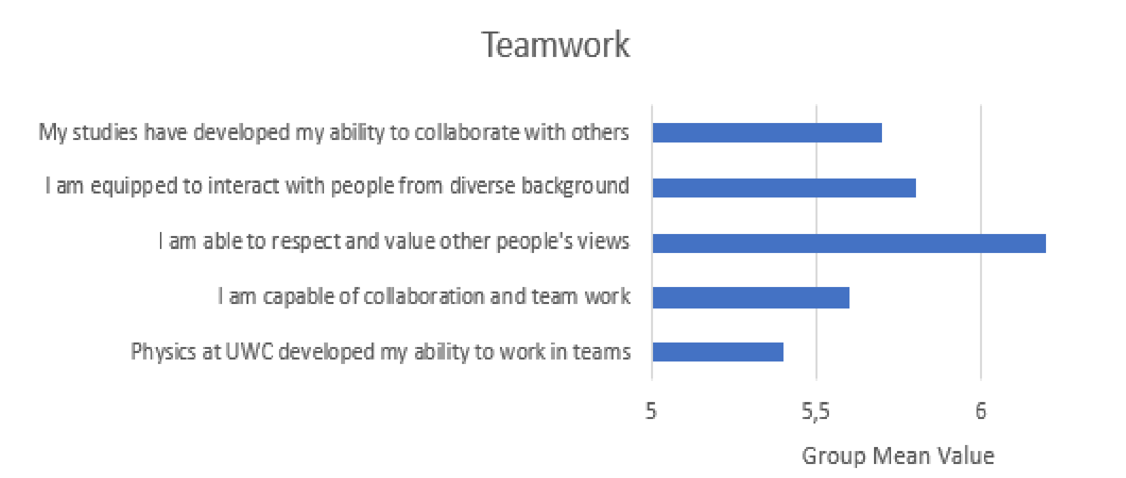

Figure 6.10: Responses to items in the Teamwork category

Participants also perceived *'Personal skills'* to be well developed (see figure 6.1). Personal skills include personal attributes that make students to be accountable for their learning, to work as independent and self-directed learners, and to take initiative and show motivation to learn. The high rating of this category indicates that students perceive that this skill has been developed, which does not mean necessarily it was developed during their physics studies, but due to their determination and motivation to succeed.

Skills perceived to be *least developed* were communication skills, ICT skills, practical skills social awareness as compared to other PGAs. Each of these skills is briefly discussed below.

As evident in figure 6.1, the perception rating of the development of *'ICT skills'* was lower than some of the other PGAs. This category included items relating to the development of students' ICT skills, including their ability to use relevant software applications for physics problems. The rating suggests that the students felt they had somewhat had the opportunity to adequately develop their ICT skills. However, the background of some of these students in this study shows the lack of computers and ICT facilities during their high schools (see section 6.2) which might have impacted their ICT skill development.

The *'Practical skills'* rating shows that students' perceived their practical skills (including designing and performing experiments) to be on the low end of being developed. This suggests that respondents felt that more could be done to develop their practical skills, even though

Practical skills are the second most prominent skill embedded in the module descriptors, second only to ICT skills (see Chapter five, section 5.3 and table 5.3b).

'Communication skills' is an important physics graduate attribute as it entails presenting physics knowledge and understanding clearly and concisely, either orally or in written formats. Figure 6.11 below shows that there was a large variation in the responses to the different items within the category 'Communication skills', students feel more comfortable with written communication skills than oral and presentation skills. This is a trend also observed in the Australian survey of physics graduates (O' Byrne et al., 2008), where graduates ranked their written communication skills as more developed than their oral communication skills.

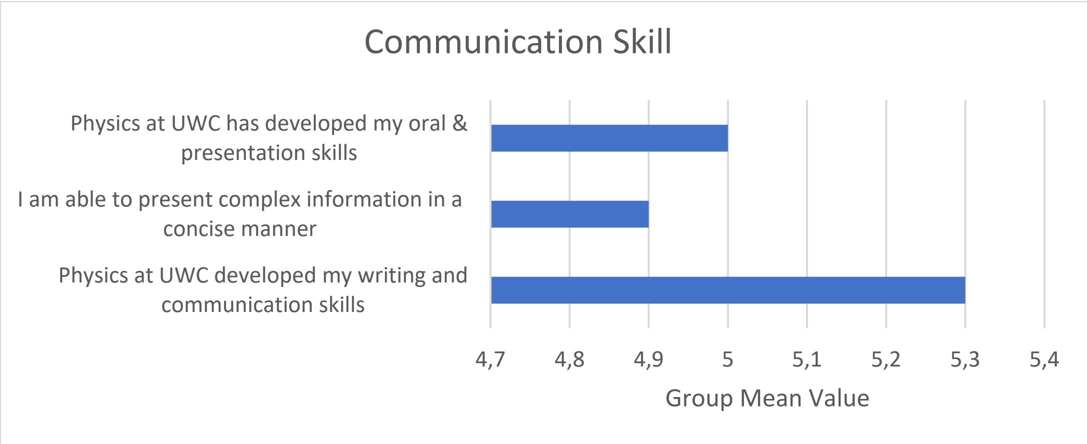

Figure 6.11: Responses to items in the Communication skills category

'Social awareness' was perceived by the respondents as the graduate attribute that was the least well-developed. This rating value for social awareness perception during their study brings up the question if respondents are exposed to becoming more aware of social/civic responsibilities. The study by O'Byrne et al (2008) of Australian graduates also found that graduates rated their development of graduate attribute 'social issues' as low.

Skills perceived to be *somewhat developed* were Environmental awareness, Investigative skills, Technological Aptitude and Ethical behaviour. In this regard, O'Byrne et al. (2008) also found that Australian graduates rated their awareness of 'ethical issues' low, and Shin and Phang (2012) found that ethics was the least prioritised skill by lecturers.

6.5 Perceptions of opportunities to engage and develop further within the University: Extra-curricular activities, career guidance and awareness of UWC graduate attributes

The study also asked students about their holistic engagements that foster personal development, social interactions, participation and UWC graduate attribute awareness. The questionnaire probed the extent of participants' involvement in a range of *extra-curricular activities* since previous studies had indicated the importance of extra-curricular activities and career guidance in developing some of the desired graduate attributes (Walker & Fongwa, 2017) and in the retention and academic success of Science Technology Engineering and Mathematics (STEM) undergraduate students (Figueroa et al., 2013).

From figure 6.15 it is evident that there is a big gap in respondents' engagement in activities that promote social engagements in clubs and societies, community-linked and sporting activities.

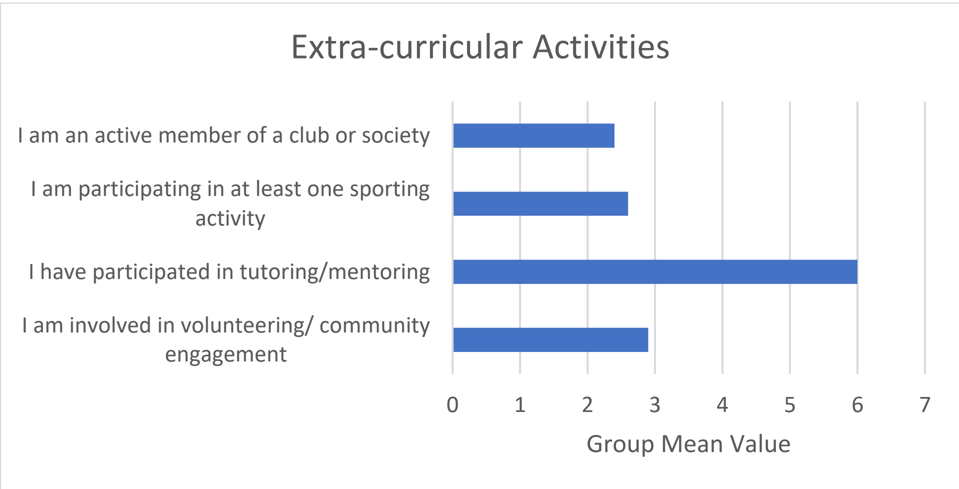

Figure 6.15: Items for involvement in Extra-curricular activities

The data indicates that students were not very involved in sports activities, clubs/societies, or volunteering/community engagement. This finding is borne out in a South African Survey of Student Engagement (SASSE) report on UWC (SASSE, 2017), which found poor participation in extra-curricular activities among science students. The item on tutoring and mentoring received the highest rating; many of the 3rd years, Honours and post-graduate students in the Department had chosen to work as tutors or volunteers in the mentor programme during the first-year orientation period. In relation to developing graduate attributes and professional skills, McNeil and Heron (2017) conclude that 'co-curricular activities are often overlooked as opportunities to develop professional skills (McNeil & Heron, 2017, p.42). This low level of involvement in extra-curricular activities at university is consistent with the earlier data in section 6.2 on students' lack of involvement in extra-curricular activities at high school.

Ideally, undergraduate students should be exposed to career guidance and the knowledge that job applicants require to maximize every opportunity (including how to apply for jobs, careers resume writing, prepare job applications and relevant interviews tailored for physics graduates). However, the items within the category 'career guidance' were also rated as low. Figure 6.16 below shows the perception of the respondents on career guidance preparedness which seems to suggest that career guidance was not provided in the way these participants would use and maximize. Students' perceptions of limited career guidance at UWC also emerged strongly in focus group discussions with students (see Chapter seven, section 7.4.2.5) and in interviews with graduates (see Chapter eight, section 8.4.2.5a).

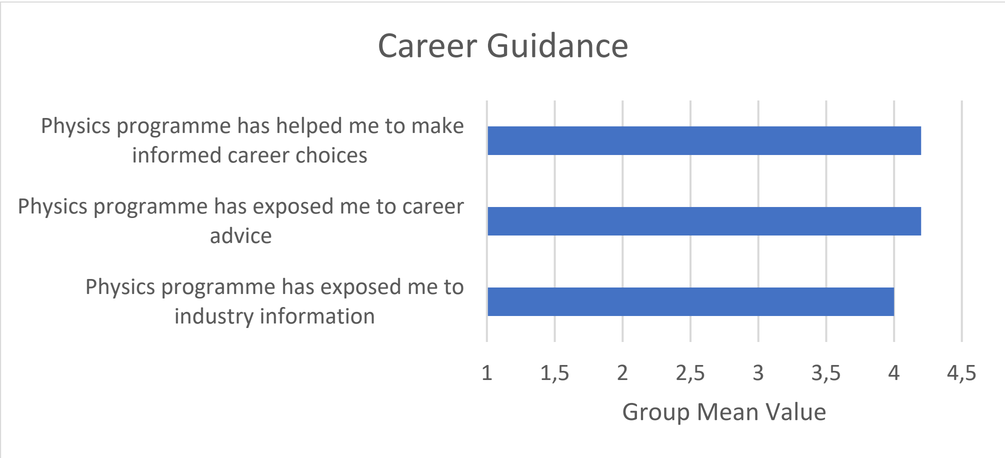

Figure 6.16: Items for Career Guidance

One final item on the questionnaire gauged students' familiarity with the UWC Graduate Attributes. The data shows that only about half of the participants are aware of the UWC graduate attributes. This finding is consistent with a recent study on UWC students' understanding and experience of graduate attributes (Bitzer & Withering 2020). They found that about 40% of the student participants had not been familiar with the term 'graduate attribute' prior to the study and that 'student participants in the study were not aware of whether UWC has a graduate attributes charter and the contents of the attributes outlined in such a charter' (Bitzer & Withering, 2020; p.22).

6.6 Discussion of questionnaire findings

As noted earlier, the Physics Graduate Preparedness Questionnaire was not designed as a robust and rigorous statistical tool, but rather to provide a broad overview of students' perception of their preparedness before more in-depth focus group discussions and interviews. Overall, analysis of the questionnaire responses showed that participants rated their perceptions of preparedness on the following skills most highly: teamwork, analytical skills, problem-solving skills and personal skills. Skills perceived to be least well developed were social awareness, communication skills, ICT skills, and practical skills.

This is in agreement with the Australian study of O'Byrne et al. (2008), in which physics graduates rated problem-solving as the most developed graduate attribute. Shin and Phang (2012), likewise found that Malaysian physics graduates perceived problem-solving to be the most developed. In the O'Byrne et al. (2008) study, practical skills and computational skills were also rated as well developed; by contrast, in this study, practical skills and ICT skills were rated as less developed. In common with the O'Byrne study, this study found that social awareness and communication skills were perceived to be underdeveloped. Interestingly, teamwork was rated highly in this study, yet in the O'Byrne study, graduates felt that teamwork needed more attention in undergraduate physics programmes. Within the graduate attribute category of 'communication skills', students perceived that their written communication skills were better developed than oral and presentation skills. This is a trend also observed in the Australian survey of physics graduates (O' Byrne et al., 2008), where graduates ranked their written communication skills as more developed than their oral communication skills.

In the previous chapter (Chapter five) the mapping of physics graduate attributes in the module descriptors was discussed. In Table 6.9 below, a summary comparison is presented of the findings from Chapter five (of embeddedness of PGAs in the curriculum) and of findings from Chapter six (6 of students' perceptions of preparedness in relation to the development of PGAs).

Table 6.9: Summary comparison of PGAs mapping and perception of PGAs development

The *mapping* of the PGAs in module descriptors (in Chapter five)	Participants' *perception* of PGAs development in regard to preparedness (in Chapter six)
Most embedded: ICT skills Practical skills **Somewhat embedded:** Problem-solving Communication **Scantily embedded** Ethical behaviour Technology aptitude Social awareness Environmental awareness **Absent/not embedded** Analytical Skills Investigative skills Teamwork Personal skills	**Most perceived to be developed**: Teamwork Personal skills Analytical skill Problem-solving skills **More Perceived to be developed:** Environmental awareness Investigative skills Technological Aptitude Ethical behaviour **Perceived to be somewhat developed:** ICT skills Communication skills Practical skills **Less perceived to be developed:** Social awareness

From the summary comparison, some interesting aspects emerged:

- *Problem-solving* is the only attribute that is both well embedded in the module descriptors and perceived by students to be well-developed. This is not surprising considering that problem-solving is such an integral part of undergraduate physics learning and teaching.
- *ICT skills and Practical skills* are most embedded in the module descriptor yet students perceive these attributes to be least developed. It seems that, while these are listed in the module descriptors, there is not enough focus on developing these explicitly.
- *Teamwork, Personal skills and Analytical skills* are not embedded in the module descriptors, yet interestingly these were perceived by the students as most developed. The high rating on Analytical skills may reflect that students perceive 'analytical skills' as integral to 'problem-solving skills'. Students rate 'Teamwork' as well-developed even not embedded in the module descriptors. The survey data indicated that they rate highly their ability to work with peers from diverse backgrounds and to respect

differences; yet also that they felt that more could be done to develop their ability to work in teams.

The questionnaire also asked students about extra-curricular involvement at university, and about the UWC graduate attributes. The findings suggested that many of the participants do not know about UWC graduate attributes. This gap between the university expectations and physics student awareness of the UWC graduate attributes is in agreement with the findings of Bitzer and Withering (2020). On extra-curricular activities and participation opportunities in the university, it is evident in this study that not many respondents engaged in activities that promote social, community and leadership roles such as membership of a club or society, participating in at least one sporting activity or being involved in volunteering/community or tutoring/mentoring engagement, showing that only a few of the respondents are involved in any activities apart from academics related. Tutoring and mentoring did receive the highest rating, expressing the kind of passion and interest respondents possess.

Ideally, students should be exposed to career guidance and job information needed to maximize every job opportunity, customized for physics graduates. The perception of the respondents on career service preparedness indicates that much needs to be done for the benefit of physics students generally. Studies such as Mendez et al. (2008), Hanson & Overton (2010), Woolf et al. (2016) and Porter (2019) all made the same observation and recommendation that more is needed to be done regarding career guidance for physics students and graduates at the department level.

6.7 Conclusion

This chapter started with introducing the demographics of the students in the study since it is important to get to know the overall background of the students (in terms of family background, high school experiences and resources). The second part of the chapter has presented a broad overview of questionnaire data on students' perceptions of their preparedness in relation to the physics graduate attributes. In doing so, the chapter has addressed Research Question 2: *What are students' perceptions of their preparedness in relation to the Physics Graduate Attributes?*

The analysis indicated that participants rated their perceptions of preparedness on the following skills most highly: teamwork, analytical skills, problem-solving skills and personal skills. Skills perceived to be less developed were social awareness, communication skills, ICT skills, and practical skills as compared to other PGAs. The analysis also indicated that there is a big gap in respondents' engagement in activities that promote social, community and membership of a club or society, volunteering and tutoring amongst others.

In the next chapter, the result of focus group discussions with students and the thematic analysis of this data will give a more detailed and nuanced insight into students' perceptions of their preparedness.

CHAPTER SEVEN

STUDENT PERCEPTIONS OF PREPAREDNESS AND CONVERSION FACTORS

7.1 Introduction

The previous chapter examined students' perceptions of their preparedness as reflected in their responses to the Physics Graduate Preparedness questionnaire. This chapter takes a more qualitative look at what lies behind these responses, and in doing so addresses research question 3:

RQ3: What are the conversion factors that influence students' perceptions of the attainment of the physics graduate attributes?

The findings in this chapter arise from the analysis of focus group discussions with 3rd year and postgraduate students. The criteria for selecting each participant are explained in Chapter four section 4.5. The data from the questionnaire and focus group discussions were collected when the respondents were about three months to finish their programmes.

During the student focus group discussions, students were asked to discuss their perceptions of their preparedness, what aspect of their undergraduate education had helped them to attain various skills, and which skills they felt needed further development. To set the context for the focus-group discussion, each participant was given a simple Ranking list of 11 graduate attributes [adapted from Sharma et al (2008) to complete before the discussion, ranking the extent to which each skill had been developed in their undergraduate studies on a scale of 'A little', 'Some' and 'A lot'].

In this chapter, each of the groups (undergraduate and postgraduate) is introduced, followed by an analysis of the students' perceptions of preparedness in relation to the conversion factors identified. Following this is a section which examines students' aspirations in terms of their future work and overall well-being.

7.2 The concept of conversion factors in relation to Physics graduate preparedness

As noted in Chapters 2 and 3, graduate preparedness is linked to the development of desired physics graduate attributes, which can in turn be linked to the valued capabilities and functionings of students. The purpose of this study was to generate in-depth perspectives on the process of formation of graduate preparedness (in relation to the PGAs) through the physics undergraduate and post-graduate programmes. When students or graduates can demonstrate confidence in the PGAs, it can be likened to a functioning (an achieved capacity). However, as noted in Chapter three, the capability approach is based on the notion that individuals are fundamentally diverse and unique, due to the different personal, social and environmental conversion factors that they experience. Therefore, each will require different resources to achieve the same functionings.

For any educational programme, the conversion of resources (for example, those on offer in the undergraduate physics programme) and capabilities into functionings will depend on the interplay between a student's background, social and institutional arrangements, and environmental factors. Therefore, this chapter explores the conversion factors that influence students' perceptions of preparedness; it examines which personal, social and environmental conversion factors enhance or hinder the development of PGAs.

Linked to the notion of graduate preparedness for life beyond university is the notion of *well-being.* Sen relates well-being to the standard of living of an individual (Sen, 1993a; 1993b; 1995) not merely wealth or income. In other words, well-being includes non-material aspects such as personal welfare and human flourishing. It hinges on what the individual has that makes the individual happy and what the individual does that brings fulfilment (Gasper, 1997; Hart 2012; Alkire, 2015). It involves the presence of necessities of material well-being, and opportunities for living a good life (Nussbaum, 2011; Orton, 2011; Alkire, 2015). From a capability perspective on education, the attainment of well-being and human flourishing through education is very important. The fostering of students' well-being (their capabilities and functionings) and their agency enables students to reason about and make choices about the life they have reason to value (Sen, 1999).

The analysis in this chapter is framed by Sen's concepts of conversion factors and well-being. However, first, we meet the participants in the section below.

7.3 Participants

There were two groups for the focus group discussions (see Chapter four, section 4.6.3) – an undergraduate group (Group 1) comprising five students in their 3rd year of study, and a postgraduate group (Group 2) comprising six students in their Honours or Master's studies. Of these eleven students, four of them were interviewed individually the following year after they had graduated and these four graduates featured again in the next chapter (Chapter eight).

The undergraduate participants (Table 7.1) were all in their 3rd year of study - one female (Desire) and four males (Albert, Duun, Siya and Wyatt)[15]. There was one black student, one white and three coloured students, all in their early twenties. At the start of the focus group discussions, the students were given the simple Ranking list of 11 graduate attributes in which they rated the extent to which each attribute had been developed in their undergraduate studies (on a scale of 'A little', 'Some' and 'A lot')[16]. This data is represented in Figure 7.1 below[17].

Table 7.1: Undergraduate participants and the perception of PGAs developed, gender, race and age.

Name	Gender	Race	Age	PGAs Developed (A little)	PGAs Developed (Some)	PGAs Developed (*A lot*)
Desire	Female	Coloured	22		Computation skills, Laboratory skills, communication skills, Investigative skills.	Ethical and social awareness, Problem-solving skills, Independent research skills, Teamwork, and Critical thinking skills.
Wyatt	Male	White	21	Ethical and social awareness	Computation skills, Laboratory skills, Communication skills, Investigative skills.	Problem-solving skills, Independent research skills, Teamwork, and Critical thinking skills.
Albert	Male	Coloured	21		Computation skills, Laboratory skills, Communication skills, Ethical and social awareness, Teamwork	Problem-solving skills, Independent research skills, Critical thinking skills, and Investigative skills.
Siya	Male	Black	24		Computation skills, Communication skills,	Ethical and social awareness, Problem-solving skills, Independent research skills, Teamwork, Critical thinking skills, Investigative skills, and Laboratory skills.
Duun	Male	Coloured	23		Laboratory skills, Communication skills, Ethical and social awareness, and Teamwork.	Problem-solving skills, Independent research skills, Critical thinking skills, Investigative skills, and Computation skills.

[15] All names of participants in the thesis are pseudonyms.
[16] Note the slight difference in terminology between PGA framework and the Ranking list - practical skills vs laboratory skills; analytical skills vs critical thinking.
[17] Despite the small number of students, I follow the approach of Sharma et al (2008) of representing the data in a bar graph format for useful overview.

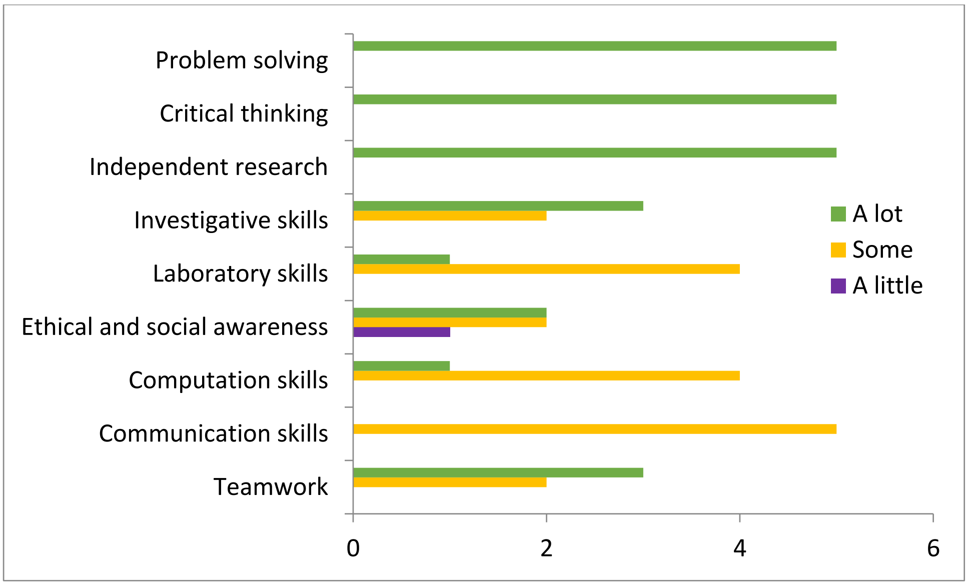

Figure 7. 1: Undergraduate (UG) participants' rating of PGAs developed

Figure 7.1 indicates that all five of the undergraduate participants felt that problem-solving, critical thinking, and independent research, have been developed ('A lot'). The least well-developed were computational skills, communication skills, and laboratory skills. One of the participants felt that ethical and social awareness was very little developed at all ('A little)'.

The postgraduate participants (Table 7.2) comprised two females (Karen and Sandra) and four males (Josh, Olckers, Nzukwen and Ukwesinde) who were in their Honours and Master's study year. There were three black students, and three coloured students, in their mid-twenties or early thirties. As with the undergraduate group, they were given a simple Ranking list of graduate attributes at the outset of the focus group interview. The perceptions on the extent to which their undergraduate programme had developed a list of graduate attributes are represented in Figure 7.2 below.

Table 7.2: Postgraduate participants and perception of PGAs developed, preparedness for next stage in life, gender, race and age

Name	Gender	Race	Age	PGAs Developed (*Some*)	PGAs Developed (*A lot*)
Sandra	Female	Black	25	Computation skills, Ethical and social awareness, Critical thinking skills, investigation skills	Problem-solving skills, Teamwork, Laboratory skills, Independent research skills, and Communication skills.
Karen	Female	Coloured	23	Computation skills, Ethical and social awareness, Critical thinking skills, Problem-solving skills, and Communication skills.	Teamwork, Laboratory skills, Independent research skills, Investigative skills.
Kwesinde	Male	black	24	Computation skills, Ethical and social awareness, problem-solving skills, and Communication skills.	Teamwork, Laboratory skills, Independent research skills, Investigative skills, Critical thinking skills.
Olckers	Male	Coloured	23	Ethics and social awareness, Communication skills	Problem-solving skills, Teamwork, Laboratory skills, Independent research skills, Investigative skills, Critical thinking skills, and Computation skills.
Josh	Male	Black	33	Ethics & social awareness, Investigative skills, Communication skills, and Independent research skills.	Problem-solving skills, Laboratory skills, Teamwork, Critical thinking skills, and Computation skills.
Nzukwen	Male	Black	32	Computation skills, Ethical and social awareness, Investigative skills, Communication skills	Problem-solving skills, Teamwork, Laboratory skills, Independent research skills, and Critical thinking skills.

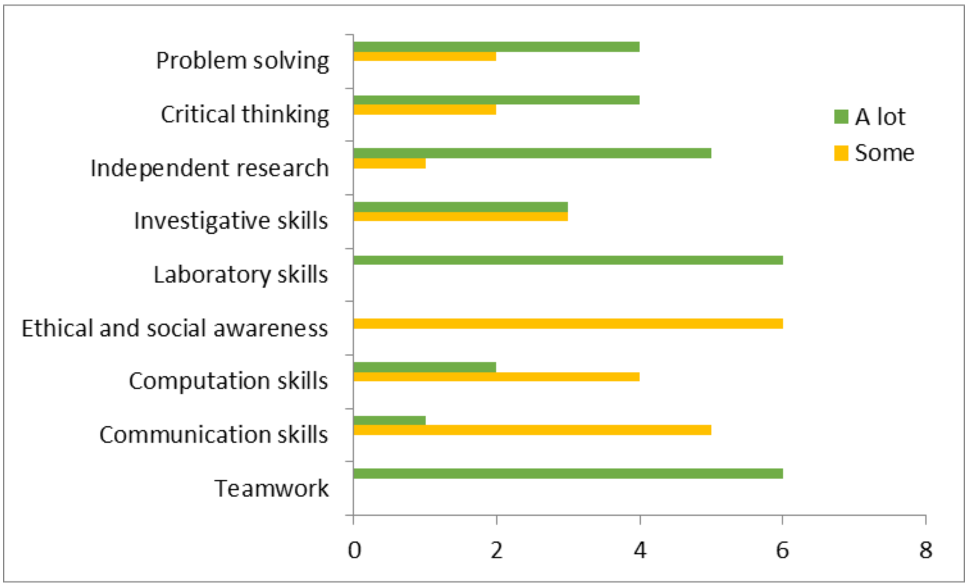

Figure 7.2. Postgraduate (PG) participants' rating of PGAs developed

Figure 7.2 indicates that laboratory skills and teamwork were felt to have been well-developed ('A lot'), while least well-developed ('some') were ethical and social awareness, communication skills and computational skills. Even though the number of participants in the focus group discussions was small, a comparison of figure 7.1 and 7.2 show some interesting differences: laboratory skills and teamwork are more highly rated as well-developed by the post-graduate students than by the undergraduate students. This may reflect that the postgraduate students are more involved in experimental work, and working as part of research teams, and so feel more confident in these skill areas.

On the other hand, critical thinking independent research skills and problem-solving are perceived by post-graduate students as less developed than by undergraduate students. This may reflect that skills such as critical thinking and independent research skills are required more as students move into post-graduate research and that they then experience this as a gap; the perception of problem-solving skills as less well-developed by post-graduate students (and thus needing more focus in the undergraduate programme), is discussed further section 7.4.2.6 later.

7.4 Conversion factors identified in this study

In this study, the data is viewed from the students' (undergraduate and postgraduate) perspective of how institutional arrangements enable them to convert available opportunities/resources into capabilities and functionings. On the flip side, the study also seeks to identify what challenges students confront and the effects these have on students developing the PGAs and their ability to convert the resources they have into functionings and capabilities.

The analysis of the focus group discussions identified conversion factors that enabled or hindered students' ability to convert opportunities/resources into functionings. These conversion factors – personal, social and environmental – are discussed below.

7.4.1 Personal Conversion Factors

Personal conversion factors comprise individual (personal) factors that influence the development of capabilities and the realisation of valued outcomes (functionings). In the context of this study, the valued outcomes are the physics graduate attributes. The personal conversion factors are the individual's attributes that play a role in how the resources (in this case, those on offer in undergraduate physics studies) are differently converted into students' capabilities. The following personal conversion factors were identified:

7.4.1.1 Motivation and Aspiration

Participants noted that they were motivated to study physics by their interest to know more about the physical world around them. In addition, the fact that only a few individuals make it to be trained as physicists is acknowledged as an advantage by the participants. As noted in

Chapter two, the limited number of students choosing to study physics is a global concern (Heron & McNeil, 2016; IOP, 2011; Sharma, Mills, Mendez & Pollard, 2005). Participants perceive this limited uptake of physics studies as an advantage for physics students and graduates. For example:

> *My study of physics is based on interest. The advantage is in the number of those studying the subject; that is, they are few (Siya, UG).*

While interest in physics is the key motivation, the reality that the physics 'scarce skills' gap may not be filled for a long time makes the study of physics appealing. The students note that more physicists are needed to fill the science skills gaps:

> *In South Africa, doing physics to me is an advantage because as you can see, there are not many of us and we need more physicists out there. Also, when you interact with people, you will be able to explain a whole lot of phenomena and things in nature. (Albert, UG)*

Here, the student notes that he is motivated by the need for more physicists in South Africa, as well as by acquiring physics knowledge that enables an explanation of natural phenomena in the world. In summary, motivation and aspiration are linked by an interest in the subject, as well as by the perception of physics being a scarce skill in South Africa. Here, motivation and aspiration are seen as enabling conversion factors for these participants. Wilson-Strydom (2015), similarly noted the importance of motivation or 'will to learn' for student success.

7.4.1.2 Confidence with oral communication

Students may express the motivation and aspiration to succeed, but many express a lack of confidence in skills needed to succeed in undergraduate physics, such as communication skills, computational skills and practical skills. All of the students in this study, except one, are not mother-tongue English speakers. Wilson-Strydom (2015) notes how confidence in the language of instruction at university can impact students' confidence to learn and contribute to lectures.

As was evident from the Ranking list data (see Fig 7.1 and 7.2), the students perceived that communication skills were not developed enough in their undergraduate studies. In Chapter six, too, we saw how students' questionnaire responses rated their communication skills as underdeveloped. In the focus group discussions, students similarly noted that the development of their communication skills was limited. For example, this student noted the importance of developing oral communication skills for further post-graduate studies:

> *For me, oral communication need to be developed more as this will be necessary in the honours and postgraduate levels (Desire, UG).*

Undergraduate participants see these skills as necessary for success in their future postgraduate studies, as well as for life after schooling and in the wider society. Thus, students noted that activities related to oral communication and presentations should be more embedded in the curriculum activities. The need for physics graduates to be able to communicate was also pointed out by other global studies on physics graduates (Woolf & Arion, 2016; Hanson & Overton, 2010; SAIP, 2004). Since students felt that communication skills should be developed more, the lack of confidence in communication is viewed as a hindering conversion factor[18].

It is interesting to note that the students emphasised the importance of *oral presentation* skills rather than written communication skills which would be needed for report writing etc. This was also a trend noted in Chapter six (section 6.4) where students' responses to the Physics Graduate Preparedness Questionnaire indicated that students feel more comfortable with written communication skills than oral and presentation skills. This is a trend also observed in the Australian survey of physics graduates (O' Byrne et al., 2008), where graduates ranked their written communication skills as more developed than their oral communication skills.

7.4.1.3 Computational/ICT skills

In the same way that a certain level of communication proficiency is assumed for enrolled students in the undergraduate programme, so too is familiarity assumed with the use of computers and the development of computation skills. However, as noted in Chapter six (section 6.2), many UWC students come from schools with inadequate computers, thus they were not privileged to use a computer at all before enrolling in university. While an 'introduction to computers' module is on offer to first-year UWC students, lecturers often assume computer proficiency from the outset. Similarly, at Honours level, students arrive from other universities and their prior experience of computational physics is very uneven. For

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[18] In Chapter eight (section 8.4.1.2) graduates reflecting back on their experiences as undergraduate *students*, similarly view communication skills as important for graduate preparedness.

students arriving with prior computer experience, this could be an enabling conversion factor, but the majority of students felt that their lack of prior experience had hindered their learning[19].

Post-graduate students felt that more should be done to develop students' computational skills. For example:

> *For me, computational skills need to be developed more as all the applications that deals with data involve computation (Karen, PG).*

This student felt it was especially important as preparation for future post-graduate studies:

> *I think computational skills need to be developed more as I see my preparation at this level is for postgraduate studies (Wyatt, PG).*

This physics graduate attribute of computational skills has become increasingly relevant and indispensable for both work and further studies (Hanson and Overton, 2010; Salagaram & Chetty, 2013). So, students in this study see its development as crucial to their studies and for various applications in the workplace. Heron and McNeil (2017) in their US study, similarly, found that graduates noted the lack of development of ICT/programming skills in their undergraduate programmes.

In summary, three personal conversion factors were identified. An enabling personal conversion factor for these students is their *motivation and aspiration*. Two hindering personal conversion factors were students' *underdeveloped confidence in communication and computational/ICT skills*.

7.4.2 Social (university) conversion factors

The social conversion factors are the basic social structure influencers that play a major shaping role for the individual. These represent social structures and institutional arrangements that either enable or hinder the conversion of available resources to capabilities and functionings by the participants. Several social/university conversion factors were identified from the focus group discussions as perceived to be enabling graduate preparedness:

[19] Similarly, in Chapter eight (section 8.4.1.3) graduates reflecting back on their experiences as undergraduate students, view lack of computer skills as a conversion factor hindering the development of other graduate attributes (for example, practical skills in the laboratory).

7.4.2.1 Peer academic engagement

The first social conversion factor that emerged as relevant to the development of graduate capabilities was peer engagement (both with classmates and with senior peers). Working in groups in the lecture classes, as well as in tutorials and the laboratory is an important feature of all academic programmes in the Physics Department. Students noted that working with their peers had been a great way of engaging with a diverse group of students in their classes, with different views and backgrounds. For example:

> *One of the best thing about being in a University is the luxury of having other students. The fact that you could go to a class and having other students come up with different views and working with them has helped me to learn a lot (Siya, UG).*

Participants also note how peer engagement specifically supported their learning of physics, and was in this way a positive conversion factor that enabled students to convert academic resources (for example tutorials or practicals) into valued capabilities:

> *Collaboration with other colleagues has really helped my learning. Being able to work with others in tutorials and experiment was great (Albert, UG).*

This peer engagement extends beyond engagement with classmates, to include engagement with senior peers too. Students note the encouragement they receive from postgraduate students and the knowledge that these postgraduate students have passed through the same programme and have achieved success. One of the participants responded thus,

> *One of the things that had helped in my learning is the presence and encouragement of postgraduate students. Just knowing that if the postgraduate students can achieve success, I too can; and the friendly environment (Desire, UG).*

This undergraduate student, Desire, would have interacted with postgraduate students in their capacity as tutors or teaching assistants, and she suggests that this interaction with senior peers is fostered by the friendly environment in the department. Participants noted the value of interacting with students from a range of countries (UWC, as an internationally ranked university, attracts students from all over Southern Africa, Africa and the world). This has given students the privilege to meet, interact and engage with students from diverse backgrounds. In summary, students describe the ‘luxury’ of peer academic engagement in terms of being in classes with students with diverse views, different approaches to tackling tasks and coming from different countries. The value of peer engagement for physics learning is well supported by physics education research (Hake, 1998), and by STEM research more generally (Gasiewski et al., 2012); in addition, peer engagement fosters social connectedness and greater social and institutional integration (Pym et al., 2011; Tinto, 2012).

7.4.2.2 Teaching approach: focus on problem-solving and group work

As noted in Chapter two (sections 2.10.1 and 2.10.2), the first-year introductory courses at UWC are designed to focus on developing students’ mastery of the multiple representations used in physics (Etkina & Van Heuvelen, 2007). In tackling physics problems, students are expected to start with qualitative analysis of a problem situation (modelling the situation, articulating relevant physics principles and making assumptions and approximations explicit etc), then use qualitative representations (e.g. sketches and diagrams), before moving to mathematical representations. In both mainstream and ECP courses, classes are held in flat-space venues, conducive to group work and enabling interactive engagement between lecturers and students.

These aspects of the teaching – the approach to problem-solving and the use of group work -- were both highlighted by students as enhancing their physics learning. Three of the postgraduate students, in particular, in reflecting on their undergraduate experiences in ECP programmes, noted the usefulness of the focus on problem-solving and student collaboration in supporting their learning:

> *The step-by-step approach to problem-solving and the student collaborative approach in the ECP programme helped my learning (Ukwesinde, PG).*

The following student also notes the usefulness of the problem-solving approach and group work in helping their learning. As with the previous student, tackling problems is described as a ‘step-by-step approach’, here alluding to the multiple representation approach (Etkina & Van Heuvelen, 2007; Van Heuvelen & Zou, 2001) whereby students were expected to start by analysing the problem situation qualitatively, using qualitative representations (sketches, graphs, free body diagrams etc.) before moving to mathematical representations:

In my experiences, the structure and administration of PHY 151[ECP module] has really helped me to learn. An in-depth approach and step-by-step approach to problem-solving too has really helped my learning. Also, the grouped way of making us work together has added to helping me learn (Olckers, PG).

Here, the student refers to the 'in-depth approach' to tackling problems, whereby students were expected to start by modelling the problem situation qualitatively, from first principles. In this quote above, as well as the one that follows, students note the learning benefits of the collaborative group work approach:

The collaborative settings of lectures and class work in my 1st year and class work helped me a lot in my learning (Nzukwen, PG).

The following student notes the value of discussion around different approaches to solving problems:

For me, the ECP programme has really helped my learning. Going through questions with the lecturer and the tutorial periods have really helped my learning. I always get to know that there are more than one way of doing something or of solving the same problem (Wyatt, UG).

It is interesting to note that the development of problem-solving ability is mentioned only at the first-year level (and only in relation to the ECP modules), and not in senior years. At a later stage in some of the interviews (see section 7.4.2.6), students suggested that problem-solving could have been developed more. This is in keeping with research that indicates that confidence in using representations in tacking physics problems takes time to develop and that explicit focus on representations needed to be sustained in undergraduate courses over an extended period (Etkina & Van Heuvelen, 2007; Eriksson, Linder, Airey, & Redfors, 2014).

7.4.2.3 Approachable teaching staff and conducive learning environment

The students noted the importance of lecturers who are approachable and foster discussion and engagement in class. Students comment on the importance of a classroom atmosphere where they feel free to engage in asking questions and communicate their own views and be open to new ideas. Participants acknowledge features which include class size and a good environment where collaborative/group work is enhanced:

> *Collaboration amongst the students is a major feature, the classroom environment and few number of physics students has helped my learning. The environment is very conducive for learning (Sandra, PG)*

Similarly, **Ukwesinde** notes how group work is fostered in the classroom, besides enhancing his physics learning, he notes how the environment allowed him to express his views and to be open to new perspectives:

> *Also, the atmosphere to express my view and communicating in the group and learning from other people in the group helped. My determination to be open to new ideas also helped my learning (Ukwesinde, PG).*

Alongside the conducive environment, participants perceived that the lecturers were experts who would take them through a module and that they had vast experience. This is perceived by the students as a motivation to learn:

> *The available expertise and teaching styles of the lecturers has really influenced and helped my learning. Knowing that the lecturers are expert in their fields inspires me to work hard to attain that same status too in the near future. Their level of passion and enthusiasm for the courses taught makes me feel immersed in the physics. This makes me to be motivated to excel in my studies (Duun, UG).*

Physics classes at UWC tend to be relatively small compared to other disciplines (ranging from 100 in the first year to 25 in the third year at the time of this study). In a smaller class, the students are given attention and required class supervision. This feature enables the students to be able to develop and exercise functionings (some physics graduate attributes) in such conditions; for example, functionings such as oral communication or teamwork skills are likely to be more easily developed in a smaller class. The importance of the approachability of lecturers is highlighted by numerous studies. Walker (2006) notes the importance of 'relational affiliation' with lecturers (p.95). Calitz (2015), similarly, identifies affiliation with lecturers as an important conversion factor. She finds the converse in her study, where alienation from lecturers 'prevented students from converting educational resources into the capability for equal participation' (p.156). In STEM undergraduate contexts, approachable lecturers who welcome student engagement and in-class questions are found to be particularly important in introductory 'gatekeeper' courses, such as first year mathematics and science courses (Gasiewksi et al., 2012).

To summarise, several social/university conversion factors were identified from the focus group discussions as perceived to be enabling graduate preparedness. These were *peer academic engagement, teaching approach (focus on problem-solving and group work) and lecturer approachability and conducive learning environments*. It was interesting that the emphasis was directed more to the many positives of the Extended Curriculum Programme (including a focus on problem-solving and collaborative group work) and how it equipped them through their programmes in the mainstream.

The focus group discussions also highlighted several social conversion factors that hindered or impeded the development of capabilities and subsequently, of functionings (in other words, the development of appropriate physics graduate attributes), which led the students to perceive a lack in their preparedness. These hindering social conversion factors are discussed below.

7.4.2.4 Opportunities for student engagement and affiliation with peers

Although participants experienced peer academic engagement in classes as positive (see section 7.4.2.1 above), they felt that physics students lacked opportunities to engage as students and to develop a sort of physics learning community and a sense of belonging *outside* of the classroom. This would include 'spaces' for academic support, engagement and interaction. The lack of such opportunities could be viewed as a hindering conversion factor.

The focus of these opportunities for student engagement and affiliation would not just be on engagement on concepts covered in lectures but also to develop wider physics graduate attributes. The focus would also be on developing student voice and a platform for student affiliation (for example a physics society, or organising a student representative structure, with class representatives). Calitz (2015) identifies the lack of student participation in decision-making as a hindering conversion factor in her study and notes that greater participation in decision-making processes would have enabled students to 'contribute to conditions that would have enhanced their opportunities to learn (Sen, 2004, p.149). In the interviews, students voice their perspectives on how informal spaces would foster greater peer affiliation:

> *Normal space where everybody is free to express his/herself. Where nobody feels intimidated to ask a question or make suggestions. Where whatever one says is not deemed to be stupid, let me put it that way. Where one is free to bring up view about any concept or theory learnt. A space for discussion; especially in small groups (Sandra, PG).*

The following postgraduate student notes that, although group work is used extensively in some modules (particularly in the ECP), there is no formal space outside of lectures for undergraduate students to meet as a group to continue working on group activities. Such spaces are only provided to Honours and Master's/PhD students:

> *With my experiences in the ECP [as a tutor], I can say that there are no formal spaces to which students own for interaction around the department, even when students are grouped in the undergraduate programme except for the honours and higher degree programmes. The spaces can be made to enable the 1st and 2nd years to interact (Ukwesinde, PG).*

The participants acknowledged that interactive student spaces for cross-level engagements in the department will be a very big boost to helping students support each other academically and to foster skills development (eg working with diverse peers; communication; teamwork). These spaces would also enable physics students to get to know each other across year levels (eg first year with senior students) and to organise themselves. Some participants have the following to say,

> *Interaction spaces owned by students and accessed for constructive use. Where postgraduate students and undergraduate students can meet without intimidation (Nzukwen, PG).*

> *I think more student-owned spaces should be available to help student transit by interaction, especially 1st year and 2nd-year students (Olckers, PG).*

One advantage that students generally have is to interact and engage themselves in one way or the other. While we cannot force them to socialize and work hard at their academics, students can be helped by creating spaces or conditions for them to have a sense of freedom around the department by designating areas for student interactions. Pym and Kapp (2013) note the importance of psycho-social affiliation with peers and the institution. The lack of such student spaces and platforms impedes the enhancements about developing the physics graduate attributes. In addition, developing a platform for student affiliation (for example a physics society, or a more formal class representative structure) would be beneficial.

In summary, the above quotes reiterate the necessity for designated ‘student space’ which physics students will own to create a platform for student affiliation, and student and graduate voice. Participants are of the opinion that the department can help students by enabling ‘spaces’ for affiliations with peers, platforms for students’ voices, and engagement forums with lecturers to enhance the development of the physics graduate attributes. Student engagement and affiliation through, for example, societies, or a more formal class representative structure, would foster greater student engagement and social integration (Tinto, 2012; Kuh, 2007; Kuh et al., 2007). In addition, supporting student extra-curricular activities is found to be important for developing students’ graduate preparedness (Walker & Fongwa, 2017); in STEM undergraduate education, in particular, extra-curricular activities are found to foster student retention and academic success (Figueroa et al., 2013) and workplace prospects (Sagen et al., 2000).

7.4.2.5 Career guidance

Students study for various reasons, but many students are particularly focused on getting a job after graduation; this is particularly important for first-generation students in higher education. Some students think about their job possibilities only after graduation. Others engage and actively seek information about work they would like to do, while still studying. Being aware of jobs they may do is an important aspect of the learning and preparation process, as many other work fields also recruit physics graduates because their expertise cuts across interdisciplinary lines of competence. Participants in this study lament the paucity of an organized way within the university of getting both undergraduate and postgraduate students to be aware of the realities of job hunting and the world of work. This is particularly important for many first-generation students who cannot get career advice from family members (Walker & Fongwa, 2017; Walker et al., 2022).

Students’ first concern is that the University’s career services seem not to cater for *undergraduate students*: participants have the following to say,

> *We have not been really exposed to employment opportunities. Most of the career EXPOs have no opportunities for undergraduate students. We are*

only encouraged to do a honours programme and a master's degree to increase our chances of getting a job (Wyatt, UG).

Students feel that, while general career advice is on offer, there is not much information provided on *specific job opportunities*. For example, one participant commented:

I have been exposed to some talks and seminars on career choices, but nothing specific on employment opportunities (Desire, UG).

The students are of the opinion that many of the university-wide career information and opportunities do not benefit students from the Department:

… when there is a visit to the University by companies, such information does not benefit physics student and graduates (Olckers, PG).

Students' main concern is the Department's lack of coordinated career service and events, which they feel should focus on exposure to career advice or employment opportunities specifically tailored for physics careers:

I think we are lacking in that regard. It should be a consistent thing organised by the department. Where the department will showcase the type of skills acquired by her students and graduates (Ukwesinde, PG).

There are no organised industry-linked career or employment opportunities and exposure in the department (Olckers, PG).

There should be coordinated career seminars and events by the department. The opportunity to be exposed to more of this information should be enhanced for undergraduates (Siya, UG).

While advice on job opportunities is useful for students in the final years of their study, many respondents noted that exposure should be created more for the *undergraduate student* who really does not know the next right step. While participants noted that one or two individual modules touched on career advice, they suggest that a more coherent departmental approach is needed:

There has been some opportunity and exposure to career advice in PHY 317, but much needs to be done at the department level. Bringing such events to *the department level will mean more to the undergraduate students (Duun, UG).*

To summarise, the concern raised by participants on career guidance provided by the Department is an aspect that needs attention and an implementable programme that would help students to understand their roles in career and job search. As Walker and Fongwa (2017) note in their study on graduate employability, while student employment prospects are influenced by wider economic and labour market factors beyond the universities' control, it is nevertheless important that universities do all they can 'to enhance the opportunities of talented young people who manage to access higher education and who hope for decent work, jobs and career pathways' (p.vi). In this regard, Walker and Fongwa (2017) emphasise the important role of career advice on offer at universities.

7.4.2.6 Explicit focus on wider graduate attributes and skills

As noted earlier in section 7.3, participants had ranked some attributes on the Ranking list (Problem-solving, Critical thinking skills, Teamwork and Laboratory skills) as having been developed 'A lot'. Similarly, in Chapter six, students rated their perceptions of preparedness most highly on the Physics Graduate Attributes Questionnaire for Problem-solving, Analytical skills, Teamwork and Personal skills.

Nevertheless, many participants in the focus group interviews felt that more could be done in the undergraduate programme to develop a wider set of physics graduate attributes and their sense of graduate preparedness. In this section, students' perceptions of gaps in their graduate preparedness are explored further.

We saw earlier that participants feel that their **confidence in oral communication** needs to be developed further, as these will be vital in their future studies and work. Similarly, they felt underprepared in **computational/ICT skills**, a physics graduate attribute that is becoming relevant for both work and further studies (Hanson & Overton, 2010).

Although students rated their preparedness in **teamwork** highly in the Physics Graduate Preparedness Questionnaire (as well as in the Ranking list), they felt that teamwork skills ought to have been more explicitly developed in their courses. Some students framed their comments in terms of an awareness that teamwork would play a key role both in the workplace and in research contexts, thus making it a necessary skill:

I think working as a team needs to be developed more. That is because most of the modules assign work to individuals to be done. Meanwhile, we all are aware that we will be working with people anyway (Sandra, PG).

This student notes that the modules do not assign sufficient teamwork tasks to students. This would be more aligned with collaborative modes of working anticipated in their future lives, either in the workplace or as researchers. Other students commented that assigning group tasks is not sufficient – they would have liked more explicit guidance on the skills needed to work productively in groups:

I think teamwork need to be developed more. That is because we compromise with our team rather than work with the team. We only do independent projects that make sense by covering for ourselves more (Albert, UG).

This student notes the struggles with group work, and how they 'compromise' in teamwork, rather than working effectively together. On the other hand, he notes how independent tasks tend to be taken more seriously by students since they cannot assume other students in the group will do the work, but they have to 'cover for themselves' and do the work themselves. The implications of this seem to be that it is not sufficient merely to put students in groups; instead, a more explicit co-operative learning approach is needed (Johnson & Johnson, 1991); where students are each assigned roles in the group and there is a clear focus on group processes.

While students perceive **practical skills** (also termed 'laboratory skills') as being developed in the undergraduate programme, one student noted that while 'laboratory skills are being developed', experimental design skills are not adequately developed in the undergraduate curriculum. The experiments are often in rather a prescriptive, recipe-like format:

For me, I think experimental design skills need to be developed more. So there would be a whole room to plan and do experiments instead of the present practice where every step is given for one to follow. It does not give one the opportunity to think for yourself and be creative. Only laboratory skills are actually being developed (Siya, UG).

Here, the student is suggesting that some undergraduate laboratories have too much of a traditional 'cookbook'-style ('where every step is given for one to follow'), rather than an open-ended experimental design (as in the case of the ISLE laboratory approach (Karelina & Etkina, 2007), which aims to develop experimental design skills). He would prefer a design-based approach to undergraduate laboratories, being given 'the opportunity to think for yourself and be creative'.

An explicit focus on **problem-solving Skills** in the teaching approach was identified in section 7.4.2.2 as an enabling conversion factor in developing perceptions of graduate preparedness (problem-solving was also perceived as well developed in the Physics Graduate Preparedness Questionnaire data in Chapter six). Despite this, students felt that problem-solving needed more development. For example:

> *I think the problem-solving skills and the critical thinking skills should be developed more. So that we will not cultivate just one lecturer's way of doing things (Josh, PG).*

Josh seems to be suggesting here that this could be achieved by more explicitly addressing problem-solving skills throughout the degree curriculum, beyond the first year. This idea of progression throughout the undergraduate curriculum is also reflected in the SAIP Benchmark statement, which notes the need for progression from 'solving problems with well-defined solutions' to tackling 'open-ended problems' (SAIP, 2015a, p.7). This progression is also borne out in physics education research literature (as noted in Chapter two), which shows that competence in physics problem-solving takes time to develop, and therefore an explicit focus on the use of representations in problem-solving needs to be sustained in undergraduate courses over an extended period (Etkina & Van Heuvelen, 2007; Eriksson, Linder, Airey, & Redfors, 2014).

Some participants also felt that the capacity for **investigative skills** (which in the Ranking list are termed 'independent research skills') needed more focus. This was particularly related to preparedness for graduate study as stated by these participants:

> *Skills that need to be developed are those that relate to what is required for the application of knowledge learnt, such as independent research skills and problem-solving skills (Ukwesinde, PG).*

> *Independent research skills need to be developed more, that is because postgraduate studies that we are prepared for will require this skill (Duun, UG).*

The above quotes about the perception of participants on problem-solving skills, critical thinking skills and independent research skills call for deliberateness in embedding the PGAs in the curriculum.

The final graduate attribute that a few students felt needed more attention was **ethical awareness and social awareness**. These two physics graduate attributes to deal with concerns, interactions and engagements with the environment and society. A participant has the following to say:

> *In my opinion, consideration of ethical and social issues are not talked about at all along real-life examples. Ethical and social issues should be related more in their context and application to physics innovations and products (Olckers, PG).*

The fact that the products of Physics in whatever form are used by real humans or their usage in whatever form will affect humans brings the issue of ethics or ethical consideration to the fore. The participants want these concepts to be talked about more in the context of physics.

The above Physics Graduate Attributes and skills are at the core of the modern-day preparedness processes for the physics graduate (McNeil & Heron, 2017; Ryan & Benson, 2020). Problem-solving skills, independent research skills, teamwork and computational skills were mentioned over and over again by participants, suggesting that both undergraduate and postgraduate students desire that these skills be developed more in physics students. The reality that problem-solving skills surfaced to be the one most mentioned, is an indication that no single PGAs should be taken for granted or assumed to be very developed in physics students. More can be done to help physics students to develop confidence about the PGAs, even the problem-solving skills that are always assumed to be developed.

In summary, three social conversion factors were identified as factors that were perceived to be limiting the development of graduate preparedness. These were the lack of opportunities for *student engagement and affiliation*; lack of *career guidance*; and inadequate *focus on wider graduate attributes and skills.*

7.4.3 Environmental conversion factors

In the capability approach, factors relating to geographical location or climate are examples of environmental conversion factors. In the context of this study, the students perceived that the urban location of the university brought with it both positive and negative aspects:

7.4.3.1 Local institutional and international collaborations

Students noted that the urban setting of the university enabled collaboration across local institutions (for example, iThemba LABS) as well as international collaborations, which helped students to learn. For example**:**

> *Collaboration amongst students and across institution has help me learn. For example, the iThemba laboratories providing and meeting experimental needs and experts from other countries during the 'Taste of Nuclear Physics" [a workshop arranged by the nuclear physics research group in the Department] has aided my learning too (Karen, UG).*

Another participant noted that the recognition of the university globally also added to the urge for the participants to learn:

> *Also, the international ranking of the Department to encourages me to learn (Desire, UG).*

In summary, the urban setting of the university was perceived here as an enabling conversion factor.

7.4.3.2 Commuter students: The need for study spaces

The negative aspect of an urban setting and the non-residential nature of the university is that many students spend long hours commuting to campus. They often do not have conducive spaces at home for studying, nor the time for studying when they get home due to many factors beyond their control (such as travel time to and fro and domestic responsibilities). These commuter students are thus at greater risk of experiencing academic and social exclusion (Calitz, 2016; 2018). This emphasises the necessity for designated 'study spaces' in the

Department which would provide support-focused spaces for studying and engagement with peers.

Students suggest that small meeting rooms with whiteboards would be useful for working together and discussing physics concepts and problems:

> *I think spaces that allow for small groups (not more than 5 in number) with whiteboards, access to internet and large spaces for voicing out ideas (Albert, UG).*

Another student envisaged a space for academic engagement and social interactions, a sort of student lounge:

> *My ideal environment to interact will be small-partitioned rooms and designated sitting space for social interactions (Duun, UG).*

These spaces would foster the engagement and affiliation described earlier in section 7.4.2.4 to build students' confidence and develop more of the PGAs. This would also help students in their transition period where consultations could be arranged for students needing assistance, especially at 1st or 2nd-year level.

In summary, participants perceived the urban setting of the university as positive in allowing for *collaboration across local institutions as well as international collaborations*. They felt that this exposure to experts and a range of facilities enhanced their learning and the development of their physics graduate attributes. On the other hand, the *lack of study spaces* for students, particularly commuter students, was a hindering conversion factor. The absence of student study spaces for undergraduates to sit and share or solve problems is not helping students to convert opportunities into functionings adequately. This emphasises the necessity for designated 'study spaces' in the Department which would provide support-focus spaces for studying and engagement with peers.

Table 7.3 below summarized the interplay of the conversion factors (personal, social and environmental) that enabled or hindered the conversion of opportunities and resources into functionings (the physics graduate attributes).

Table 7.3: Summary of conversion factors

S/N	Conversion Factor	Enabling	Hindering
1	**Personal**	Motivation and aspiration	Confidence in Communication, Computation/ICT skills
2	**Social (University)**	Peer academic engagement Teaching approach: focus on problem-solving and group work Approachable teaching staff and a conducive learning environment	Opportunities for student engagement and affiliation with peers Career guidance Explicit focus on wider graduate attributes and skills
3	**Environmental**	Urban setting: Local institutional and international collaboration	Commuter students: Lack of study spaces

7.5 Students aspirations and well-being

As noted earlier in section 7.2, taking a capability approach to education, the development of well-being and human flourishing through education is key. Walker and Fongwa (2017) see the potential for higher education as an "aspirations-making space" (p.182), which can motivate students to work towards future aspirations and goals, thereby fostering their agency. They explore the aspirations students hold for their lives after graduating from university, as does the Hoppenaar (2016) study with engineering students.

This section explores students' responses to focus group interview questions that probed students' aspirations for the future, how they perceived the relevance of the development of the PGAs and the extent to which they felt that their studies have equipped them for the next stage in their lives. In other words, leading to what these participants' will do and find fulfilment (Sen, 1999).

Questions such as 'What do you hope to achieve in terms of the kind of life you would like to live in the near future?' and 'How do you think your studies will enable you to attain these goals?' were asked.

Students articulated a range of aspirations and valued functionings relating to their careers and lives beyond university (in other words, what they aspired to able to be and do in the future). These are discussed below.

Aspiration to further my studies and learn more

Many students described a quest to learn more as a drive to further their studies. For example, the following three 3rd year students describe their intentions to pursue Honours and Master's level studies, and envisage their studies leading to a range of careers, including a medical physicist, a material science researcher, and a theoretical physicist:

> *For me to get to the point of leading the kind of life I would like to live, an Honours and Master degree will be a necessity. I like teaching young kids, but I want to be a medical physicist (Wyatt, UG).*
>
> *I have all these ideas to learn as much as I can in my area of interest, that is material science. Only when I do an Honours degree and a Master's degree that I will be happy pursuing the life I would want to live (Siya, UG).*
>
> *I want to be a researcher and a theoretical physicist. To lead a comfortable life in this chosen path, I am looking forward to doing what I enjoy most of all – physics (Duun, UG).*

The following Master's student, Ukwesinde, describes aiming to follow his passion for physics, though becoming a researcher while providing for his family:

> *One thing that would influence my decision is to getting to do what I like doing best - physics; with the ability of being able to provide for my family as a researcher. I want to be happy doing what I want without stress whatsoever (Ukwesinde, PG).*

Josh, another Master's student, aspires to work in a career aligned with his Master's degree in Physics Education:

> *In the near future, I will choose something to do along my present interest in pursuing a Master's degree. Something to make me happy (Josh, PG).*

It is interesting to note that, in these extracts, students hope that through furthering their studies and meeting their career aspirations they will attain well-being and fulfilment (as indicated through phrases such as 'to lead a comfortable life', 'happy pursuing the life I want to live', 'to be happy doing what I want without stress'. The prevalence of the word 'happy' is striking; although there is some mention of being 'comfortable' and 'to provide for my family', their aspirations are not mainly about money or material well-being.

Equipping me with computational skills to further my interest

Participants relate the study of physics to their aspirations. To them, studying physics equips them with the valued capabilities and functionings of computational skills that will eventually translate into a handy tool to use to seek work or pursue further studies:

> *With the physics I am doing, I think it will equip me with the computational skills and teaching interest to lead a happy life I want, as I pursue a higher degree (Desire, UG).*

> *I desire to further my studies in computational physics till I become an expert. That is what I would like to be doing and I know I will be very happy with life (Albert, UG).*

Here, too, the focus is not just on the material benefits of possessing computational skills; students link the aspiration to develop and use their computational skills in the future to achieving satisfaction, and well-being. The development of skills such as computation along with their interest in becoming experts at it or taking the skill into teaching will make them lead happy lives.

Further my teaching and mentoring interest.

This aspiration reflects a desire to be involved in teaching or mentoring in their future lives – either through the teaching profession or in taking on a mentoring or outreach role in their work. These participants are looking forward to using physics as a platform to inspire the younger generation and learners to take on physics.

> *I want to go into teaching. I would like to see young people achieve good grades in physics; to also have a good grasp of the subject. (Sandra, UG)*

> *I want to be happy doing what I want and what I enjoy most: which is teaching or lecturing. It is not about making money, but I hope to get a good job to keep me doing what I love doing (Karen, UG).*

> *I am hoping to use my knowledge gain in the study of physics as a platform to encourage the younger generation to excel in physics (Olckers, PG).*

I am all about outreaches to encourage kids by getting the knowledge out there. I am aiming at encouraging people to do what they want to do. Something they will be doing, and be happy doing it (Nzukwen, PG).

It is interesting to note that these teaching/mentoring choices were mainly by postgraduate participants, reflecting a strong desire to contribute to human development, mentoring and influencing society for good. Again, phrases linked to fulfilment appear in these extracts ('doing what I love most', 'I want to be happy doing what I want').

To summarise, students' aspirations were not only related to career aspirations (e.g. medical physicist, researcher, teacher) but also valued capabilities and functionings, as it pertains to their perception of what skill set developed, will help them achieve well-being and happy life. They describe valued capabilities and functioning as being able to use their computational skills and enjoyment of teaching /mentoring.

Their immediate aspiration was to study further; this would enable them to expand their capabilities and functionings for whatever they aspire (Nussbaum, 1997; Alkire & Black, 1997; Gasper, 1997; Sen, 2004). They acknowledge the development of the PGAs which they see as very useful for the workplace, research or further studies. Through the lens of the capability approach, it appears that for these physics students, their undergraduate education has developed their aspirations and expanded their opportunities to be and do what they have reason to value (Sen, 1999).

7.6 Conversion factors that enable or hinder the development of physics graduate attributes

Analysis of the focus group discussions highlighted the conversion factors that either enable or hinder the participants' ability to convert capabilities into functionings. In the sections below, the key findings are briefly summarised.

7.6.1 Conversion factors that enable

As noted throughout this study, the potential of higher education is within its impact on human development by equipping students with knowledge, skills and agency to lead a life as chosen by the individual. Each student is differently located within socio-structural and class-based inequalities (Calitz, 2015), and has a unique capabilities set, linked to family resources and income. Each student is therefore differently able to convert available resources and opportunities into capabilities or functionings. For example, a student entering university with advanced computer skills or experience of doing practical work is likely to more easily engage with conducting experiments and writing lab reports than a student with limited computer experience. Using the capability lens, this section examines how institutional arrangements and other factors enhanced or enabled students to convert available resources and opportunities into functioning and capabilities (the development of the physics graduate attributes).

In summary, several enabling personal, social and environmental conversion factors were identified. Even though they are described separately, the conversion factors are easily interrelated and mutually reinforcing, as illustrated in some examples below.

Personal conversion factors: Motivation and aspiration were perceived as driving student learning and enhancing the development of graduate attributes. This motivation was linked to a passion for the discipline of physics and a perception of it has a 'scarce skill'. Wilson-Strydom (2015), similarly noted the importance of motivation or 'will to learn' for student success. This intrinsic motivation expressed by the students is also likely to benefit them in their future careers. For example, a study of physics graduates well-established in the workplace (Porter, 2019) found that 'intrinsic passion and interest for their job' were important factors in their career success.

Social (institutional) conversion factors: Peer academic engagement in classes was experienced as supporting students' physics learning, as borne out by the literature on physics education (Hake, 1998; Mazur, 2007); it also exposed students to diverse peers. These peer engagements enabled participants to navigate both their academic and social dimensions of university life. Other studies have shown the importance of psycho-social affiliation with peers and the institution (Pym & Kapp, 2013; Tinto, 2012; Kuh, 2007), and the importance of encountering 'norms, values, attitudes and beliefs different from their home discourses' (Pym & Kapp, 2013, p 275).

The *teaching approach* was another aspect of the institutional arrangements experienced as positive by the participants. Students valued the explicit multiple representations problem-solving approach (Rosengrant, Van Heuvelen & Etkina, 2009; Etkina & Van Heuvelen (2007) and the use of group work in classes. Here, we can see the interrelationship between conversion factors: for example, motivation and aspiration may be linked to a greater 'will to learn' and to engage actively in peer academic engagement and group work during classes. Participants here have the freedom and choice to engage with educational opportunities to develop the physics graduate attributes through academic interactions with peers.

Besides the enabling teaching approaches, students valued the *approachability of teaching staff and the conducive learning environment created*. Students comment on the importance of a classroom atmosphere where they feel free to engage in asking questions and engaging with others – this was enhanced by relatively small class sizes and an environment where collaboration/teamwork is encouraged. Relational affiliation with lecturers and lecturer approachability are seen as important for student success (Calitz, 2015; Walker, 2006).

Environmental conversion factors: An environmental conversion factor that enabled the conversion of resources and opportunities into functionings was institutional collaborations, enabled by the urban setting of the university. This enabled collaboration across local institutions as well as international collaborations, and the perceived high ranking of the university also fostered motivation among participants. The significance of university reputation is noted by Walker & Fongwa (2017) as important for student employability.

7.6.2 Conversion factors that hinder

Using the capability lens, this section examines how institutional arrangements and other factors limited or constrained students in converting available resources and opportunities into functioning and capabilities (the development of the physics graduate attributes). In summary, several enabling personal, social and environmental conversion factors were identified.

Personal conversion factors: Students' underdeveloped confidence in communication and computational/ICT skills were two limiting conversion factors. The need for graduates to be able to communicate adequately is perceived as a challenge for some of these students if they have to further their studies. The need for physics graduates to be able to communicate is also pointed out by SAIP (2004) and Hanson and Overton, (2010). Conversion factors are easily interrelated and mutually reinforcing: for example, Wilson-Strydom (2015a) notes how confidence with the language of instruction at university can impact students' confidence to learn and contribute in lectures or engage with peers. Similarly, as noted earlier, for students entering university with limited computer skills, this may well hinder their learning in their undergraduate years.

Social (institutional) conversion factors: Several social (institutional) conversion factors were identified that hindered the conversion of resources and opportunities into functioning. While peer engagement in classrooms was experienced as positive, students noted the lack of opportunities for student engagement and affiliation with peers outside of classes. Students felt structural arrangements such as a physics society, a student representative structure and opportunities for students across levels to interact with each other would foster a greater sense of belonging (Pym et al., 2011; Tinto, 2012; Kuh, 2007).

The capability approach embraces the notion that individual students must take the initiative to play an active role in the process of their education instead of passively being assisted or offered help (Sen, 1999). Thus, the notion of agency expresses a student's position within the department/university community as the student makes choices, sometimes choices to claim access to real alternatives (Sen, 1999). This allows students to participate or contribute to decision-making (Crocker & Robeyns, 2010). The lack of opportunities for student engagement and affiliation with peers and the lack of study spaces or student lounges hinder the articulation of students' voices in the department. This lack is expressed in the inability of students to propose or demand structural arrangements that will benefit the system. Bozalek and Boughey (2012) puts it this way,

> *'The aim of recognizing student voice is to create a more horizontal process of deliberation so that all students have access to conditions under which they can develop the capability for voice' (Bozalek & Boughey, 2012, p.695).*

The absence of such space and platform to convert educational resources and affiliation opportunities into functionings hinders students' from *further* developing the physics graduate attributes such as communication skills, social awareness and teamwork.

Another institutional limitation identified was the *lack of career guidance*. Participants expressed their disappointment with the paucity of processes for getting both undergraduate and postgraduate students to be aware of the realities of the world of work and job searching. Such career guidance is especially important for first-generation students without family members they could rely on for advice (Walker et al., 2022). The role of career guidance and social capital in developing students' employability is noted in the study by Walker and Fongwa (2017).

Students also noted a lack of sufficiently explicit *focus on developing the wider graduate attributes and skills* needed for the workplace. Besides the communication and computational skills mentioned earlier, these included teamwork, experimental design skills, more rigorous problem-solving and critical thinking skills, independent research skills and ethical/social awareness. These are all skills identified as important in the SAIP benchmark statement (SAIP, 2015), and in other physics graduate literature internationally (McNeil & Heron, 2017; Ryan & Benson, 2020). Walker and Fongwa's study (2017) similarly found that students felt that their programmes lack sufficient focus on practical learning and skills development.

Environmental conversion factors: Finally, an environmental conversion factor that hindered the conversion of resources and opportunities into functioning was the urban, largely non-residential nature of the university. This meant that many commuter students spent long hour's community to campus and lacked conducive spaces for study at home. For these students, there was a lack of study spaces on campus.

7.7 Conclusion

- This chapter focused on addressing Research Question 3: *What are the conversion factors that influence students' perceptions of attainment of the physics graduate attributes?*

The analysis of focus interview data identified the personal, social (university) and environmental conversion factors that enable and hinder the conversion of resources and opportunities into capabilities and functionings. Personal conversion factors identified were motivation and aspiration, and inadequate communication skills and computational skills. Social (university) conversion factors identified that students felt enabled or hindered their development of physics graduate attributes are: peer academic engagement in classes, teaching approach (including problem-solving and group work), lack of opportunities for student engagement and affiliation, lack of career guidance, and insufficient focus on wider graduate attributes and skills in the curriculum. Finally, two environmental conversion factors were identified, linked to the urban setting of the university. The positive aspect was the perception that the urban setting fostered institutional collaboration and exposure for students. The negative aspect of the urban setting was the lack of study spaces on campus for commuter students.

This chapter also focused on students' aspirations and well-being. Motivation and aspiration enabled these students to forge through the preparedness process and develop the necessary physics graduate skills for the 21st century society and workplace. There was evidence in students' responses of higher education being an 'aspirations-making space' (Walker &

Fongwa, 2017, p.182) for them; students expressed a range of aspirations and valued functionings relating to their lives after graduating. These included to pursue a research/academic career, to use their computational physics skills in the workplace, or to take up teaching or mentoring roles. Career aspirations were coupled with aspirations for achieving well-being and fulfilment.

In the next chapter, the study follows four of the students featured in Chapter seven into the workplace and life beyond university. Chapter eight presents an analysis of interview data with these four graduates, to identify the conversion factors that influence these graduates' perceptions of their preparedness as they enter the workplace and life post-university.

CHAPTER EIGHT

GRADUATE PERCEPTIONS OF PREPAREDNESS AND CONVERSION FACTORS

8.1 Introduction

The previous chapter examined the conversion factors that were found to influence physics students' perceptions of their graduate preparedness. Here, the analysis was based on data from focus group discussions with undergraduate and post-graduate students. In this chapter, we follow up with four of these students, who had subsequently graduated and entered the workplace. The chapter examines the conversion factors that were found to influence their perceptions of graduate preparedness, thus addressing Research Question 4:

RQ4*: In relation to physics graduates entering the workplace, what are the conversion factors that influence their preparation on entering the workplace?*

While the focus of the interviews with these four graduates was to understand their transition to the workplace and life beyond the university walls, the participants chose to tell the stories about their early lives too: getting to university, completing university studies (which relates to RQ3), and finding work which relates to RQ4. Therefore, the conversion factors identified in this chapter span the participants' home circumstances as well as university-related concerns. This is not surprising since their current situation as a graduate is a product of where they come from and how they navigated challenges along the way to be where they are. Interestingly, while participating in the interviews, some of the participants expressed that it was a relief to be able to share their stories.

The data was collected through audio-taped interview conversations with four UWC graduates who had entered the workplace. These graduates had been among the eleven students featured in Chapter seven; the other seven students had not entered the workplace but had continued with their post-graduate studies (except for one graduate who was also working but opted not to be interviewed).

The in-depth interviews were conducted between six and ten months after graduating from the university (that is, one year after the survey and focus group discussion) and lasted between 1-2 hours. The interviews explored any changes in the perceptions of these participants of their graduate preparedness during the process of looking for jobs, taking up work, and contributing to their work community and society. Following a narrative inquiry approach, the graduates discussed their life stories, which encompassed their stories of living through university and after graduation, and their storied view of getting a job and experience of work, within the wider context of society.

The analysis of these narratives sought to understand the conversion factors that seemed to influence their perceptions of graduate preparedness and their workplace choices.

In this chapter, a brief overview of the relevant literature on conversion factors in relation to graduate preparedness is presented. Following this, the four participants are introduced, followed by an analysis of the graduates' perceptions of their preparedness for work and society, and the conversion factors that have influenced their preparedness. Arising from graduates' reflections on their preparedness and experiences of life beyond university are two related themes: graduates' perceptions of the outcomes of higher education and its influence on their lives; and the role of student agency. These are also discussed in this chapter.

8.2 Concept of conversion factors in relation to physics graduate preparedness

In Chapter seven, the concept of conversion factors in relation to physics students' perceptions of preparedness was discussed (see section 7.2). As discussed in Chapter three, conversion factors influence how each person is able to convert his/her bundle of goods (resources) into capabilities (Sen, 1999); conversion factors are personal, social and environmental differences that explain why individuals benefit differently from the same resources (Robeyns, 2005). This chapter explores the conversion factors that influence graduates' perceptions of their preparedness; it examines which personal, social and environmental conversion factors enable or hinder the development of their PGAs in relation to their current employment. As noted in Chapter three, previous studies on graduate employability pathways (Walker & Fongwa, 2017; Walker et al., 2022) have identified a range of conversion factors that influence the ease with which graduates enter the workplace, including race and social class, university reputation, career advice on offer, and the location of the university.

8.3 The research participants

This part of the study begins with the introduction and description of the participants, their backgrounds, motivations for pursuing physics, and their future aspirations[20]. Four participants were part of all three phases of the project data collection: the questionnaire phase (the Physics

[20] Pseudonyms are used for the students' names and for the universities they attended.

Graduate Preparedness Questionnaire), the focus group discussion phase, and the graduate interview phase. The fifth participant (the only female) opted out in the 3rd phase. The 3rd phase of the research was the one-on-one, open-ended interview.

Nzukwen studied for a BSc in Maths and Physics as an undergraduate at the University of the East. He is a black 32-year-old male student, from a low-income family. His parents had little formal educational background. He grew up in a rural environment in a town which lacked most of the public facilities and amenities. He began to take an interest in Physics when he was in high school. He chose Physics at the undergraduate level because the physics component of the Matric subject Physical Sciences was his favourite subject in high school. After his undergraduate programme, he moved to UWC to study a BSc (Honours) in Physics, funded by an NRF bursary. He then proceeded to an MSc in Nuclear Physics on the same NRF bursary. His research field and interest are in Nuclear Physics.

During the focus group discussions in the ***2nd phase*** of the project (in the second year of his Master's in Nuclear Physics**),** Nzukwen reported that he was prepared and confident that he would successfully complete his Master and would be successful in getting a good job related to his study field of nuclear physics. He recounted how he had learned about the interaction of radiation with matter, and this made him realize how the environment can be affected by radiation and the impact of nuclear activities. He noted that he aspired to work in the nuclear industry, in particular in the field of Nuclear Power Generation and Management in the next 3 years.

When he was interviewed in the ***3rd phase*** of the research project, he was working with the Nuclear Regulatory Agency outpost station at the nuclear plant. He had seen a job advertisement online and had applied. One major factor that made him pursue his career choice immediately (while still registered for the 2nd year of his Master's degree) was family pressure – being the first graduate in the family. Nzukwen believed that working would empower him to help his family.

Ukwesinde studied for a BSc in Applied Mathematics and Physics at the University of the South. He is a black 24-year-old male student from a rural environment. He is from a very low-income family, and his parents had very little education, not completing any level, not even a Matric qualification. His home village had no high school, so he was sent to stay with his grandmother in another town, who supported him on her social grant.

The high school he attended had no library, computer room, or science laboratory. He played soccer while in high school as an extracurricular activity. When he completed high school, he was stuck at home for three years because he had no guidance from his high school about how to apply for NSFAS funding or how to apply for universities.

When he finally applied to the University of the South he did not get into his first choice of study (Microbiology and Biochemistry), so at this point, he opted for Physics and Applied Mathematics. As an undergraduate with little financial and academic resources, he faced many hardships, but he teamed up with other financially struggling students and together they helped each other succeed academically. His resilience against all odds was to use resources within his reach to better his life and influence his siblings. He notes that he preferred to study Physics more than any other course because the fundamental nature of physics thrills him, and he believed he would come up with an invention that would add to the technological advancement of South Africa and the future of humankind. After his undergraduate programme, he moved to UWC to study a BSc (Honours) in Physics, funded by an NRF bursary.

At the time of the focus group discussions in the ***2nd phase*** of the project**,** he was at the end of his Honours year. **Ukwesinde** noted that he hoped to continue with Material Science at the Master's level in the following year and that he hoped to proceed to study Material Science at the PhD level in 3-year time. However, he lamented his inability to use the computer maximumly and his absence of computational skills.

When he was interviewed in the ***3rd phase*** of the research project, **Ukwesinde** was working at a Science Centre in another province. He had heard about the job vacancy from a friend who lived in the area, and he had been under immense pressure to support his family at the time. So he had to forgo his desire to further his studies in the Master's programme immediately. He opted for a job closer to home because of family responsibilities (he had a partner and a young child). As the first graduate in the family, he also felt he wanted to assist his younger sisters to access university easily, rather than sit around at home after completing high school, as he had done.

Josh obtained his first degree at the University of West Coast in Ghana and an Honours degree from the University of the Western Cape. He is a black male aged 33 years, and grew up in an urban environment, with many public facilities and amenities. He is from a middle-income family and attended a high school resourced with a library, computer room, and science laboratory. He was involved in sports while in high school as an extra-curricular activity. His parent both have a Diploma as their highest academic qualification; he is the first to obtain a university degree in his family.

Josh chose to study Physics at the undergraduate level in Ghana because the programme had funding for students wishing to study physics. He noted that what he valued most about what he had learned through his physics studies was the ability to break down problems and seek solutions. The availability of full funding for postgraduate studies got him to enrol at UWC for Honours.

At the time of the focus group discussions in the ***2nd phase*** of the project, he was in the 2nd-year of his Master's programme at UWC, specialising in Physics Education. **Josh** noted that he hoped to obtain a Master's degree the following year, and in three years, he would be employed as a qualified teacher or lecturer in an institution.

When he was interviewed in the ***3rd phase*** of the research project, Josh was a full-time high school teacher. He had found out about the job via a friend. His aspiration to be a teacher had come to pass. Despite having a full bursary, he did not complete his Master's due to feeling an obligation to support his family back in Ghana.

Albert studied as an undergraduate for a BSc in Physics at UWC. He is a 21-year-old coloured male, who grew up in an urban environment. He is from a middle-income family, and his father's highest academic qualification is a Matric certificate, while his mother had no Matric qualification. The high school he attended had a library and computer room, but no science laboratory. At high school, his extra-curricular activities were sports and socialising with friends, and he portrayed himself in the interviews as an active individual who loved adventure. His mother had insisted that he study after school, and so he had chosen Physics since he had enjoyed physics in high school.

At the time of the focus group discussions in the ***2nd phase*** of the project, he was at the end of his 3rd year. He hoped to do his Honours degree the following year and expressed interest in continuing with his interest in computational physics**.**

However, when he was interviewed in the ***3rd phase*** of the research project, **Albert** had not fulfilled his aspirations from the previous year. He had fallen in with a group of students who did not give time to their studies, and he had not realised that a minimum grade of 60% was needed for entry into Honours. So, he was not admitted to the Honours programme and had instead enrolled for a PGCE degree, to become a teacher. However, he left the programme after only two weeks, after he had concluded that teaching was not for him. He noted that he missed not seeing any of his friends in the Post-Graduate Certificate in Education (PGCE) programme; moreover, the lack of problem-solving in the education-focused programme made it very different from his undergraduate physics training.

This made him abandon his dream of pursuing a career in teaching. He had then gone for interviews for jobs in the fire service, police, and at call centres, all of which he has seen advertised online. He was not successful in getting a job in the fire service or police, but he did find work in a call centre.

Albert was the most privileged of the four participants. He had everything that would have helped him maximize the opportunities the physics programme afforded every student to develop their skills and be the best, but he opted to engage more of his time with his friends and not in his studies. On campus, he had tended to show off his acquisitions that enhanced his indulgences, such as a power bike.

Table 8.1 Summary of graduate participants – family background, aspirations expressed in their final year at UWC and their current employment.

Graduate	**Home**	**Family background and undergraduate degree**	**Level of study during focus group interview (2nd phase of the research project)**	**Aspirations expressed in final year at UWC**	**Current employment and circumstances**
Nzukwen	Rural	Low-income, rural family; parents had little formal education. Chose to study physics because it was his favourite subject in high school Completed his Honours at UWC	MSc (Nuclear Physics) - in 2nd year of study	He aspired to work in the nuclear industry To be involved in outreach with kids	Working at the national nuclear regulatory agency He saw an advert in his area of interest and so quit his MSc to support his family
Ukwesinde	Rural	Low-income, rural family; parents had little formal education. Moved to live with my grandmother to complete high school Chose to study physics because his first choice programme (Microbiology & Biochemistry) was full Completed his Honours at UWC	BSc (Honours)	He aspired to continue with his Master's in Material Science	Working at a Science Centre Due to pressure to support his family, he didn't pursue his MSc studies and took up this job closer to home.

Josh	Urban	A middle-income family. Grew up in Ghana and obtained his BSc degree there. Completed his Honours at UWC	MSc (Physics Education) - in 2nd year of study	He would like to qualify as a teacher or lecturer in a further education institution	Full-time high school teacher He had found out about the job via a friend. Quit his Master's studies to support his family back in Ghana.
Albert	Urban	A middle-income family. Chose to study physics because his mother had insisted he study further, and he had enjoyed physics at high school.	BSc 3rd year	He hoped to do his Honours degree the following year and expressed interest in continuing with his interest in computational physics**.**	Working at a call centre He had not obtained the marks needed for admission to Honours. He had applied for jobs online in the fire service, police, and at call centres.

Prior to the interview, each graduate was given a simple Ranking list of 11 graduate attributes (adapted from Sharma et al., 2008), similar to the version in Chapter seven). In this version, they were asked to rate the extent to which they used each attribute in their current work, the extent to which each attribute had been developed in their undergraduate studies, as well as the extent to which they wished the attributes had been developed more in their undergraduate studies. This data is represented in table 8.2 below.

Table 8.2: Summary of graduate participants' perceptions of the PGAs development

Graduate	Gender (age)	Race	Duration Trained	PGAs wished to have developed more	PGAs that are well developed	PGAs that are used at work
Albert	Male (21 yrs)	Coloured	BSc	Independent research skills, Communication	Problem-solving skills, Laboratory skills, Critical thinking skills, Investigative skills.	Problem-solving skills, Teamwork, Ethical & social awareness Communication skills.
Ukwesinde	Male (24 yrs)	Black	Honours	Communication Computation skills, Ethical and social awareness.	Problem-solving skills, Laboratory skills, Critical thinking skills, Investigative skills, Independent skills, Teamwork.	Problem-solving skills, Teamwork, Communication skills, Laboratory skills, Critical thinking skills,
Josh	Male (33 yrs)	Black	Left in 2nd year of Masters	Independent research skills, Communication Ethical & social awareness.	Problem-solving skills, Laboratory skills, Critical thinking skills, Teamwork, Computation skills, Analytical thinking skills.	Problem-solving skills, Teamwork, Ethical & social awareness, Communication skills, Laboratory skills, Analytical thinking skills.
Nzukwen	Male (32 yrs)	Black	Left in 2nd year of Masters	Ethical awareness, Investigative skills, Teamwork.	Problem-solving skills, Independent research skills, Teamwork, Computation skills, Analytical thinking skills.	Problem-solving skills, Teamwork, Analytical thinking skills, Independent research skills, Computation skills.

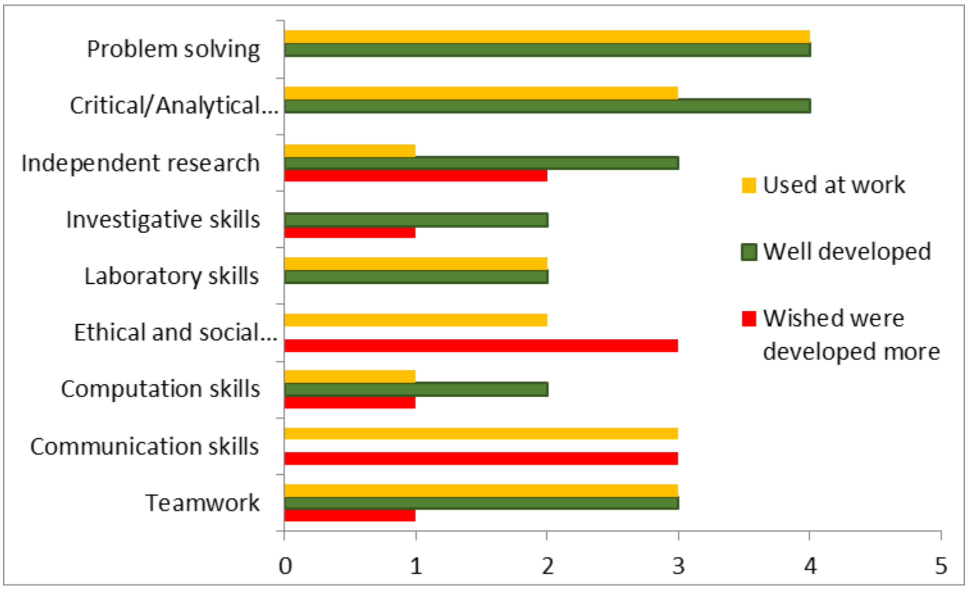

Figure 8.1: Summary of the graduates' views of the attributes they use in their current work

Figure 8.1 provides a summary of the graduates' views of the attributes they use in their current work, those that they perceived to have been well developed, and those that they wished were more developed. From figure 8.1, it is evident that problem-solving, critical/analytical thinking, communication skills and teamwork are most used in the workplaces of these four graduates (and that of these four attributes, three of them (problem-solving, critical/analytical thinking and teamwork) were perceived as well developed; communication skills and ethical and social awareness were the two attributes which graduate most wished had been developed more. Similarly, in Chapter seven, we saw that the students had ranked communication skills and ethical and social awareness as least well-developed. This perception of under-preparedness in communication skills was also flagged in Chapter two in the international studies on physics graduate preparedness: Australian physics graduates rated oral communication as poorly developed (O' Byrne & Mendez, 2012), and UK employers of physics graduates ranked graduates' communication skills as lacking.

8.4 Conversion factors identified in this study that enable or hinder graduate preparedness

In the context of this study, each participant experienced personal, social and environmental situations that impacted their perceptions of preparedness for the workplace and life beyond university. In their interviews, they reflected on how these personal, social and environmental conversion factors either enhanced or limited their freedom and opportunities to convert resources into capabilities and functionings.

While the focus of the interviews was to understand participants' transition to the workplace and life beyond university, the participants' narratives also included accounts of getting to university, completing university studies, and entering the workplace. Therefore, the conversion factors identified in this chapter span the participants' home circumstances as well as university-related concerns. These conversion factors – personal, social and environmental – are discussed below.

8.4.1 Personal conversion factors

Personal conversion factors comprise individual (personal) factors that influence the development of capabilities and realization of valued outcomes (functionings). These are the individual's unique attributes that lead to choices and decisions and may determine how individuals see and respond to social and environmental structures. The personal conversion factors are the individual's attributes that play a role in how the resources (in this case, those on offer in undergraduate physics studies) are differently converted into students' PGA capabilities. The following personal conversion factors were identified in this study: motivation and aspiration; confidence in communication, and computer literacy and computational skills.

8.4.1.1 Motivation and aspiration

The data in this section indicates that motivation (or the lack thereof) can act as both an enabling and a hindering conversion factor. All four participants had initially chosen to study physics (see section 8.3). For **Josh**, his interest in the physical world and the skills inherent in studying physics were too compelling to let go of. The knowledge that many concepts in physics find application in many fields of specialization and everyday life made physics his preferred choice. **Josh** remarked:

> *"I think, what kept me …(silence)… was that it was very interesting, and it equips one with problem-solving skills and the knowledge of the physical world. The concepts one study in physics in the classroom helps one to break down a problem so that one can find solutions to them. Even outside the field of physics, these concepts really help".*

Nzukwen also liked what he was studying in High School: his two best subjects were Maths and Physics:

"It was at High School that I started doing Mathematics and Physics and I started loving them …

For **Ukwesinde**, he had not originally intended to take up physics for his undergraduate studies. He had stayed at home for three years after completing high school (due to a lack of guidance on how to apply for higher education funding) and then he did not make the list to study the course of his choice (Microbiology and Biochemistry). So at this point, he opted for Physics:

"…actually, at University of the South, I didn't apply to do Applied Mathematics and Physics. I applied to do Microbiology and Biochemistry. Only to find that there was no space there for me, they had taken the required number of students. They told me that if I go to Science and apply for Applied Mathematics and Physics, there is space still available there. Then, I did go there because there was space".

His decision to take up physics was its availability, driven by his resolve not to stay home again for another year without being enrolled in a university programme. This drive motivated him to come up with ways of navigating the university system for the minimum resources that would help him perform well academically:

"Imagine you are in the University, you don't have books and you have to borrow books from other learners. You don't have even laptops to download some books or to do assignments or anything that would help you to further your studies. So you have to keep borrowing books each and every time. You can imagine how difficult it is, you see. [But]… we survived it."

Here, motivation is seen as an enabling conversion factor which helped **Ukwesinde** to complete his undergraduate studies, despite limited resources (no books or laptop). In their study of graduate employability in sub-Saharan Africa, McCowan et al. (2016) found that 'attitude and personal motivation (to work hard; to take advantage of university opportunities)' (p. 23) were found to be important personal conversion factors for enhancing graduate success in entering the workplace. Walker et al. (2022), similarly, found that the low-income students in their study displayed significant aspiration and determination in overcoming the challenges they faced.

In contrast to the other three graduates, **Albert**'s story illustrates that personal motivation (or the lack thereof) can act as a hindering conversion factor. His mother had insisted that he study further after school, and so he went on to study physics:

> *"but I enjoyed Physics in high school and my mum said I have to study and that it doesn't matter what I study as I must still study. Then I decided to study Physics"*

He decided to study physics, though supported by his mother. However, in the case of **Albert**, it is how he handles that parental support that matters. **Albert** is from a middle-income family and his parents made sure he had the necessary support to be able to convert his exposure, available resources and guidance from his parents into aspirations for higher education and to study physics. However, during his studies, he was not focused. He took this parental support for granted: he allowed other influences to take his attention from his studies and dedicated his time to having fun.

Albert's lack of personal motivation resulted in him not obtaining the 60% minimum required for admission to the Honours programme in Physics. In his reflections, **Albert** links his lack of motivation to the lack of career guidance offered as an undergraduate (for more details, see the section 8.4.2.5 below on 'lack of career guidance'). He felt that clearer career information would have led him to be more motivated towards a 'clear goal', and that clearer expectations should be set by the Department for students (for example, the entry requirements for Honours):

> *'Yea, basically just to let them [students] know what it is they can do and what outcomes will be or can be. But, but I think it is a very big responsibility on, on young people … if there is a wrong choice. So, it will end up taking one longer to achieve one's goal, if one is not prepared'.*

Albert's lack of personal motivation and not being sure of what he genuinely wanted to do with his undergraduate degree came to light when he registered for teacher training and opted out of the programme after two weeks. He then ended up working at a call centre. **Albert**'s lack of motivation to work hard and aspire to be successful contributed immensely to his inability to convert his opportunities into functionings that would have enhanced his well-being.

In summary, the data illustrates how motivation and aspiration can function both as enabling and hindering conversion factors. In her study on student access, Wilson-Strydom (2015a) notes how motivation can be conceptualised both as a personal conversion factor and as a capability to be developed during students' undergraduate studies. The implication of Wilson-Strydom's position is to consider how students' motivation and aspirations might be explicitly addressed in undergraduate studies, rather than being viewed entirely as the fault of individual students easily labelled as ‘un-motivated’ (as in the case of **Albert**). This is discussed further in Chapter nine.

8.4.1.2 Confidence in oral communication

The interview data with final-year students, discussed in Chapter seven, revealed that many participants in this study feel that their oral communication and presentation skills need to be developed further. Similarly, the interviews with recent graduates revealed that confidence in communication skills could be an enabling or hindering factor in their new workplace contexts. It is interesting to note that the graduates chose to interpret communication skills in the workplace as *oral presentation* skills rather than written communication skills. **Nzukwen** felt that his physics training had equipped him with the necessary communication skills (which include language skills) amongst other skills needed in his job at a Nuclear Regulatory Agency.

Similarly, **Ukwesinde** mentioned the need for oral and communication skills when asked what skills he was using in his job at the Science Centre. He noted how the communication skills he felt he had developed at UWC were handy for all the experiment demonstrations and career guidance sessions he presented to an audience at the Science Centre:

> *‘I use …. skills that help one to stand before people and to present and to talk to people in front to explain or teach something - communication skills. … They help me a lot in making me stand to explain or express something. We are used to presenting at UWC, and it help me not to be that shy as I used to be’.*
>
> *I am not shy to stand before people to do this. Unlike my other colleagues. For me it is not difficult, you see due to my exposure and communication skills from UWC.*

Ukwesinde notes here how developing communication skills developed his confidence to overcome his shyness. As other studies (Wilson-Strydom, 2015a; Walker et al., 2022) have noted, a lack of confidence in communicating can result in hesitancy in speaking up in class or in engaging with peers.

Josh felt that the physics department could do more to ensure the development of presentation skills:

> *… presentation skills should be enhanced, and I think it shouldn't always be a …. I think 90% of the work is routine stuff [theory]. The oral presentations were not that much.*

Albert felt that he wasn't adequately prepared for oral communication in his undergraduate studies and that more could have been done to help in that regard. His work in a call centre revolves around listening and communicating with clients orally, and talking to diverse people across cultures and languages:

> *"I work on the computer, mostly looking at the screen to help clients and looking on the computer for policies and investments, life covers, and all the rest. It also involves talking with the guys to answer questions. We also give the guys on the phone listening ears that is the basics…."*

He noted that the small group talks and presentations had helped him learn to speak to an audience:

> *"… the presentations, through like speaking to other students in class, helped me learn to speak to small groups and audiences".*

However, he noted that more presentations in class would have developed students' confidence in communication skills. He compared himself to another graduate with whom he is working and noted that this graduate had better communication skills:

> *"There was other guy that did not study physics, but he was a better consultant than I was… His personal skills - his talking ability is strong. He is good at talking to clients. He has got the power of speech".*

Although he was required to do small group talks and presentations during his undergraduate studies, **Albert** felt that more presentations in class would have been helpful. For **Albert**, practice and more presentations and volunteering to speak in class could have helped.

In summary, the data illustrates how confidence in communicating functioned as an enabling or hindering factor in the graduates' undergraduate studies and their new workplace contexts.

8.4.1.3 Computational/ICT skills

Computational skills were identified in Chapter seven as a conversion factor that students perceived to hinder their graduate preparedness. Similarly, the graduate students interviewed highlighted the need for more of a focus on developing computer literacy and computational skills. **Ukwesinde** describes how in his undergraduate studies (completed not at UWC), it was assumed that students arrived at university computer literate. However, this was not the case for many students:

> *'Many of us come to the university with no knowledge about how to type or use the computer. It becomes a nightmare for some of us when demand is put on submitting lab works or assignments in a typed format, especially in the second year of study & this demand is made compulsory without simple modules such as 'Basic Computing' or 'Introduction to Computer for Beginners' for students & there are no free computer stations for students to go in and do their work anytime.*

Here, lack of computer skills functioned as a conversion factor hindering the ability of students to fully benefit from the practical laboratory sessions, as they were distracted by the 'nightmare' of submitting laboratory reports without the requisite skills to type and format the written report on a computer. **Ukesinde** suggests that an introductory course should have been offered for all first-year science students.

The challenges he faced being expected to type and submit practical laboratory assignments, as well as the lack of a computer, did not stop him from developing this functioning during his undergraduate studies. At the Honours level, he encountered a similar assumption that all students had some computational experience, yet Honours students (like himself) arrive from other universities not exposed to computational physics or computer programming. Despite this, during his Honours year, he mastered computational skills, including MATLab, which he uses currently in his workplace:

> *'I was equipped with many skills [for the workplace], … We did the MAT-Lab programming skills at UWC just within the Honours year. Before then, I knew nothing about programming nor software to help with such'.*

For **Ukwesinde**, the lack of programming skills was a major concern, but learning wherever and whenever the opportunity surfaces are linked to agency and confidence that education has given him the opportunities for acquiring the basic skills and he needs to build on what he has acquired in his training.

In summary, three personal conversion factors were identified in the interviews with graduates regarding their perceptions of graduate preparedness during their studies and beyond into the workplace and life post-university: these were *motivation and aspiration*; *confidence in communication; and computer literacy and computational skills.* The next section discusses the social conversion factors perceived to influence graduate preparedness.

8.4.2 Social conversion factors

The social conversion factors involve the interpersonal interactions, social structures and institutional arrangements that either enable or hinder the conversion of available opportunities and resources to capabilities and functionings. In this section, the social conversion factors identified include family and community resources, family support for education, and societal norms and family needs. Other social (university) conversion factors identified include career guidance, peer influence and an explicit focus (or lack) on graduate skills and attributes in the curriculum.

In summary, the section below discusses how these social conversion factors shape each graduate with the possibilities of enabling the development of the physics graduate attributes and becoming the kind of physics graduate they desire or value to be.

8.4.2.1 Lack of family/community resources

Lack of family/community resources emerged strongly in the data as an obstacle to students' educational progression. Students from low-income family backgrounds and with little resources are enrolled in universities which puts them at a disadvantage even before they begin their graduate journey. This disadvantage in terms of resources is captured as a material conversion factor in the Miratho project (Walker et al., 2022). The obstacles **Ukwesinde** faced are related to his parents' income status, which put him at a disadvantage:

> *"Because sometimes my parents could not afford money to give me".*

As **Ukwesinde** recounted earlier in the section on 'Motivation and aspiration', he found it difficult to cope at university without money for books or a laptop – essential resources to further his studies:

> *'Imagine you are in the university, you don't have books and you have to borrow books from other learners. You don't have even laptops to download*

some books or to do assignments or anything that would help you to further your studies".

In some cases, this is an extension of the fact that students are from rural villages with few basic amenities. All the above contributed to the experiences and the difficulties they faced navigating through high school and university education. Their families could not afford to provide the resources needed to enhance their studies; lacking in resources, but being motivated to succeed, they navigated through these challenges (McCowan et al., 2016; Walker et al., 2022).

This situation that **Ukwesinde** and **Nzukwen** found themselves in contributed to their experiences and the difficulties they faced navigating through high school and university education. Their parents could not afford to provide the resources needed to facilitate their studies. Instead of being able to focus fully on their studies, these participants were compelled to utilise their precious study time to think of how they would survive in high school and university.

Besides material resources, students' home and community environments also did not provide the sorts of social and cultural capital often associated with success in school and higher education (Reay et al., 2001; Ball, 2004). However, despite the lack of family/community resources, these participants being highly motivated and aspiring to succeed, navigated through these challenges. They displayed what Walker et al. (2022), drawing on Yosso (2005), refer to as 'navigational capital'; skills and experience of having navigated through challenging and unsupportive environments.

8.4.2.2 Family support for education

Despite families often not being able to provide much financially or materially, *family support for education* was an enabling conversion factor in supporting students' pathway towards becoming a graduate. All four graduates interviewed were first-generation students in higher education, and did not come with social capital or from well-resourced schools (Calitz, 2015) Although some of their families could not provide financial support for material resources (for example, tuition fees, textbooks, meals, transport, and accommodation), having a supportive family that encourages the individual to learn, even with the little that they could provide, is an advantage that helped them stay focused on their studies.

As noted earlier in the section ‘Motivation and aspiration’, **Albert** had a mother’s encouragement and support, which led him to be a physics graduate today; for him, it was what he did well in at high school, but also the mother’s push,

> *“So, when it came to the time of Matric, we did a project on career and stuff, then I did not take it seriously still. I did not know what I wanted to be, but I enjoyed Physics in High School and my mum said I have to study and that it doesn’t matter what I study as I must still study”.*

For **Ukwesinde**, the support came from the little his parents and grandmother gave as support to be in the four walls of a school; he relates that,

> *“In fact, when I was, I was in primary school, I was living with my parents and both of them were unemployed you see. So, when I was in high school, I went to live with my grandmother who was earning little money from what we call a grant”.*

For **Ukwesinde**, the determination to see ways of overcoming financial need and to ‘maximize the minimum’ was key to staying on to study and to learn against all odds; the absence of financial, material, and academic resources was a common theme in his daily life at the university. Against this backdrop, he was able to borrow books and other educational devices (as real opportunities) to use available resources to complete assignments, thereby converting capabilities into functionings or valued outcomes (learning how to type and present his work) and in the long run, knowing how to use the computer. This did not stop his freedom to take initiative, since the capability approach embraces the stance that people must have the freedom to play an active role in the process of their education instead of passively receiving interventions (Sen, 1999).

Being the first in the family to go to university in a family is a huge responsibility for many graduates as it gives them honour, but with additional responsibility. For **Nzukwen**, though his parents had little formal education - *“my parents are not educated in the modern sense of it”* – his family is very supportive of his studies. Despite **Nzukwen’s** difficulties because of his background and the socioeconomic status of his parents, that was compensated for by the support the family extends to him.

> *'I am from a very supportive family …, they have been there and supporting me a lot, even though I continue studying on and on for many years' … 'Yes, I am the first to complete a degree and a Honours programme in my family'.*

Having a supportive family is an advantage that helped him stay focused on his studies and made him the first graduate in the family.

Ukwesinde, his situation was further complicated by being the first in his family in higher education and having many younger brothers and sisters. This unique position in the family comes with responsibility for the family and societal pressure. He stated that,

> *"My studies was very difficult at the University of the South you see. To be honest, I was the first child in my family to go to the university, …".*

For **Ukwesinde** and **Nzukwen** to forge ahead with their studies, despite their environmental situations, family background, and status as 1st generation graduates from their families, shows that having a drive, desire, and focus for knowledge and learning; they were not reliant on where they come from or on parents with social capital, or from well-resourced schools (Calitz, 2015).

In summary, although graduate families were not able to provide much financially or materially, *family support for education* was an enabling conversion factor in supporting students' pathway towards becoming a graduate. This is in line with other research showing how family support for higher education can be important for educational success (Case et al., 2018).

8.4.2.3 Societal norms and family needs

Societal expectations and norms and community pressure play a significant role in students' accounts of their decisions and choices. This is particularly the case for first-generation students. In the context of societal norms and the power of community pressure, it is the worldview of that society and the cultural belief that society exerts, that influences an individual's efforts and achievement. Since these participants belong to families and communities, these graduates may give in to societal and family pressures rather than live the dream they aspire to. Even when an individual is educated at a university, they are still the product of their community and society. **Nzukwen** notes the pressure he feels from the community to get a job, rather than pursue post-graduate studies:

> *'If I am to compare myself with those who have got a degree; with physics, one has to study for many years. There is always that thing that you will see others start work early, and it seems like they are upgraded, while you as a physicist are not. That is why if you are studying physics there is always that temptation to want to go and look for work and not to continue with the master's or PhD'.*

Here, the pressure to abandon studies and to seek work is increasingly triggered by "peer comparison". When peers of the same age seem to have upgraded due to their work status, physics graduates are also tempted to get a job and lead life. Within the family and community structure, continuing to study may trigger social exclusion, where social inclusion or recognition in the community is based on economic attachment linked to a job or income.

For **Josh**, the pressure is to be able to support the family back home in Ghana. He feels that his schooling is only meaningful if he can help his parents and siblings; he notes how fulfilling it is to be able to assist his family:

> *'Taking us back to where I come from, you know it is quite fulfilling to us when someone need something and you are approached, because you have a job, you can also help and you are still not a burden to your parent but rather trying to better their lives. Emm, just being in the situation whereby you can be called upon and you can help just because you have a job is very fulfilling to me.*

While **Ukwesinde** is an example of many graduates caught in family pressure to get a job and support their grandmother, parent, siblings, and their offspring; he says:

> *'Yes, actually, I will continue with my studies. But the reason why I stopped is because I am coming from a difficult background and I have a son. For me, it was difficult, but not as difficult as for others because my son's mother (my girlfriend) works. My girlfriend teaches in a school. She is a teacher, so it is a bit… but not that difficult. But the thing is back at home, you see; they are still struggling and I need to support my brothers, sisters and mother there, you see. That is why I did not continue with my Master's studies… That is because if you are from a poor family you see, and you are not*

> *working, they will de-motivate you and say "you are going to continue studying until you die. Why don't you try and find a job and earn money?", you see. They will go ahead to make examples of someone in the community who studied to Master's degree and did not work nor have a job, had bad luck and the person died. They will make jest of someone with this situation'.*

The above quote spells out the responsibility put on graduates by family and communities. They see university education as a door out of poverty and for a good life, not only for the individual but also for his family. The graduates feel the pressure of acquiring and demonstrating material resources as a reference point for success in society. These social factors in the form of job pressure and the need for family support constitute a significant obstacle to participants' choice to further their postgraduate studies or complete the programme they are on. Many graduate students are eager to complete the programme they are on to get a job to earn money; many of them drop out and go look for work to support their families to be seen to be a good reference in the community.

As first-generation students, graduates describe how they experienced a huge expectation to provide for their families while studying. They also describe the social pressure on a graduate to demonstrate that they can earn a living, rather than continuing with further studies. In this way, family expectations, coupled with comparing themselves to high school peers who are already in the workplace, can lead to pressure to abandon their postgraduate studies and seek employment. These social factors in the form of job pressure and the need for family support constitute a significant obstacle to participants' choice to further their postgraduate studies or complete the programme they are on.

8.4.2.4 Peer group influence

This category refers to the influence of peers in the environment in which the student finds themselves, for example on campus, in the residence or home environment. Students' ease of interacting and seeking to belong to a group as they come into a 'new peer world' at university affects their engagement with learning positively and sometimes negatively. From the data, peer group influence is seen to function both as an enabling and a hindering conversion factor, influencing students' choices and work attitudes and eventually their achievements at the end of their studies. Three of the graduates interviewed described positive peer influence. **Ukwesinde** described how, during his undergraduate years, he worked with four of his friends to overcome the challenge of feeding himself adequately due to lack of money. Although they all came from low-income family backgrounds and their parents could not afford to give them enough funds for their survival at university, they were resourceful:

> *'Yes, we survived it [lack of family funding for university]. Do you know what me and friends did? Me and my friends, we were five of us. What we did, we managed to say each of us should contribute R200 (Two hundred rand) each of us, that money made One thousand rand. Then we go buy groceries and we cook together, that decision helped us a lot. That was what we were doing. We did that from first year till final year. We made an arrangement for taking turns to cook too. If I cook today, tomorrow some else will cook'.*

This effort by the five friends helped them work as a team and focus on their studies, as they took turns cooking and sorting out food matters. Here they display what Walker et al (2022) refer to as 'ubuntu capability', a communal and relational way of being, characterized in this vignette by solidarity and mutual generosity.

Josh's peer experience was also a positive force that pushed the group to work hard and support each other, with a view of success as teamwork:

> *'If you tell someone that you study physics, you tend to be seen in a different light [seen as being smart]. So, to prove this [that I am smart] ... so, I think the edge to prove people wrong em...that I was capable of doing physics ... I am seen doing physics and the friends around us, with the urge to make it in whatever field we find ourselves. I think even if it wasn't that, we were very determined to hold on and to study hard in our various endeavours and trying to push friends to study and to take part in discussions; in doing that, we helped to cement what we were studying, especially concepts. Those were the things [pushing each other; studying together] that really helped'.*

Josh and his friends urged themselves on in their studies, and they were determined to go through with whatever they were studying by learning concepts for understanding and encouraging each other to take part in discussions on what they were learning. In this example, too, we see evidence of the 'ubuntu capability' (Walker et al., 2022) where each student's academic success is viewed as connected with the success of others in the study group.

Albert's experience was quite different from **Ukwesinde's** and **Josh's**. The peer group influence gave him a tilt towards the opposite of what **Ukwesinde** and **Josh** had with their peer groups, and it affected his capacity to utilize the opportunities available to develop many of the physics graduate attributes. **Albert** had a peer group that had other interests. They were all from comfortable family backgrounds and socialized together on the weekends. Interestingly, **Albert** made a point in the interview to note that his peer group friends were black, seemingly to signal that diversity is something to be proud of. He described his peer group as follows:

> *'Most of them [my friends], yea, the friends that I have, the ones that I was close with were all black. They were naturally smart, so they didn't need to study to pass. But that was why their marks was also average'.*

He describes them as 'naturally smart' students who felt that they didn't need to study to pass their courses (this perhaps reflected that they felt they came better prepared for university than some other students). However, he also acknowledges that their approach to their studies led to them attaining average marks. He went on to describe their approach to studying:

> *'Yea so, the friends that I had were negative and had negative influences. They didn't study (silence for few minutes). So, they made me not to study. But when we realized, Oh! (exclaims) our CAM [continuous assessment mark]is low, then we do those assignments and when it reached a point like that then, we get high marks'.*

He described how these peer groups had influenced his study and positioned him for low marks. Even though he was aware of this downward spiral in his academic performance, this did not give him a wake-up call to switch friends.

His peers' attitudes towards studies showed in their performance and achievement. These peers did not hand in assignments and did not study regularly until there was a deadline for an exam. **Albert** acknowledged that there was one student in the class (not part of his peer group) who was passionate and wanted to study more:

> *'But there was this one guy; …he was passionate. He wanted more, he was always studying and studying on. So, he was one the only influence as the one who help us with our questions. He helped us with solving stuff, most often we go to him'.*

This was the colleague they always went to for academic problems. 'This one guy' would have been a good influence on them, but they left him out of their circle and did not change their attitude. The choice for **Albert** to stick to his academically lazy peers was deliberate. He showed a lack of agency in taking up opportunities on offer because of peer group influence. This affected his capacity to convert the opportunities and resources on offer during his undergraduate studies into capabilities and functionings.

8.4.2.5 Lack of career guidance

As was the case in Chapter seven, the graduate participants in this chapter also highlighted the lack of career guidance as influencing their pathways into university and the workplace.

Ukwesinde's rural environment provided little career information or guidance for high school students, and he paid the price for lack of career guidance before gaining entrance into the university:

> *'After finishing my High School, I spent three years unemployed and I didn't have the information that when you want to go to the University, you must apply for NSFAS, apply for space in any institution you see. So I was offered bursary to do clinical psychology at the University of Pretoria, only to discover that I did not apply to University of Pretoria. In that case, it did not work for me'.*

It is unfortunate for a learner, such as **Ukwesinde**, to spend three years at home due to not knowing what steps to take to seek further education. Although **Albert** attended an urban high school, he also experienced a lack of career information at high school:

> *'... in High School ... my marks was always average like 60% like that. I never know what I wanted to be; like career or anything like that'...*

He went on to regret that career guidance had been missing in his undergraduate studies:

> *'Definitely information on careers and maybe not careers only, but jobs specifically and their requirements, that was missing.*

For him, the consequence of the lack of career guidance is too enormous to overlook. He would have a valued discussion on careers or at least a notice board for information on careers and jobs and other general information that are career linked. **Albert** links the lack of career information to his lack of self-motivation or clear career goals:

> *'If these career information were there, I wouldn't have been doing what I am doing now. I would have been in a different job or still studying. I would have had a clear goal'.*

Albert attributes his lack of self-motivation during his studies to his lack of a career goal.

Josh had similar perceptions to Albert: he felt that lecturers focused too exclusively on the physics curriculum:

> *'I think the lecturers are only interested only in finishing their scope of work, the syllabus and you passing the exams. I am not sure they take any aspect of career guidance as their responsibility'.*

He feels that lecturers need to take some time to put out information about careers and emerging trends in the workplace and other employment-related information. Interestingly, none of the graduates interviewed had found their jobs through career information or advice received via the Department or university – instead, they had found the information online or via friends.

While the *lack of career guidance* may seem to be synonymous with rural institutions, this study found that urban institutions also need to step up the efforts directed at career guidance. The analysis of the data showed that the rural environment provided little or no career information or guidance across all levels. Some participants paid the price for this lack of career information or guidance before gaining entrance into the university.

International studies show that the issue of lack of career guidance cut across diverse national settings, especially among the black and coloured communities (Woolf & Arion, 2016). The common grounds are that educational systems at various levels are not doing enough to help learners and students recognize their strengths in school subjects, and to guide them appropriately (Mendez *et al.*, 2008; Porter, 2019).

8.4.2.6 Explicit focus on wider graduate attributes and skills in the curriculum

The development of graduate attributes and skills emerged from the data as an issue that graduates felt needed closer attention. The graduates interviewed felt prepared in some aspects for the workplace and life beyond university. For example, **Nzukwen** noted that he felt prepared for his job in many respects:

> *The university education armed me with research skills and how to do research. This has helped me a lot in my work and in the pursuit of more knowledge in physics. Also, physics equips you with analytical skills and problem-solving skills and communication skills and ICT skills just to mention a few".*

However, **Nzukwen** and the other graduates noted that the lack of development of some skills had led them to feel underprepared. They felt that there was perhaps too much focus on the physics content in the undergraduate curriculum, and not enough on graduate attributes or skills. **Josh** suggested more emphasis on the link between 'the theory and the practical', more focus on presentation skills and technology:

> *'So, basically, I think there should be a very strong link between the theory and the practical. That is No.1 on my list. Then, No.2, the presentation skills should be enhanced and I think it shouldn't always be a…. I think 90% of the work is … is routine stuff. The oral presentation wasn't that much. Ehm…, so I think that should be something, yea they can look at; as well as technology is advancing by the day'.*

Josh's perception is that a lot can be done to connect theory with practice, enabling students to do more independent research, organize data/information, present data/information in different forms, and communicate to audiences.

The need for more focus on **confidence in communication** and **computational skills** has already been discussed earlier in section 8.4.1 on *Personal conversion factors*. The four graduates interviewed, in reflection on their experience in the workplace, identify other skills that would have wanted to have been developed during their studies (see Figure 8.1).

Nzukwen identifies the importance of *teamwork* in his career, and wants all physics training programs to involve the development of "*Teamwork",*

> *'One also need to know how to work with people. I remember one of the course I attended while on the job is emotional intelligence. It help me understand that working with people is important, such that one may be good*

at their physics and one does not know how to work as a team or in a team, one will not be productive and it will affect one's work adversely. Looking back, teamwork will be the skill that was left out. It was only in first year that the focus was on us to work as a team by grouping us together in groups of 3 or 4 (students) to work together. After that, nothing more'.

Here, he notes that at his rural undergraduate university, teamwork was developed only at the first-year level and he suggests that teamwork ought to be extended to higher levels of studies. He contrasts that with his experience of UWC, where he sees teamwork as being fostered at all levels:

…since I came to UWC, I see how the undergraduate programme is run from the first year through to the third year – the students work as a team.

His suggestion is for lecturers and academics to do more in this regard. Teamwork should be encouraged to solve problems in class, as it may further develop students' and graduates' individual and group communication skills. **Nzukwen**'s comments reflect the modern workplace where many work problems are handled as a team or group of colleagues.

Physics knowledge is not the only element in the training of physics graduates, but many students focus only on physics knowledge, at the expense of the processes skills and competencies that are embedded in the learning. **Nzukwen** was one of such graduates who got to the workplace only to realize that it is not just the physics knowledge that is important nor the problem-solving skills, but how to work with colleagues and other people:

'When I was studying, I was only focused on studying physics, and when I got to the work place I realized that no, it is not only the physics that you know or the problem that you are solving. One also need to know how to work with people… It help me understand that working with people is important, such that one may be good at his/her physics and one does not know how to work as a team or in a team, one will not be productive and it will affect one's work adversely'.

The advantage of working well with colleagues and others is premised on the fact that many modern workplace issues are interdisciplinary or have implications for another department in the same workplace. Working with others to achieve the desired result becomes teamwork.

In summary, although the graduates interviewed felt well-prepared in some respects, overall they felt that there was too much of a focus on the physics content in the undergraduate curriculum: they would have liked a stronger link 'between the theory and the practical' (**Josh**). It was only when entering the workplace that some graduates realised that, 'it is not only the physics that you know' that matters in the workplace (**Nzukwen**), but also skills such as teamwork. In their study of conversion factors influencing employability, Walker and Fongwa (2017) identify the 'misalignment of theory and practice' as a social-university conversion factor that students perceive as influencing their employability prospects. The students in their study rated skills such as teamwork, written communication, problem-solving, ICT skills and time management as poorly developed at university. McCowan et al. (2016) similarly note the need for greater attention to the 'theory/practice balance' (p.99) in higher education.

8.4.3 Environmental conversion factors

In the capability approach, factors relating to geographical location or climate are examples of environmental conversion factors. Every individual has a geographical location or an area that reflects the individual's identity. Two environmental conversion factors (those factors linked to the geographical location that enabled or hindered the conversion of opportunities to functionings) emerged from the data, both related to the issue of rurality – the rural/urban university location, and the lack of resources in the rural home community.

8.4.3.1 Rural and urban Higher Education Institution: Exposure difference

Two of the graduates, **Ukwesinde** and **Nzukwen,** attended rural higher education institutions before coming to UWC. **Ukwesinde** coined the term 'exposure difference' to compare UWC with his former university: at his rural university they had had no educational visits to industries or research centres, and no career guidance or information directed at physics students:

> *'At UWC, it was better as we were always taken to iThemba labs and show us how things work or how things are done practically and for us to meet people on the job. We meet physics professionals in material science, nuclear physics and instrumentation. How they work was explained to us, and the various applications of their research. One of the reasons of the exposure difference and how it impact on me is the location of the two universities; University of the Western Cape and the University of the South. University of the South is in a very rural area. There was no career*

> *information or talks. There was no excursion visits to companies or research centres, you see. That is part of what was lacking seriously in my undergraduate training'.*

For **Josh** and **Albert**, coming from urban areas enhanced their access to information and options. Growing up in large cities accorded them the luxury of the enrollment application and other resources and infrastructure that enhance learning. This difference in career exposure and access to career information is also noted in the study of Walker *et al.*, (2022) who found that there are disparities in exposure between graduates from rural universities and those from urban universities.

8.4.3.2 Rural home community: Lack of resources

The second environmental conversion factor concerned *the lack of resources in the rural home community*. While the rural environment has positive aspects for community life, the two graduates from rural areas described coming from remote areas with few facilities and amenities. While **Albert** and **Josh** are from urban communities, **Ukwesinde** and **Nzukwen** are from rural communities. **Ukwesinde** describes the lack of high school in his rural area and the challenges to access high school education:

> *'Yea, I did my primary school in a place called Mpune… it is a very big rural area, as I told you before that I am staying near the border place of Mozambique and Swaziland which is a deep-deep rural area of South Africa. So, after I completed my primary school because where I was staying there was no secondary school, I have to go and stay in another place with my grandmother where I completed my high school'.*

The rural environment **Ukwesinde** grew up in was so rural that it has only a primary school. After completing his primary education, he had to leave for another village to complete his secondary education. His use of the phrase "huge rural area" does not mean the size of the village but the extent of its ruralness, without many amenities and facilities. As noted earlier in the 'career guidance' section, **Ukwesinde**'s rural environment provided little career information or guidance for high school students, and he spent three years after school at home, unsure about what steps to take to seek further education.

Nzukwen has a similar rural primary and secondary school arrangement as **Ukwesinde**, but, unlike **Ukwesinde** (who moved to live with his grandmother), **Nzukwen** did not have to move from one village to another to continue and complete his secondary education. This rural environment affects the type of information and engagement that come their way, with implications on career information and guidance, and enrollment application for further education.

These challenges were only mitigated by the determination of the participants to make academic progress at their own pace, with the bits of information they acquired that led them to study physics at university. The rural environment has a lot of positives for community life, but as noted in the Miratho project, 'Rural… students spoke of inadequate infrastructure and ICT arrangements' (Walker et al., 2022, p 99)

While this category has some similarities to the social conversion factor 'Lack of family/community resources' discussed previously, what makes it distinctive is the lack of key resources specific to *rural* areas. Walker et al. (2022), similarly, note that while the home community can serve as a social conversion factor, in the case of rural students they characterise it as an environmental conversion factor 'to capture the specificity of rural development.' (p. 83).

Only few learners from rural communities make the required grades to proceed to university education due to their situatedness, as stated by **Nzukwen**;

> *'Actually, the school I went to used to produce average students. They always end up with an S (senior certificate) or an M (matric exemption) due to the village environment code. We learners that want to be different, we fight for an M pass. At my grade 12, we were about 120 learners, and learners that get the M pass are less than 20. That means that many of the learners passed but cannot get an offer to go to the university'.*

Here, **Nzukwen** emphasizes the lack of aspiration among learners in this rural context towards further education. The quote above reiterates the need to help guide students at all levels and inspire them to aspire to become something they genuinely want to be, so they can aim to be creative and achieve academic excellence. However, as noted earlier in the section on social conversion factors, rural students have limited exposure to career guidance or access to libraries/internet where they might access such career information.

In summary, from the participants' narratives, we can discern environmental conversion factors that hindered the conversion of opportunities and resources into functionings. These included urban/rural university exposure differences and the resources on offer in the rural home community. Nevertheless, we also see in the participants' stories that determination to move out of rural circumstances motivates some young people (this is also evident in Walker et al., 2022). The social and economic challenges, lack of career information, and fact that going to university was uncommon in the community only strengthened the resolve of some participants to make academic progress at their own pace and in their own way, despite information and career guidance not being provided for them.

Table 8.2: Summary of Conversion Factors.

Conversion Factor	Enabling	Hindering
Personal	Motivation and aspiration Confidence in oral communication	Lack of motivation and aspiration Inadequate confidence in oral communication Lack of computation/ICT skills
Social (University) & social (family)	Family support for education Explicit development of wider skills Peer group Influence	Lack of family/community resources Societal norm and family needs (Lack of) Explicit development of wider skills Adverse peer group influence Lack of career guidance
Environmental	Rural-urban Higher Education Institution exposure difference.	Rural home community - lack of resources,

Table 8.2 above summarizes the interplay of the conversion factors and the development of the physics graduate attributes in regard to the enhancement of the development of these PGAs (positive) or limiting the development of the PGAs (negative).

8.5 Graduates' reflections on preparedness for the workplace and life beyond university

This section explores graduates' reflections on their preparedness for the workplace and life beyond university. They reflect on how they had benefitted from their university studies and describe the specific skills and attributes that they found helpful in their transition to the workplace. They also describe the wider outcomes of higher education that they had experienced. These descriptions of their valued capabilities and functionings reflect what they valued most about their studies. In many cases, students describe how higher education has had a 'life-changing' effect on their lives. Some have changed their physical environment (from rural villages to urban universities) and gained knowledge that influences all aspects of their lives. As Walker et al. (2022) note in their study, referring to McLean et al (2019), 'knowledge acquired at university can change how students see the world and their position in it: this is transformative education' (Walker et al., 2022, p.93). In the following two sections, the developmental and transformative aspects of higher education are discussed. The discussion is framed by Dreze and Sen's capability framework on education, in which they consider how education can be intrinsically, instrumentally and socially valuable for individuals and society (Dreze and Sen 1995).

8.5.1 Knowledge, skills, and attributes

As noted in Chapter two, it is not merely the physical knowledge that matters for graduates, but the transferable skills (generic skills and citizens skills) – also referred to as physics graduate attributes – that are essential also for the transition to the workplace (see (IOP), EPS, AIP and APS physics degree statements - section 5.2, table 5.1). The development of these graduate attributes and skills enabled some graduates to feel prepared in a range of aspects of the workplace and life beyond university. Here we see education fulfilling what Dreze and Sen term an *instrumental personal role,* enabling graduates to access the workplace and benefit from economic opportunities on offer. In reflecting on their transition to work, the graduates mentioned the value and usefulness of particular skills they had acquired. For example, **Nzukwen** noted that his physics studies had equipped him with the necessary skills for his job at the nuclear regulatory agency:

> *… physics equips you with analytical skills and problem-solving skills and communication skills and ICT skills just to mention a few".*

Ukwesinde expressed how *his problem-solving skills* helped in his confidence in working at the Science Centre:

> *Even in problem-solving, if you did mathematics with your physics, you will have different ways of doing the same thing, in case the kids do not understand that particular way you are using to solve the problem, you can use another method; this has helped me greatly and it always worked for me. Showing learners and my colleagues that this problem can be solved in 3 ways; you can do it this way, or in this way or in this other way, that works to my advantage because they know only one way of solving the problem and I know the various ways of solving the same problem'.*

At the Science Centre, **Ukwesinde** describes how he does the experiments, works with the team, and gives career lectures and counselling as he attends to clients and students from various schools. This is illustrative of ever-changing workplaces that would need more of a team-based approach, and multi-skilled, multi-tasking physics graduates, possessing physics graduate attributes (PGAs) that are much broader.

For **Nzukwen**, his confidence is predicated on his training and preparedness from UWC, which equipped him with the skills and physics knowledge needed at his workplace, the Nuclear Regulatory Agency**. Nzukwen** felt that his undergraduate studies equipped him with *independent research skills,* which are valuable to his contribution to the workplace and his postgraduate studies. It gave him the freedom to study what content would lead to his specialization at his own pace and understanding, which he liked:

> *'The university education armed me with research skills and how to research. This has helped me a lot in my work and in the pursuit of more knowledge in physics. … the information that you get from research itself is very much helpful. Unlike going to class and studying things and next year you forget, but when one is studying a single thing, one focuses on one area; one learns a lot from there and that is what I like. I learn at my own pace, so I am able to understand what I am doing, rather than be given a course and say you have to write an exam on this date. Then one studies to pass and not study to understand'.*

Nzukwen was afraid that his level of research was just at the beginner's stage because he was just in his first year of the master's programme in Nuclear physics, where he believed he has got much to study and research, thinking he was not ready. But he got the job, and he is doing well on the job too. He thought he was not prepared for the workplace; he said,

> *'Before, now I have always thought that I wasn't ready for workplace. I really think of learning more and getting specialized knowledge. Even after my honours, I still need some more research skills. At least at that time till I got my job during my first year in the master's programme'.*

From the above, his thought about not being ready for the workplace and his fear of inadequate specialized knowledge disappeared when he got the job, and all the physics graduate attributes came in handy for use in the workplace**.**

8.5.2 Wider outcomes of higher education, including citizenship skills and well-being

Besides the *instrumental personal role* of education described above (in this case, in enabling graduates to access the workplace and economic opportunities), Dreze and Sen (1995) characterise four other ways in which education is intrinsically, instrumentally and socially valuable for individuals and society.

The first is the *intrinsic importance* and value of education in itself in contributing to 'a flourishing life'. While to some graduates, it helped them realise their career dreams and goals, others see their studies as an experience to be valued in itself. In some of the graduates' accounts, we find evidence of this intrinsic love and enjoyment of learning.

Graduates also comment on their sense of being a part of a community or society or nation. **Nzukwen**, in comparing himself before and after enrolling at university ('the person I was before coming to university and the person I am now'), notes how university education has been transformative for him. He describes this transformation in terms of being able to identify problems in society and be involved in finding the solution:

> *'I think university education did help a lot if I look at the person I was before coming to university and the person I am now, in comparison to other people like me who did not study or go to the university at all. It is evident that after studying in the university, one becomes that person that can see or identify a problem in society that can be solved or improved and things like that. I am from a village, and what I have learnt and I know now will help my small village when I go back home.*

This illustrates Dreze and Sen's *instrumental social role* played by education in equipping people to contribute to public discussions as informed and active citizens. For physics graduates, this tends to be framed by the recognition and value placed on scientific knowledge and its application as related to society.

For some physics graduates, higher education is an instrument in their hands for family upliftment, allowing them to pull their families out of ignorance and poverty. Dreze and Sen describe this in terms of the *empowerment and distributive role of education*: education can open opportunities for others in the communities of the educated and 'interrupt intergenerational inequalities' (Walker & Fongwa, 2017, p.10). **Josh** noted earlier in this chapter how 'being in the situation whereby you can …help, just because you have a job, is very fulfilling to me'.

Nzukwen, similarly, describes how studying physics enabled him to secure his current job and the significant impact this had on his family:

> *'You know, getting a job makes a huge difference if one comes from a family like mine (laughs). I think learning Physics has made all the difference for me'.*

Ukwesinde describes how has applied his knowledge and experience of higher education to help his siblings, making sure they do not go through what he had to in terms of making informed choices towards school enrolment and other academic issues,

> *'So, all I can say is, since I graduated I have tried to make sure that the younger ones that come after me at least they must go to the university and try to do something better. At least the other one now is doing Education at the University of Pretoria and my big sister also had faced the same problem like me had spent many years without going to school because she did not have the knowledge how to continue her studies ... so what I did now is talk to my sister to go to UNISA and I applied for her at UNISA and now she is doing B.Ed in teaching and I also applied for NSFAS for her'.*

Another strong theme emerging from graduates' accounts is the experience of higher education fostering inclusivity and tolerance. Dreze and Sen (1995) describe this as the *instrumental process role* of education, whereby young people engage with diversity and have their perspectives broadened and challenged. We saw how students in Chapter seven describe the value of learning within a diverse peer group in classes, with different views. These graduates also stress the role of higher education in fostering tolerance, engaging with diversity and building social cohesion. In this regard, **Nzukwen** noted:

> *I have learnt a lot to think differently in terms of society, diversity and ideals of togetherness in trying to live in the larger society'.*

For **Ukwesinde**, the togetherness sought in society is better enhanced by university education, as was his case:

> *'Yes, yes and yes. University education has prepared me very well. There is also what we call Ubuntu in my language, which I translate as humility. The university has taught us a lot, even how to live and communicate in a diversity of people; especially people from other countries. It taught me how to treat people and to be a citizen. So that I don't see people like the illiterates would see and call them 'Shangani' (foreigners who come to take our jobs), you see'.*

Here, **Ukwesinde** specifically focuses on citizenship and tolerance. He notes how education has set him apart from 'illiterates' who hold xenophobic views of foreigners. It is interesting to note that while graduates describe their civic duties as citizens, some are reluctant to vote. **Albert** reflects on a growing awareness of responsibility; he notes that, while he does his civic duties, he does not participate in the voting process as a citizen:

> *'Yea, basically there are rules and I can follow all rules. It is also the realization that one is becoming more responsible. But that is the way I see it in relating to people. I have always been a good citizen and doing my civic duties except to vote. The parties we have now have not earned my trust to go out and vote them yet. For where I am staying, everybody is more for themselves, being selfish with all that is happening around like insecurity'.*

Many physics graduates take the same stance as **Albert**. While they claim to contribute to their society's well-being and progress and perform their civic duties, they leave out voting for public officeholders. What is the significance of performing one's civic duties without participating in the voting process that should bring good leadership to society at all levels? This lack of participation in structures was evident in Chapter six, which indicated that few students were involved in clubs or societies on campus; the main involvement was tutoring. This has implications for departmental arrangements - such as setting up elected structures (class representative structures, physics society etc.) – which can mirror representative structures in society.

8.6 Student agency

Sen emphasizes the **agency** aspect of freedom when he asserted that people have to be seen as being active in shaping their own destiny and not just passive recipients (Dreze & Sen, 1995). The graduates' narratives reflect powerfully the exercising of agency in navigating through higher education and into the workplace. Despite the lack of family/community resources, three of the participants were highly motivated to succeed, in navigating challenging home and institutional contexts. We saw examples of student resilience and resourcefulness: sharing and preparing food together and forming study groups to mutually support each other's' learning. Here participants displayed what Walker et al. (2022) refer to as 'ubuntu capability', a communal and relational way of being, with solidarity and mutual generosity.

Participants found ways to progress with their studies despite lacking resources, such as textbooks or a laptop. They displayed what Walker et al (2022), drawing on Yosso (2005), refer to as 'navigational capital'; drawing on the skills and experiences of having navigated through challenging and unsupportive environments. The study found that these participants took along with them to the university various forms of resources that came in handy for their survival in the new environment, such as work ethic, resilience, and aspiration to perform well.

The capability approach encourages the individual to be the one in charge of their own lives by allowing each person to exercise agency towards achieving goals that they value. The following section examines how graduates describe using their agency to navigate the constraints and challenges of being at university. For this study, the ability of students/graduates to seek assistance or support, and to take every opportunity on offer, were seen as important aspects of exercising agency.

8.6.1 Seeking assistance and support

Higher education had the potential to increase opportunities for university graduates to participate socially and academically thereby narrowing any form of exclusion or feeling of inadequacy due to feelings of under-preparedness. In the narratives, graduates described how exercising their agency through seeking help was an approach to navigating their university studies. In reflecting on his experiences as a student**, Ukwesinde** noted his willingness to take up any opportunity. He expressed agency in taking the initiative to ask for required support from lecturers or peers if needed:

> *'For me, what worked well for me was to study very hard. When you are doing a course like Physics, one must always be busy trying to study hard and to push hard and to ask questions. If you have any question, keep on asking. Don't give up easily. If something is giving you problem, just go and consult anyone; go for consultation to a lecturer, a friend or anyone you*

> *think you can get help. Because Physics is not for these people [the people who can assist you] only'.*

Ukwesinde's approach can be summarized as follows: if there is any support, take it. If there is no support; create a means by which it can be made available and given to you by taking the initiative. This was also identified in the studies of Wilson-Strydom (2015b) and Calitz, (2015a) as an important trait for students. **Ukwesinde** notes that access to other students, lecturers, and experts is freely on offer, so he urges students to get their challenges addressed through appropriate assistance.

On the other hand, **Albert** looked back and wished he had taken the initiative and asked for help or assistance. He has the following to say,

> *'I say, this is physics, you graduate and you are on your own. But maybe not that only, if you ask for help, there is help; but it is not presented, and you are under the impression - or you have the wrong idea in your head - you won't know without asking. … then I would have done more'.*

He was carefree and did not ask for help, even though he knew help was available. As O'Meara, (2013) notes, '*Agentic action is discrete from, but often closely follows, and is related to, agentic perspective*' (O'Meara, 2013, p.3). **Albert**'s lack of agentic perspective (with no clear motivation towards defined goals) manifests in a lack of agentic action in asking for help.

8.6.2 Students need to take every opportunity on offer

Agency on the part of these graduates to study physics enabled them to show resilience and resolve to circumvent scenarios and situations that would have hindered them from completing their studies. In doing so, these graduates used the available resources on offer and converted them into functionings. As we saw earlier **Ukwesinde**, arrived at university with no prior exposure to a computer: "*with no knowledge about how to type or use the computer*". This hindered his ability to fully engage with learning activities: *"…It becomes a nightmare for some of us when demand is put on submitting lab works or assignment"*. Nevertheless, **Ukwesinde** seized all opportunities to improve and develop this functioning during his undergraduate studies. Similarly, at Honours level, he expanded his mastery: despite having much less computer exposure than other Honours students in his class, he quickly mastered MATLAB programming skills.

For **Ukwesinde**, the lack of programming skills was a major concern, but learning wherever and whenever the opportunity surfaces, he takes the agency and confidence that education has given him for acquiring the basic skills, and he needs to build on what he has acquired in his training years.

8.7 Conclusion

This chapter focused on addressing Research Question 4,

RQ4: In relation to physics graduates entering the workplace, what are the conversion factors that influence their preparation on entering the workplace?

However, while the main focus of the interviews was to understand graduates' perceptions of their preparedness for entering the workplace, the graduates also chose to describe their pathways through accessing university and completing their studies (which relates to Research Question 3: *What are the conversion factors that influence students' perceptions of the attainment of the physics graduate attributes*?).

The analysis of the interview data identified the personal, social (university) and environmental conversion factors that enable and hinder the conversion of resources and opportunities into capabilities and functionings. *Personal conversion factors* identified were motivation and aspiration, confidence in oral communication, and computational/ICT skills. *Social (university) conversion factors* identified that students felt enabled or hindered their development of physics graduate attributes were; lack of career guidance, focus on wider graduate attributes and skills in the curriculum, and peer group influence. In addition, there were social conversion factors identified that were more community, rather than university, based; these were: lack of family/community resources, family support for education, and societal norms and family needs.

Finally, two *environmental conversion factors* were identified. The first was the enabling aspect of being at an urban university, which fostered greater exposure for students. The second hindering conversion factor was the lack of resources that had been on offer in their rural home settings.

If we now turn specifically to addressing Research Question 4, the data analysis of students' narratives highlighted that three of the social conversion factors described above were more directly linked to students' perceptions of preparedness and their pathways into the workplace:

these were *lack of career guidance, societal norms and family needs, and the development of wider skills and attributes in the curriculum*.

These findings can be used to inform changes to undergraduate teaching approach and departmental/institutional arrangements to enable students to more easily convert resources and capabilities into functionings. The implications of these findings are discussed more fully in Chapter nine.

CHAPTER NINE

CONCLUSION AND IMPLICATIONS

9.1 Introduction

Chapter nine summarises the findings from the study in relation to the research questions that have framed the study. The implications of the research findings for pedagogical practices and institutional arrangements are discussed. The chapter concludes with a discussion of the significance of the research and recommendations for future research.

9.2 Addressing the research questions

9.2.1 Research Question 1: How are the espoused physics graduate attributes (as specified by SAIP and UWC graduate documents) embedded in the UWC physics module descriptors?

As noted in Chapter two, the graduate preparedness of physics students is an international concern. Physics professional bodies globally have characterised the sorts of skills and attributes that physics graduate should ideally possess (for example, the Institute of Physics (IOP) in the UK, the American Physical Society (APS) in the USA, the European Physical Society (EPS) and the Australian Institute of Physics (AIP), and the South African Institute of Physics (SAIP) in South Africa). National higher education bodies also set out desired graduate outcomes of higher education (for example, the CHE). At the university level, universities also develop specific graduate attributes that they aim to develop in their graduates.

One of the outcomes of this study was the development of the Physics Graduate Attribute (PGA) Framework. This was used to address the first research question (RQ1) in Chapter five. Using this framework to analyse physics module descriptors, it was found that PGAs are very unevenly embedded in the module descriptors. Most embedded were ICT skills and Practical skills, with Problem-solving and Communication skills somewhat embedded. Interestingly, attributes such as Ethical behaviour, Social awareness, Environmental awareness, Teamwork and Personal skills were scantily embedded or completely absent.

The analysis showed that there was only one undergraduate course (the extended curriculum programme (ECP) modules PHY151/152) that had a significant number of PGAs evident in its module descriptor, but this range of PGAs was not evident in more senior-level modules.

In summary, the analysis showed that there are gaps in the phasing in of the SAIP Benchmark statement and the UWC graduate attributes into the physics curriculum, resulting in the current embeddedness of PGAs in the module descriptors being very scanty across levels[21]. Implications of these findings are discussed in section 9.3 below.

9.2.2 Research Question 2: What are students' perceptions of their preparedness in relation to the physics graduate attributes?

In addressing this research question (RQ2), the study examined the extent to which students and graduates felt that the PGAs had been developed. This research question was addressed in Chapter 6, which reported on data from the Physics Graduate Preparedness Questionnaire, as well as in Chapters 7 (and 8) where students (and graduates) elaborated in focus group discussions (and individual interviews) on their perceptions of graduate preparedness.

To understand students' perceptions of their preparedness we first needed a background understanding of the cohort, including details of their family and school background. The first part of the Physics Graduate Preparedness Questionnaire sought details about the demographic features of the students. The analysis showed that they were mostly first-generation students, mostly from rural environments and with low socio-economic status. Most of the students had limited exposure to computers or science laboratories at high school and had not been very involved in extra-curricular activities. At university, likewise, they were not very involved in clubs or societies either, and their main involvement was in tutoring.

The analysis of the Physics Graduate Preparedness Questionnaire data showed that participants rated their perceptions of preparedness on the following skills *most highly*: teamwork, analytical skills, problem-solving skills and personal skills. Skills perceived to be *less developed* were social awareness, communication skills, Computational/ICT skills, and practical skills as compared to other PGAs.

From a *combined analysis* of the curriculum mapping (in Chapter five), questionnaire data (in Chapter six) and interview data (in Chapter seven), some interesting findings emerged:

- **Computational/ICT skills and Practical skills** are most embedded in the module descriptors, yet students in the Physics Graduate Preparedness questionnaire perceive

[21] This low level of embeddedness does not imply that there is not focus on these PGAs in these modules; these skills and attributes could nevertheless be present (i.e. enacted) in the teaching and assessment of these modules, though in an ad hoc fashion.

these attributes to be *least* developed (along with social awareness) (see Figure 6.1 in Chapter six). It seems that, while these are embedded in the module descriptors, there is not enough focus on actually developing these explicitly through teaching and learning activities and assessment. This is borne out in the interviews with students and graduates, where they suggest a greater focus is needed on developing computational/ICT skills, as well as experimental design skills as part of Practical skills.

- **Problem-solving** is the only attribute that is both well embedded in the module descriptors and perceived by students to be well-developed. This is not surprising considering that problem-solving is such an integral part of undergraduate physics learning and teaching. Nevertheless, students noted in the focus group interviews that problem-solving should be developed more explicitly, not only in the first year of the degree but throughout the undergraduate programme.
- **Analytical skills, Teamwork and Personal skills** were seen not to be embedded in the physics module descriptors, yet interestingly these were perceived by the students as *most developed*. The high rating on Analytical skills seemed to reflect that students perceive 'analytical skills/critical thinking skills' as integral to 'problem-solving skills'. Students rate 'Teamwork' as well-developed on the survey, though in the interviews students suggested that there is a need to develop teamwork expertise more explicitly – working in teams can be difficult and more guidance on teamwork processes would be useful. The high rating of Personal skills can be seen as linked to Teamwork since the Personal Skills category includes working with others, as well as independent learning. This implies positives since it is a key skill that enables students to position themselves properly to utilize other skill-set development opportunities (which can in turn be linked to agency).

In summary, while many participants felt prepared in some areas of the PGAs, they felt that more could be done in the Physics programme to develop a wider set of physics graduate attributes to enhance their sense of graduate preparedness. This perceived insufficient *focus on wider graduate attributes and skills* was identified as a significant social/university conversion factor and is discussed more fully under RQ3 below.

9.2.3 Research Question 3: What are the conversion factors that influence students' perceptions of the attainment of the physics graduate attributes?

The broad aim of this study was to examine physics graduate preparedness for work and society from the perspective of physics students and graduates. While RQ2 examined students' perceptions of the extent of their preparedness in the various PGAs, RQ3 looked specifically at the conversion factors that enable or hinder students' development of the PGAs.

This research question was addressed in Chapter seven, through the analysis of focus group discussion data. It was also addressed in Chapter eight, where graduates reflected back on their experiences *as students* in relation to the structural constraints and enablers they had encountered on their educational pathways. From the data on students' perceptions of their graduate preparedness, personal, social and environmental conversion factors were identified as either enabling or hindering the development of graduate preparedness. A summary of conversion factors identified in this study is presented in Table 9.1 below. The social conversion factors could be broadly grouped into two aspects – those related to university arrangements (social/university conversion factors) and those more related to home community factors (social/community conversion factors).

Table 9.1: A summary of conversion factors identified in this study

Personal conversion factors	Motivation and aspiration Confidence in oral communication Computational/ICT skills
Social conversion factors	
Social/university conversion factors	Peer academic engagement (in class) Teaching approach (problem-solving and group work) Approachable lecturers and a conducive classroom environment Platforms for peer affiliation and students' voices Career guidance Peer group influence Explicit focus on the development of skills
Social/community conversion factors	Lack of family/community resources Family support for education Societal norms and family needs
Environmental conversion factors	Rural/urban university location Lack of rural community resources

Three **personal conversion factors** were identified as influencing students' perceptions of their graduate preparedness: these were personal motivation and aspiration; confidence in communication and computational/ICT skills.

The data illustrates how *personal motivation and aspiration* can function both as enabling and hindering conversion factors. It enabled many participants to make the most of the opportunities presented to them and to convert resources and opportunities into capabilities and functionings. It also enabled some graduates (Nkwuzen and Ukwesinde) to overcome challenges in their educational pathways. However, one graduate (Albert, who ended up in a call centre job), showed a lack of aspiration during his undergraduate years to work hard and be successful; he did not appear to maximize the opportunities presented to him during his studies. This contributed to his inability to convert capabilities into functionings and to develop the necessary physics graduate attributes. For example, in retrospect, Albert felt that if he had taken up more opportunities to engage in class, he would have developed more confidence in his communication skills (which he experiences as a lack in his current workplace).

Computational/ICT skills were identified by students and graduates as a conversion factor that they perceived to hinder their graduate preparedness. In some undergraduate contexts, there was an assumption that students came to university with computer literacy skills, and for these students, completing tasks that needed these skills was a huge challenge (a 'nightmare' as Ukwesinde noted). These students would be limited in their ability to convert educational resources and opportunities (in the practical lab) into functionings (for example, developing experimental skills and or writing a report). Similarly, at the Honours level, it was assumed that students entering from various universities all had the same computational physics background, yet Ukwesinde arrived with deficits which he needed to address to complete Honours projects. In this way, he was unequally positioned in relation to his classmates.

Confidence in communication emerged as a significant personal conversion factor. Interestingly, in the interviews, students chose to interpret communication skills as oral presentation skills and did not raise concerns about written communication skills. Many of the students are English second language speakers. Wilson-Strydom (2015) notes how confidence in the language of instruction at university can impact students' confidence to learn and contribute to lectures. The participants perceived that communication skills were not developed enough in the 1st and 2nd years of their studies and that the development of their communication skills was limited.

Ten **social conversion factors** were identified in the focus group discussion and interviews regarding students' and graduates' perceptions of graduate preparedness during their studies and beyond into the workplace and life post-university: these could be broadly grouped into two aspects – those related to university arrangements (social/university conversion factors) and those more related to home community factors (social/community conversion factors).

Social/community conversion factors: *Lack of family/community resources* emerged strongly in the data as an obstacle to students' educational progression. Students from low-income family backgrounds and with little resources are enrolled in universities which puts them at a disadvantage before they begin their graduate journey. This disadvantage in terms of resources is captured as a material conversion factor in the Miratho project (Walker et al., 2022). In some cases, this lack of resources is an extension of the fact that students are from rural villages with few basic amenities, or poorly-resourced schools in urban areas (Calitz, 2015). All the above contributed to the experiences and the difficulties they faced navigating through high school and university education. Their families could not afford to provide the resources needed to enhance their studies, lacking in resources, but being motivated to succeed, they navigated through these challenges (this was also noted by McCowan et al. (2016) in their sub-Saharan study). Despite the lack of family/community resources, the participants navigated through higher education. They displayed what Walker et al. (2022), drawing on Yosso (2005), refer to as 'navigational capital'; skills and experience of having navigated through challenging and unsupportive environments.

Despite families often not being able to provide much financially or materially, *family support for education* was an enabling conversion factor in supporting students' pathway towards becoming a graduate. All four graduates interviewed were first-generation students in higher education and did not come with much social capital (Reay et al., 2001). Nevertheless, having a supportive family that encourages the individual in their studies was an advantage (Case et al., 2018).

Societal norms and family needs play a significant role in students' accounts of their decisions and choices. First-generation students are the most pressured group, and when families are less able to provide for them, it further complicates the difficulties for them to study. As first-generation students, graduates describe how they experienced a huge expectation to provide for their families while studying. They also describe the social pressure on a graduate to demonstrate that they can earn a living, rather than continuing with further studies. In this way, the data showed that family expectations, coupled with comparing themselves to high school peers who are already in the workplace, led to pressure to abandon their postgraduate studies and seek employment (three of the graduates gave up their studies to take up work opportunities).

Social/university conversion factors: *Peer academic engagement* in classes was experienced as supporting students' physics learning and exposing students to diverse peers. These peer engagements enabled participants to navigate both their academic and social dimensions of university life. Other studies have shown the importance of psycho-social affiliation with peers and the institution (Kapp & Pym, 2013).

The *teaching approach* was another aspect of the institutional arrangements experienced as positive by the participants. Students valued the use of an explicit multiple representations problem-solving approach (van Heuvelen, 1991; Etkina & van Heuvelen, 2007) and the use of student engagement and group work in classes (Hake, 1998; Johnson & Johnson, 1991). Students who had passed through the ECP particularly valued these aspects of the teaching approach.

Besides the enabling teaching approaches, students valued the *approachability of teaching staff and the conducive learning environment created,* Students comment on the importance of a classroom atmosphere where they feel free to engage in asking questions and engage with others – this was enhanced by relatively small class sizes (in comparison to their other science subjects at UWC) and an environment where collaborative/teamwork is encouraged. Relational affiliation with lecturers and lecturer approachability are seen as important for student success (Walker, 2006; Pym & Kapp, 2013; Calitz, 2015).

While peer engagement in classrooms was experienced as positive, students noted the *lack of platforms for student voice and affiliation with peers* outside of classes. Calitz (2015) identifies the lack of student participation in decision-making as a hindering conversion factor in her study. Pym and Kapp (2013) note the importance of psycho-social affiliation with peers and the institution. Students felt structural arrangements (such as physical spaces to meet, a physics society, a student representative structure and opportunities for students across levels to interact with each other) would foster a greater sense of belonging and enhance the development of the physics graduate attributes.

Peer group influence did not emerge as significant in the focus group discussions but emerged strongly in interviews with graduates, in which they reflected on their educational pathways into higher education and beyond. The influence of peers was seen in the data to function both as an enabling and a hindering conversion factor. Three of the graduates interviewed described positive peer influence, with examples of working as a team, pooling limited resources, cooking together and studying together. But for one of the participants (Albert), peer influence was seen to have a negative impact. It affected his capacity to utilize the opportunities available to develop many of the physics graduate attributes.

Lack of career guidance emerged strongly in the data both from the student focus groups as well as the interviews with graduates. Participants were uniformly disappointed with the paucity of career information or guidance provided during their undergraduate years. They suggested that visits to career-linked industries and departmental talks and visits from alumni could foster awareness of employment possibilities and opportunities. This is particularly important for first-generation students who cannot draw on their parents' social capital or networks to become familiar with career options or establish workplace connections (Walker & Fongwa, 2017; Walker et al., 2022).

The final social conversion factor identified was *insufficient focus on wider graduate attributes and skills in the curriculum.* This emerged strongly both from student focus groups as well as interviews with graduates. The undergraduate students felt that many skills should be more explicitly developed in the undergraduate curriculum, including communication and computer skills, teamwork, experimental design skills, more rigorous problem-solving skills, independent research skills and ethical/social awareness. The graduates, similarly, felt that there had been too much focus on the physics *content* in the undergraduate curriculum: they would have liked a stronger link 'between the theory and the practical' (Josh). It was only when entering the workplace that some graduates realised that other skills were also needed, such as teamwork, communication skills, ICT skills, and so on. In their study of conversion factors influencing employability, Walker and Fongwa (2017) similarly identify the 'misalignment of theory and practice' as a social-university conversion factor that students perceive as influencing their employability prospects.

Two **environmental conversion factors** were identified in the focus group discussion and interviews regarding students' and graduates' perceptions of graduate preparedness during their studies and beyond into the workplace and life post-university; *these were the rural/urban location of a university* and *lack of rural community resources*.

For students and graduates, the differences between rural and urban environments were noted at all stages of their academic pathways to high school, university and beyond. The graduates interviewed recounted the high school stages of their educational journeys, noting *the lack of resources in the rural home community* as a hindering conversion factor. While the rural environment has positive aspects for community life, the two graduates from rural areas described coming from remote areas with few facilities and amenities (for example, for one graduate, there was no high school in the area).

This rural environment affects the type of information that comes their way, with implications for career information and guidance, and enrollment applications for further education (Walker et al., 2022). Another feature of this rural environment is evident in the small numbers of learners that make the required grades to qualify for university education due to the rural situatedness (including lack of resources and lack of aspiration). While this category, *lack of resources in the rural home community,* has some similarities to the social conversion factor 'Lack of family/community resources' described earlier, what makes it distinctive is the lack of key resources specific to *rural* areas. Walker et al. (2022), similarly, note that while the home community can serve as a social conversion factor, in their study on rural students, they characterise this as an *environmental* conversion factor 'to capture the specificity of rural development' (p 83).

Moving on to the university, the participants noted the benefits of the urban geographical location of the university in enabling collaboration across local institutions as well as international collaborations. Nzukwen termed this the *'exposure difference'* between UWC and his former rural university. In the urban location, the students felt they benefited from exposure to experts, and visits to industries or research centres. This difference in career exposure and access to career information is also noted in the study of Walker et al., (2022) who found that there are disparities in exposure between graduates from rural universities and those from urban universities.

On the other hand, the urban location of the university, with a large cohort of *commuter students*, was a hindering conversion factor for these students, many of whom lacked conducive learning environments or adequate free time to study at home. Students felt that designing study spaces for undergraduates to sit and share or solve problems would be helpful to students to convert opportunities into functionings adequately.

In summary, then, in addressing Research Question 3 a range of personal, social and environmental conversion factors was seen to influence students' perceptions of their graduate preparedness and the development of PGAs. Conversion factors were seen to play a different (enabling or hindering) role for different students, and this explains why individual students may benefit differently from the same educational resources bundle. Moreover, the analysis revealed how conversion factors were interrelated and sometimes mutually reinforcing. For example, motivation and aspiration were seen to be linked to students' keenness to engage with peers or in group work during classes. For Albert, motivation was a conversion factor hindering his peer engagement, which he felt in turn limited his developing confidence in his communications skills. Here, as Wilson-Strydom (2015a) notes, motivation (or a 'will to learn') functions as a hindering personal conversion factor, but it could also be regarded as a capability to be developed during students' undergraduate studies.

The data also showed how prior experience with computer skills functioned as a personal conversion factor that positioned some students as better able to convert educational resources (for example, a physics practical) into capabilities and functionings (for example, developing experimental skills or report-writing skills). An environmental conversion factor of being at an urban university means that commuter students would be less able to participate in group work with peers after classes, or extracurricular activities such as clubs and societies, thus hindering students from further developing the physics graduate attributes such as communication skills, social awareness and teamwork.

9.2.4 Research Question 4. In relation to physics graduates entering the workplace, what are the conversion factors that influence their preparation on entering the workplace?

Interviews with four graduates highlighted three social conversion factors that were perceived to have enabled or hindered their graduate preparedness and entry to the workplace.

Development of wider graduate attributes and skills in the curriculum: While the graduates interviewed felt well-prepared in some respects, overall they felt that there ought to have been a stronger focus on the development of wider graduate skills and attributes. As Nzukwen realised one entering the workplace, 'it is not only the physics that you know' that matters in the workplace, but also other skills, such as teamwork. Graduates also noted that when looking at job adverts, these adverts listed other skills (for example, programming skills) besides just a physics qualification. This perception of wider skills being important for employability prospects is noted in other studies (Walker & Fongwa, 2017; McCowan et al., 2016).

Lack of career exposure and guidance: As was the case with the students interviewed, the four graduates also noted the lack of career exposure and guidance as hindering their preparation for the workplace and the career choices available. The department offered limited exposure to career pathways other than research or academia. This lack of career guidance is particularly hindering to first-generation students, who lack the social capital (including social networks) which are often useful in securing employment (Walker & Fongwa, 2017). In all four cases, the graduates secured their employment (at a national nuclear regulatory body, at a science centre, at a school and a call centre) without any guidance or information obtained from the Department – they found the advertisements via friends or on the internet.

Societal norms and family needs: While possessing the required skills and career information might enhance students' preparedness for the workplace, the choice of whether or not to seek employment was found to be strongly influenced by societal norms and family pressures. Ukwesinde left university after his Honours degree to secure his Science Centre job; Josh and Nzukwen left during their Master studies (to take up posts at a high school and the national regulatory body respectively). All three students described the pressure they felt to stop studying to meet family obligations. Although this may be limited freedom to lead the life that one values (Sen, 1992) since they did not complete their graduate studies, the graduates expressed fulfilment at being able to assist their families financially while doing meaningful work that they enjoyed.

9.3 Implications for pedagogical and institutional arrangements

This section draws on the research findings of this study to discuss the implications for undergraduate pedagogical approaches and institutional arrangements to enable students to effectively convert resources into capabilities and functions.

9.3.1 Embedding physics graduate attributes and curriculum mapping

The document analysis of yearbook module descriptors (in Chapter five) revealed that PGAs are unevenly embedded in the module descriptors. While the introductory ECP modules had good coverage of PGAs, this was not continued in more senior-level modules. On the other hand, some GPAs which were not embedded in module descriptors were nevertheless perceived as well-developed by students. However, overall, students and graduates had the perception that there was an emphasis on physics content coverage which raised the need for more explicit development of wider skills in the physics curriculum.

To address this uneven embedding of espoused graduate attributes in the curriculum documents, it is suggested that a ‘graduate attribute mapping’ (Lowe & Marshall, 2004) or a ‘backward design’ process (Wiggins & McTighe, 2005) might be useful. This would entail starting with the skills and attributes required in a physics graduate (as specified in Physics Graduate Attribute Framework) and then mapping these backwards from the Honours level modules, into 3rd year, 2nd year and 1st-year modules.

This deliberate, scaffolded development of skills across year levels is important since research shows that skills take time to be developed. For example, physics education research on *problem-solving* suggests that students take time to master representations in problem-solving and develop representation competence (Etkina & van Heuvelen, 2007; Eriksson et al., 2014). This is also implied in the SAIP Benchmark statement where a progression from solving ‘problems with well-defined solutions’ to solving ‘open-ended’ problems (p.7) is suggested.

Similarly, developing confidence in *communication* would also need to be mapped across the curriculum. Students suggested that ‘more practice’ would develop their confidence in communication, especially as they were all second (or third) language English speakers. This could be scaffolded to start with small in-class discussion activities (for example, ‘check your neighbour’ peer instruction (Mazur, 1997) and short group presentations in the first year to improve confidence, and progress to longer individuation presentations in senior years.

Teamwork is another skill that students identified as needing more explicit development. While students are often instructed to work in groups, this is often challenging and students felt the need for a more explicit focus on group work processes. While principles of co-operative learning (Johnson & Johnson, 1991) inform aspects of the ECP group work, this could perhaps be strengthened and reinforced in senior courses.

Computational/ ICT skills were found to be well-embedded in the module descriptors, yet the students rated these skills as among the *least developed* in the questionnaire. Nevertheless, students viewed computational/ICT skills as important for their studies and the workplace (Hanson and Overton, 2010; Salagaram & Chetty, 2013; Heron and McNeil, 2017). Analysis of students' interview data identified a lack of computational skills as a conversion factor that students perceived to hinder their graduate preparedness. At the first-year level, a lack of computer skills can function as a conversion factor hindering the ability of students to fully benefit from the educational resources on offer to them (e.g. practical laboratory sessions). Similarly, at the Honours level, students noted how it was assumed that all students (coming from other universities) had similar computational skills. The suggestion here is that computer literacy and computational skills be embedded and more explicitly developed from the first year (this is also recommended in an AAPT report *Computational Physics in the Undergraduate Curriculum* (AAPT, 2016). Also, the capability approach implies treating students as individuals, with an awareness of student diversity in terms of skills, and therefore tailoring computational skills development according to individuals' needs.

9.3.2 Creating platforms for student voice and affiliation

What we see as 'widening participation' in higher education is the critical increase in student numbers in our universities, yet there is often a lack of institutional structures that give access to platforms for *actual* student participation. In this study, there is evidence of a big gap in student engagement in activities that promote social, community and leadership roles. This is also borne out in broader institutional data showing little involvement by UWC science students in extracurricular activities (SASSE, 2017). There could be many reasons for the lack of involvement in extracurricular activities, but some identified in other studies include a need to focus on academics, and the travel needs of commuter students (Walker & Fongwa, 2017). This lack of involvement in extracurricular activities may also be linked to other institutional structures that enhance or limit student engagement. However, participation in extra-curricular activities should be encouraged as this is often viewed by employers as improving employability (Kinash & Crane, 2015). Researchers argue that participation in campus-based democratic structures and processes is also important for developing citizenship capabilities (McCowan, 2012). Ideally, the process of encountering real-life 'civic duties' such as voting or consensus nomination for student representation should start at the departmental/university level.

One of the important implications of this study is the need for creating departmental platforms for students' voices. These could include a physics society and the adoption of a more functional class-representative system across the Department. This would give students the experience of voting and involvement in democratic processes, also experience in service and representing peers' concerns to Departmental senior management. The approachability of lecturers emerged as an enabling aspect of the learning environment; however, formal platforms for students' voices would further support student-staff relations and reduce hierarchy. Students could also be encouraged to participate in wider campus-based societies as well as in students' home communities.

Linked to creating platforms for students' voices and developing a sense of affiliation is the need for physical spaces for students to meet. These would be spaces to socialise, as well as to study together. This would be especially useful for commuter students who often lack conducive home environments for studying, and so could study here before going home. In addition, if co-operative learning teamwork is to be more formally developed, then students need designated spaces to meet and work collaboratively outside of class time. It would also help new students in their transition period (especially first and second-year students), where students of all levels could interact, or where tutor-student consultations could take place, thus enabling a platform for student affiliation.

These spaces could also support formal structures such as student class representative meetings, a physics society, or networking with students across levels or with alumni. Increasing research specialisation in the Department (with graduate students based in different research groups) has diminished collective student engagement, and common spaces could address this.

In summary, student engagement and affiliation through, for example, societies, or a more formal class representative structure, would foster greater student engagement and social integration (Tinto, 2012; Kuh, 2007; Kuh et al., 2007), as well as citizenship capabilities (McCowan, 2012). Participation in such activities is also important for developing students' graduate preparedness and employability (Kinash & Crane, 2015; Walker & Fongwa, 2017), and for fostering; in STEM undergraduate education, such participation is found to foster student retention and academic success (Figueroa et al., 2013) and workplace prospects (Sagen et al., 2000).

9.3.3 Career exposure and guidance

The need for career exposure and guidance emerged strongly in the data from the students and graduates. From a capability approach perspective, career guidance expands the student's scope to make the most informed choices. Some suggested interventions include:

- Career exposure and guidance from 1st year – the provision of dedicated notice boards, posters and pamphlets in departments to address this need; discussion of physics-linked career information and purposeful exposure to career fairs. Inviting alumni to lead career seminars for students.
- A formal departmental portfolio to be created to address this across all levels, so career exposure is not left to individual lecturers. Every level should involve career discussions and students' reflections on their strengths and interests. This portfolio would include liaising with the UWC Careers Office and with UWC alumni.
- The Departments could explore working with industries and start-up tech companies for collaborative internships and placements to expose students and graduates to career information (McNeil & Heron, 2017; Ryan & Benson, 2020). Such links would be useful since often academics lack experience of working in industry and are unaware of the range of skills required in the workplace (McNeil & Heron, 2017; Kinash et al., 2016).
- Educational visits to career-linked industries to help to bridge the career information-employment gap. These educational visits would expose undergraduate and postgraduate students to practical knowledge of possible career paths and trends in physics employment, and to identify the skills and attributes required to successfully seek a career.

At the post-graduate level, similarly, the need was expressed for greater career exposure and visits (industry, research centres). This would develop students' social capital and networks needed when entering the workplace. There is also a need to develop an awareness of the range of pathways for physics graduates besides academia or research (for example, the usefulness of computational skills in the financial or retail sector). Career preparation services, such as job search strategies, CV writing or mock job interviews would also be beneficial, tailored for physics students in consultation with the UWC Career Service. It was significant that none of the graduates had found their jobs through the benefit of departmental or university career services.

9.3.4 Assessing and meeting students' needs

The capability approach tells us that individuals enter university with different resources and capabilities and are therefore differently positioned to make use of opportunities on offer and to convert resources into capabilities and functioning. For example, this study showed how students' confidence in communication or computer literacy skills can impact their ability to learn. Therefore, it would be useful to conduct a student needs survey when students enter first-year physics to assess their level of computer literacy, access to computers, confidence in communication, and other relevant details. Based on this, interventions could be put in place in the Department, tailored to students' needs.

Student advisors at the first-year level could also play an important role, ensuring that students get the support they need, and can access assistance according to their needs (e.g. financial aid, student support services etc). Early tracking of students who seem to be struggling would enable early interventions. At a senior level, advisors could assist with information about the requirements for Honours, career advice and how to apply for post-graduate bursaries etc. This would foster students' aspirations and personal motivation, which the study has shown are important for student success.

9.4 Implications for student agency

The capability approach encourages the individual to be the ones in charge of their own lives by allowing people to exercise agency towards achieving goals that they value. As O'Meara, (2013) notes, '*Agentic action is discrete from, but often closely follows, and is related to an agentic perspective*' (O'Meara, 2013; p.3). Here, having goals and aspirations is important for an agentic perspective. In this study, three of the graduates showed a strong sense of agency. This enabled them to show resilience and resolve to circumvent scenarios and challenges that would have hindered them from completing their studies. In doing so, these graduates used the available resources and converted them to functionings, drawing on the 'navigational capital' (Yosso, 2005) they had developed. On the other hand, Albert's lack of agentic perspective (with no clear motivation towards defined goals) manifests in a lack of agentic action in asking for help.

Chapter eight examined how graduates describe using their agency to navigate the constraints and challenges of being at university. Here, it was noted that seeking assistance was an important aspect of agency. For example, **Ukwesinde**'s approach was to seek help from peers or lecturers or create a means by which it can be made available by taking the initiative. On the other hand, Albert looked back on his undergraduate studies and wished he had taken the initiative to ask for help or assistance.

Graduates also spoke about the need to take up every opportunity on offer in the university context. For example, **Ukwesinde** arrived at university with no prior exposure to computers, yet he seized all opportunities to develop these skills as an undergraduate student. Similarly, when he came to Honours, despite having much less computational physics exposure than the other Honours students in his class, he quickly mastered the MATLAB software programme for his research work.

Taking into account these examples of students exercising their agency, how might pedagogical and institutional arrangements enlarge and foster student agency?

As Sen (1992) notes, agency can be seen in terms of an individual's ability to pursue goals that are important and meaningful to them. In this view, having clear goals and aspirations would be important for enacting agency. In her study on student access, Wilson-Strydom (2015a) notes how motivation can be conceptualised both as a personal conversion factor and as a capability to be developed during students' undergraduate studies. The implication of Wilson-Strydom's position is to consider how students' motivation and aspirations might be explicitly addressed in undergraduate studies, rather than being viewed entirely as the fault of individual students easily labelled as 'un-motivated' (as in Albert's case). Walker (2006) similarly notes how higher education pedagogy has the possibility to foster student agency. Some possible pedagogical practices and institutional arrangements might include:

Developing students' motivation and aspiration – as discussed above, being oriented towards clear goals is an important aspect of agency. The data showed that students were often unclear about possible pathways beyond university, so greater career exposure would help to develop student goals and aspirations; visits from alumni would also be beneficial, sharing their stories of getting to where they are. In addition, an explicit embedding of graduate attributes in the curriculum at all levels would also frame discussions about the aims and purposes of higher education and the development of these broader skills and attributes for life beyond university (for the workplace and wider societal roles).

Making *academic support structures explicit* – some students in this study described exercising their agency by seeking assistance from peers and lecturers. This was enabled by the conversion factors of peer academic engagement and approachable lecturers. To extend this support, student advisors could be created at all levels of the undergraduate physics degree, and tailored interventions to meet students' needs (for example, computer proficiency or communication skills) could be offered to all students. Linked to student support structures is the need for physical spaces, ensuring that students can assess computer labs and study spaces (this is especially for commuter students).

Some graduates in the study described exercising their agency by taking up every opportunity on offer in the university context. In developing student agency, these opportunities for students need to be extended through *expanding platforms for student voice and affiliation* (for example, a physics student society, or class-representative system). In this way, a 'transitional environment' would be created that fosters authentic participation and depicts real life. For example, student societies and a class representative structure would foster student agency in assuming leadership positions, and representing peers in voicing concerns and would reflect democratic participation structures in society.

Finally, the capability approach reminds us that, while pedagogical and structural arrangements might be set up to develop student aspirations and foster agency, in the end, it is up to each student to choose whether to exercise that agency or not.

9.5 Value of the capability approach as a lens

As discussed in Chapter two, the capability approach is a normative framework well-suited to thinking about education in relation to social justice and equity. In this regard, Walker (2006, p142) describes the advantages of the capability approach: i) the intrinsic value of education is recognised; ii) it addresses both recognition and redistribution; iii) individual agency is foregrounded; iv) individual agency is placed on the same plane as social/institutional arrangements; and v) it considers the capabilities needed for educational rights. Some of these advantages she lists are elaborated on below in relation to the findings from this study.

9.5.1 An alternative to human capital development perspectives on higher education

Research on graduateness and graduate outcomes and employability tend to be dominated by human capital development discourse, with its focus on the *instrumental* value of higher education. By contrast, the capability approach provides an alternative framework for thinking about graduate preparedness by also recognising the *intrinsic value of education.* This highlights the value of having a wider set of PGAs in the undergraduate education of physics students that goes beyond the circle of challenges of finding jobs and will sustain the consciousness of physics students to equip themselves with PGAs for different workplaces and a life of well-being in society. In Chapter eight, using Dreze and Sen's framework (1995) the analysis showed how higher education was not only experienced as playing an *instrumental personal role* (enabling graduates to access the workplace and economic opportunities) but also experienced as intrinsically, instrumentally and socially valuable for individuals and society. Graduates reflected on how being at university had shaped them in terms of seeing the world differently, developing awareness of diversity and tolerance and roles as citizens in society.

9.5.2 Every student is unique

The capability approach takes the position that each individual is differently positioned to make use of resources. Conversion factors can play a different (enabling or hindering) role for different students, and this explains why individual students may benefit differently from the same educational resources bundle. As the earlier examples illustrate, some students come to university with more developed communication skills or computer skills than others, due to their exposure at school, so they are better able to convert educational resources and opportunities into functionings (for example, students confident in computer skills will benefit more from an experimental lab session that requires computer-based data analysis and report writing). Similarly, when group work is required for projects to be completed in students' self-study time, commuter students may be less able to participate than on-campus residence students, hence the need for study spaces within the Department. Therefore, a departmental focus on equitable access to resources for students is not sufficient; individuals need differing levels of resources if they are to come up to the same level of capability to function (Nussbaum, 2003). Therefore, since each student enters university differently positioned to make use of resources, students' unique needs should be addressed (see earlier section 9.9.4 *Assessing and meeting students' needs*).

An additional strength of the capability approach is that it does not only focus on the *individual's* characteristics (for example, abilities, knowledge, motivation etc), as is sometimes the case with 'deficit' perspectives in higher education; these perspectives tend to position student success as individually-determined and disregard the impact of structural constraints (Bozalek & Boughey 2012; Pym & Kapp 2013). Instead, the capability approach is focused on the entire process that leads the individual to acquire a particular set of capabilities, and how institutional and social arrangements can enable or hinder this process.

9.5.3 The capability approach foregrounds agency

The capability approach views individuals as able to exercise agency in the face of structural challenges. The study has shown how students faced adversity at high school and rural universities yet persisted and studied at all costs. Through overcoming challenges and adversity, they build resilience and developed 'navigational capital' (Yosso, 2005) which enabled them to exercise agency in the university context. The capabilities approach thus resists the commonly held 'deficit' view of first-generation students (Pym & Kapp 2013; Marshall & Case, 2010) by acknowledging the resources and strengths that these students bring with them to university and their exercising of agency.

The capability approach also implies that one should not overlook an individual because they do not conform to a standard. Sen gives the example of a graduate choosing to look after an ageing parent rather than using their education to work. This is a deliberate choice linked to personal fulfilment. Similarly in this study, three of the graduates decided to quit studying further to provide for their families. From the university perspective, this could be viewed as a 'waste' or a 'failure' yet these students, describe the contentment of being able to provide for their families while engaged in fulfilling work.

9.6 Significance/contribution of the study and future research

9.6.1 Development of a Physics Graduate Attributes framework for UWC

As noted in section 9.1 one of the contributions of this study was the development of a Physics Graduate Attribute (PGA) Framework for UWC, which is wider than the more narrow SAIP Benchmark Statement. This was developed by examining the physics graduate attributes from various international physics bodies, as well as the attributes included in the UWC Charter of Graduate Attributes and SAQA guidelines. What is significant in the development of this framework is that it extends the list of skills and attributes contained in the SAIP Benchmark Statement; in particular, it includes attributes such as *Environmental awareness'* and *'Social/civic awareness'* as well as a wider focus on ethical behaviour and implications of the applications of physics knowledge. For example, while the SAIP Benchmark statement has a narrow focus on data ethics, the framework extends this focus on the ethics of data handling and plagiarism to include a wider focus on the ethical implications of the applications of physics, and ethical professional decision-making. It is important that graduates develop a professional awareness that scientific knowledge is not value-free but can be used for good or ill (East *et al* (2014) for a discussion of this in relation to 'public-good professionals').

9.6.2 Suggestions for implementation of curriculum mapping

This study examined the extent to which espoused physics graduate attributes (as specified in the SAIP and other institutional documents) are embedded in the University of the Western Cape (UWC) undergraduate physics module descriptors. The study found that key graduate attributes are scantily embedded, with many skills gaps revealed. At a *departmental level*, the study has highlighted the need for 'graduate attribute mapping' in the curriculum (see section 9.3.1 above). A further step for implementation and research would be to examine how *espoused* graduate attributes are actually *enacted* in the curriculum through teaching and learning activities and assessment.

At a *national level*, the study raises implications for the potential role that the SAIP (as the national physics body) might play in providing guidance and support for departments in embedding the SAIP Benchmark skills and attributes into the curriculum, and later overseeing that process through programme reviews. In this regard, it might also be useful to look to other professional bodies for implementation guidance, for example, the Engineering Council of South Africa (ECSA, 2012). Such professional bodies require the mapping of graduate attributes across modules in a programme as part of their accreditation processes.

Although the SAIP Benchmark Statement sets out the list of suggested skills to be developed in the BSc Physics degree, the document notes that '…it is up to each institution to formulate the precise and measurable indicators that apply to its situation in the context of various national policies, including the Higher Education Qualifications Framework (HEQF), Level Indicators, and the generic Qualification Standard for the Bachelor of Science degree, as well as the respective university rules' (SAIP, 2015, p.2). This study suggests that leaving 'it up to each institution to formulate the precise and measurable indicators that apply to its situation' could have led to universities not engaging adequately with the Benchmark Statement.

A threshold for the embedding of the physics graduate attributes in the physics curriculum documents might offer a baseline to which various departments of physics could aim. For example, a minimum threshold might suggest that a specific skill (e.g. communication) be embedded in several modules at various stages of an undergraduate programme (because skills take time to develop, across years of study, and cannot be 'fixed' in a single module). As noted in Chapter two, although a focus on developing problem-solving and communication skills might be seen as valuable by lecturers, often these skills are not explicitly developed (Jones, 2009). Furthermore, as noted in Section 9.2 above), physics education research studies show that developing students' representational competence in problem-solving to begin to 'think like a physicist' (van Heuvelen, 1991) requires careful and explicit attention over an extended period (Eriksson et al., 2014).

9.6.3 A fine-grained qualitative case study of physics graduate pathways from university into the workplace

An additional contribution of this study is that it provided a rich, qualitative case study of graduate preparedness. There have been several large-scale surveys conducted internationally on physics graduates' perceptions of preparedness (for example, Ivie & Stowe, 2002; O'Byrne et al, 2008; Porter, 2019); in South Africa, too, graduate destination and employment surveys tend to be at a macro-level (for an excellent overview of research on graduate outcomes and employability patterns, see Fongwa (2018). This study contributes to growing research which looks in more detail at students' experiences of developing graduate attributes during university and making their way after graduation (Walker & Fongwa, 2017; Case et al., 2018; Walker et al., 2022).

9.6.4 Future research

This study looked only at how PGAs were embedded in module descriptors, not how they were *enacted*. I expect that future research will examine how the espoused graduate attributes are actually enacted in the curriculum of individual physics modules, through a detailed analysis of the teaching and learning activities and assessments in these modules. In addition, students in this study perceived some PGAs to be well-developed, despite not having been explicitly embedded in the module descriptors. Further research could uncover the ways in which these PGAs are being enacted in these modules, through the teaching and learning activities and the assessment modes.

Unlike other capability approach studies, which developed capabilities sets through in-depth, participatory methods, this study did not aim to develop capabilities set for physics graduates. Instead, a framework of physics graduate attributes (which could be likened to capabilities and functionings) was developed, not through participatory means, but through analysis of documents (from physics bodies, including the SAIP Benchmark Statement, the SAQA critical cross-field outcomes, and the UWC Charter of Graduate Attributes). A further study could adopt more participatory methods with physics students and graduates, in order to develop an emergent capabilities set for physics graduate, employability and preparation for work and society.

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APPENDICES

Appendix A: Ethics clearance letter

11 August 2021

Mr B Audu

Physics and Astronomy

Faculty of Natural Sciences

HSSREC Reference Number: HS21/6/12

Project Title: Physics graduate preparedness for work and society.

Approval Period: 10 August 2021 – 10 August 2024

I hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report by 30 November each year for the duration of the project.

The permission to conduct the study must be submitted to HSSREC for record keeping purposes. The Committee must be informed of any serious adverse events and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer, University of the Western Cape, Private Bag X17, Belville, 7535
NHREC Registration Number: HSSREC-130416-049

Director: Research Development University of the Western Cape
Private Bag X 17 Bellville 7535
Republic of South Africa Tel: +27 21 959 4111
Email: research-ethics@uwc.ac.za

Appendix B: Participants' info sheet + informed consent for PWPWS survey and focus group discussions

DEPARTMENT OF PHYSICS AND ASTRONOMY

Project: Physics Graduate Preparedness for work and society

PARTICIPANTS' INFORMATION SHEET

Dear Participants,

I am a registered doctoral student in the Department of Physics and Astronomy, Faculty of Natural Science, University of the Western Cape (UWC), South Africa. You are invited to voluntarily participate in this survey on physics students and **physics graduate preparedness for work and society;** with particular interest in the physics students and graduates of the University of the Western Cape.

I am currently conducting research with students to assess their perceptions of graduate preparedness in terms of knowledge, skills, co-curricular involvement and attributes acquired and experience gained in the process of their studying physics in UWC. I will be conducting a survey and also be conducting focus-group interviews with students. All participants in this study will be free to withdraw at any time. Your identity would be kept **anonymous** in any research that is published out of this project.

The principal investigator is Bako Audu, who can be contacted on 3699756@myuwc.ac.za .

Alternatively, you can contact the Head of Department of Physics and Astronomy, Prof Delia Marshall on dmarshall@uwc.ac.za.

For further queries or concerns, please contact: HSSREC (Human and Social Sciences Research Ethics Committee, UWC Research Development, Tel 021 959 4111, Email: research-ethics@uwc.ac.za

Department of Physics and Astronomy

Project: Physics Graduate Preparedness for work and society

DECLARATION: Informed consent for participation in <u>the PGPWS Survey</u>

I_… .... … _(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

As part of a focus group, I undertake to maintain the confidentiality with respect to issues raised by others in these discussions.

SIGNATURE OF PARTICIPANT:

DATE:

Contact information

The principal investigator is Bako Audu, who can be contacted on **3699756@myuwc.ac.za .** Alternatively, you can contact the Head of the Department of Physics and Astronomy, Prof Delia Marshall on dmarshall@uwc.ac.za.

For further queries or concerns, please contact: HSSREC (Human and Social Sciences Research Ethics Committee, UWC Research Development, Tel 021 959 4111, Email: research-ethics@uwc.ac.za, Private Bag X17, Belville, 7535

Appendix C: Student Questionnaire

DEPARTMENT OF PHYSICS AND ASTRONOMY

Project: Physics Graduate Preparedness for work and society

FOCUS GROUP PARTICIPANTS' INFORMATION SHEET

Dear Participants,

I am a registered doctoral student in the Department of Physics and Astronomy, Faculty of Natural Science, University of the Western Cape (UWC), South Africa. You are invited to voluntarily participate in this survey on physics students and **physics graduate preparedness for work and society;** with particular interest in the physics students and graduates of the University of the Western Cape.

I am currently conducting research with students to assess their perceptions of graduate preparedness in terms of knowledge, skills, co-curricular involvement and attributes acquired and experience gained in the process of their studying physics in UWC. I will be conducting a survey and also be conducting focus-group interviews with students. All participants in this study will be free to withdraw at any time. Your identity would be kept **anonymous** in any research that is published out of this project.

The principal investigator is Bako Audu, who can be contacted on 3699756@myuwc.ac.za . Alternatively, you can contact the Head of the Department of Physics and Astronomy, Prof Delia Marshall on dmarshall@uwc.ac.za.

For further queries or concerns, please contact: HSSREC (Human and Social Sciences Research Ethics Committee, UWC Research Development, Tel 021 959 4111, Email: research-ethics@uwc.ac.za

Department of Physics and Astronomy

Project: Physics Graduate Preparedness for work and society

DECLARATION: Informed consent for participation in a <u>Focus Group interview</u>

I_…... … _(full names of participant) hereby confirm that I understand

the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

As part of a focus group, I undertake to maintain the confidentiality with respect to issues raised by others in these discussions.

SIGNATURE OF PARTICIPANT:

DATE:

Contact information

The principal investigator is Bako Audu, who can be contacted on **<u>3699756@myuwc.ac.za .</u>** Alternatively, you can contact the Head of the Department of Physics and Astronomy, Prof Delia Marshall on <u>dmarshall@uwc.ac.za</u>.

For further queries or concerns, please contact: HSSREC (Human and Social Sciences Research Ethics Committee, UWC Research Development, Tel 021 959 4111, Email: research-ethics@uwc.ac.za

Appendix D: PGPWS Student Questionnaire

Student Questionnaire

Physics Graduates' Preparedness for Work and Society Questionnaire

Section A: Respondent's Personal Data and Background (Demographic Data)

Instructions: Please tick as appropriate (√ or X) and fill in where necessary.

Gender: Male [ ] Female [ ] Other [ ]

Age Bracket: 21 – 25 [ ] 26 – 30 [ ] 31 and above [ ]

Growing-up Environment: Urban [ ] Rural [ ] **Name of Home Town**:

How would you describe your family Socio-economic status/Income?: High [ ] Middle [ ] Low [ ]

Did your High School have any of the following?

Library [ ] Computer Room(s) [ ] Science laboratory(ies) [ ] Race: Black-African [ ] Coloured [ ] Indian [ ] White [ ] Other [ ]

Extra-curricular activities that you were involved in at High school,

if any: Sports [ ] Clubs/Societies [ ]

Others (mention)……………………………………………………………………

Parent/Guardian Education Status:

Parent/Guardian – 1; No Matric [ ] Matric [ ] Dip/Cert [ ] Degree [ ] Higher Degree [ ]

Parent/Guardian – 2; No Matric [ ] Matric [ ] Dip/Cert [ ] Degree [ ] Higher Degree [ ]

What interested you most, beside your academic work, during your days in High School?

If you are a ***3rd year student***, what programme are you on? ………………………………………

What modules are you enrolled for this year? ………………………………………………………..

If you are an ***Honours student***, are you ***MANuS*** [ ] ***MATSCI*** [ ] Others (Mention):

If you are a ***Master student***, what is your research field?

SECTION B: On a scale of 1 – 7 (with 1 = Lowest, 7 = Highest) ***rate the extent to which you agree*** with the following statements by ***ticking your appropriate choice*** for that statement.

S/N	Personal skills	Lowest						Highest
PS1	I am capable of individual learning and furthering my understanding	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
PS2	I have an ongoing desire to learn	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
PS3	I am motivated to learn and engage in new knowledge	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
PS4	I have an intellectual curiosity	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
PS5	I am able to contribute by explaining ideas in diverse settings	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Problem Solving Skills							
PSS1	UWC has helped developed my problem solving skills	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
PSS2	I am able to use knowledge acquired to solve problems	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Analytical Skills							
AS1	UWC has helped developed my analytical skills	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
AS2	Physics at UWC has sharpened my critical thinking skills	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Investigative Skills							
InS1	Physics at UWC developed my independent investigation skills	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
InS2	I am confident to find out things and get result by myself	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Practical Skills							
PS1	Physics at UWC has developed my experimentation skills	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
PS2	I am good at designing and performing experiments.	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Technology Aptitude							
TA1	I do not fear to use computers or technology to solve problems	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
TA2	I always look forward to using technology for different purposes.	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	ICT Skills							
IS1	Physics at UWC developed my ICT skills	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
IS2	I am able to use software applications for Physics problems	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]

IS3	There is accessibility to computers and workstations	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Communication Skills	Lowest						Highest
CS1	Physics at UWC developed my writing and communication skills	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
CS2	I am able to present complex information in a concise manner	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
CS3	Physics at UWC has developed my oral & presentation skills	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Team Work							
TW1	Physics at UWC developed my ability to work in teams	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
TW2	I am capable of collaboration and team work	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
TW3	I am able to respect and value other people's views	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
TW4	I am equipped to interact with people from diverse backgrounds	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
TW5	My studies have developed my ability to collaborate with others	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Ethical Behaviour							
EB1	Physics at UWC equipped me to discern ethical & unethical behaviour	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
EB2	I am knowledgeable about social, cultural and ethical issues	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
EB3	I take responsibility for my actions on social and ethical issues	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
EB4	I am aware of my social contributions for local & global good	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]

SECTION C: On a scale of 1 – 7 (with 1 = Lowest, 7 = Highest) ***rate the extent to which you agree*** with the following statements by ***ticking your appropriate choice*** for that statement.

S/N	**Social Awareness**	Lowest						Highest
SA1	Physics at UWC made me to become more aware of social issues	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
SA2	Knowledge acquired has placed me as an agent of social good	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
SA3	I am actively participating in community activities	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
SA4	I am more aware and responsive to my civic duties	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
SA5	I am involved in democratic/civic duties that foster democratic principles	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Environmental Awareness							
EA1	I am able to take responsibility for the environment	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
EA2	I am able to see the need to contribute to develop my local community	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Extra-curricular Activities							
ECA1	I am involved in volunteering/ community engagement	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
ECA2	I have participated in tutoring/mentoring	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
ECA3	I am participating in at least one sporting activity	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
ECA4	I am an active member of a club or society	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	Career Guidance							
CG1	The Physics programme has exposed me to industry information	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
CG2	The Physics programme has exposed me to career advice	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
CG3	The Physics programme has helped me to make informed career choices	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
	UWC GA Awareness							
UGA1	I feel confident to identify with the University as a centre of excellence	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
UGA2	I am aware of the list of UWC graduate attributes	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
UGA3	I am confident to lead where necessary	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]
UGA4	I feel confident to take on a leadership role	1[ ]	2[ ]	3[ ]	4[ ]	5[ ]	6[ ]	7[ ]

Thank you

Appendix E: Group Discussion Questions

Focus group discussion questions

1. Which skills do you think needed to be developed more in the physics programme generally?

2. What features of your undergraduate/Honours physics studies have most helped your learning? (Focus on approaches, teaching & learning environments, assessment practices & skills. *Not* topics, content or individual lecturers, or how difficult physics or maths is.)

3. What would be your ideal student environment for physics students to interact?

4. Did your undergraduate/Honours Physics studies relate physics to other areas of science and society and the environment? If so, how?

5. Do you feel it is an advantage for you doing Physics? If so, elaborate…

6. Do you think you have an advantage over other graduates from other disciplines? If so, elaborate….

7. Did your undergraduate/honours physics studies help you find out about employment opportunities for Physics graduates? If so, how?

8. What do you hope to achieve in terms of the kind of life you would like to live in the near future?

9. How do you think your studies will enable you attain all these goals or target?

Appendix F: Coding Example Project: Group Discussion

Report created by B.N. AUDU on 2019/12/12

Quotation Report – Grouped by: Documents

All (178) quotations

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1 GROUP DISCUSSION UNDERGRADUATE

93 Quotations:

1:1 oral communication need to be developed more as this will be necessary…… (132:240) - D 1: GROUP DISCUSSION UNDERGRADUATE

Text quotation

oral communication need to be developed more as this will be necessary in the honours and postgraduate levels

1 Codes:

Skills that need to be developed more

Comment: by B.N. AUDU

The following skills will always be needed and so develop them.

19 Quotations:

1:1 oral communication need to be developed more as this will be necessary…… (132:240) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:17 computation skills need to be developed more (2140:2183) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:18 computation skills need to be developed more as I see my preparation a…… (2140:2250) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:37 team work need to be developed more (4600:4634) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:38 That is because we compromise with our team than to work with the team…… (4637:4787) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:56 For me, I think experimental design skills need to be developed more. (6875:6943) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:57 For me, I think experimental design skills need to be developed more.…… (6875:7145) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:75 Independent research skills need to be developed more, (9287:9340) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:76 Independent research skills need to be developed more, that is because…… (9287:9428) - D 1: GROUP DISCUSSION UNDERGRADUATE / 2:1 working as a team need to be developed more. (174:217) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:2 working as a team need to be developed more. That is because most of t…… (173:365) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:19 computational skills need to be developed more (2810:2856) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:20 For me, computational skills need to be developed more as all the appl…… (2802:2921) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:33 Skills that need to be developed are those that relate to what is requ…… (5241:5419) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:48 In my opinion, consideration of ethical and social issues are not talk…… (8232:8342) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:49 Ethical and social issues should be related more in their context and…… (8344:8461) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:64 problem solving skills and the critical thinking skills should be deve…… (10956:11037) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:65 I think the problem solving skills and the critical thinking skills sh…… (10944:11107) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:75 problem solving skills. (13512:13534) - D 2: GROUP DISCUSSION POSTGRADUATE

0 Codes

1:2 the presence and encouragement of postgraduate students. Just knowing…… (539:703) - D 1: GROUP DISCUSSION UNDERGRADUATE

Text quotation

the presence and encouragement of postgraduate students. Just knowing that if the postgraduate students can achieve success, I too can; and the friendly environment.

1 Codes:

Features that helped my learning

Comment: by B.N. AUDU

What helped individuals to study

29 Quotations:

1:2 the presence and encouragement of postgraduate students. Just knowing…… (539:703) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:3 the friendly environment (679:702) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:4 the international ranking of the Department too, encourages me to lear…… (711:782) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:19 For me, the ECP programme has really helped my learning. (2496:2551) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:20 Going through questions with the lecturer and the tutorial periods hav…… (2553:2649) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:21 Going through questions with the lecturer and the tutorial periods hav…… (2553:2756) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:39 Collaboration with other colleagues has really helped my learning (5033:5097) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:40 Being able to work with others in tutorials and experiment was great. (5100:5168) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:41 Collaboration with other colleagues has really helped my learning. Bei…… (5033:5169) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:58 One of the best thing about being in a University is the luxury of hav…… (7444:7531) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:59 The fact that you could go to a class and having other students come u…… (7534:7677) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:60 One of the best thing about being in a University is the luxury of hav…… (7444:7677) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:77 The available expertise and teaching styles of the lecturers has reall…… (9673:9778) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:78 Knowing that the lecturers are expert in their fields inspire me to wo…… (9780:9907) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:79 Their level of passion and enthusiasm for

the courses taught makes me…… (9909:10060) - D 1: GROUP DISCUSSION UNDERGRADUATE / 2:3 Collaboration amongst the students is a major feature, (633:686) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:4 the classroom environment and few number of physics students has helpe…… (688:770) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:5 The environment is very conducive for learning. (773:819) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:6 Collaboration amongst the students is a major feature, the classroom e…… (633:819) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:21 Collaboration amongst students and across institution has help me lear…… (3189:3260) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:22 Collaboration amongst students and across institution has help me lear…… (3189:3422) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:34 The step-by-step approach to problem solving and the student collabora……(5688:5811) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:35 Also, the atmosphere to express my view and communicating in the group…… (5813:5935) - D 2: GROUP DISCUSSION POSTGRADUATE
/ 2:36 My determination to be open to new ideas also helped my learning. (5936:6001) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:50 In my experiences, the structure and administration of PHY 151 has rea…… (8730:8822) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:51 An in-depth approach and step-by-step approach to problem solving too…… (8824:8923) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:52 Also, the grouped way of making us work together has added to helping…… (8925:9003) - D 2: GROUP DISCUSSION POSTGRADUATE / 2:66 The availability of reading resources and staff to guide and direct so…… (11375:11480) - D 2: GROUP DISCUSSION POSTGRADUATE /
2:76 The collaborative settings of lectures and class work in my 1st year a…… (13803:13917) - D 2: GROUP DISCUSSION POSTGRADUATE

0 Codes

1:3 the friendly environment (679:702) - D 1: GROUP DISCUSSION UNDERGRADUATE

Text quotation

the friendly environment

1 Codes:

Features that helped my learning

Comment: by B.N. AUDU

What helped individuals to study

29 Quotations:

1:2 the presence and encouragement of postgraduate students. Just knowing…… (539:703) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:3 the friendly environment (679:702) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:4 the international ranking of the Department too, encourages me to lear…… (711:782) - D 1: GROUP DISCUSSION UNDERGRADUATE / 1:19 For me, the ECP

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2:76 The collaborative settings of lectures and class work in my 1st year a…… (13803:13917) - D 2: GROUP DISCUSSION POSTGRADUATE

0 Codes

1:4 the international ranking of the Department too, encourages me to lear…… (711:782) - D 1: GROUP DISCUSSION UNDERGRADUATE

Text quotation

the international ranking of the Department too, encourages me to learn.

1 Codes:

Features that helped my learning

Comment: by B.N. AUDU

What helped individuals to study

29 Quotations:

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Project: Open-ended Interview

Report created by B.N. AUDU on 2019/09/22

Quotation Report – Grouped by: Code Groups

All (161) quotations

Coping

Strategies

17Quotation:

1:31 But there was this one, this one guy; he was also making his worth but…… (6081:6414) - D 1: Telephone Interview Script UnderGrad

> But there was this one, this one guy; he was also making his worth but he likes physics, but okay we also like physics but, he was passionate. He wanted more, he was always studying and studying on. So, he was one the only influence as the one who help us with our questions. He helped us with solving stuffs, most often we go to him.

Codes:

The Challenge

Comment: by B.N. AUDU

> *This refers to the a situation where by the same thing is done differently. Also, the act is focused on being the best, consistent or being the real opposite.*

1 Groups:

Coping Strategies

12 Quotations:

1:31 But there was this one, this one guy; he was also making his worth but…… (6081:6414) - D 1: Telephone Interview Script UnderGrad / 1:34 Early age starts in High School when you choose your subjects at grade…… (7061:7680) - D 1: Telephone Interview Script UnderGrad / 1:48 There was other guy that did not study physics but he was a better con…… (11400:11554) - D 1: Telephone Interview Script UnderGrad / 3:9 Actually, the school I went to used to produce average students. They…… (2397:2917) - D 3: Telephone Interview Script Masters 1 / 3:11 Yea, actually, it helps a lot studying things like the masters and goi…… (3329:3881) - D 3: Telephone Interview Script Masters 1 / 3:35 Before, now I have always thought that I wasn't ready for work place.…… (14606:14892) - D 3: Telephone Interview Script Masters 1 / 4:7 You see, my father was an artisan. You see, those people who are doing…… (2750:3260) - D 4: Telephone Interview Script Honour / 4:8 My studies was very difficult at the University of the Zululand you se…… (3262:3334) - D 4: Telephone Interview Script Honour / 4:9 To be honest, I was the first child in my family to go to the universi…… (3335:4220) - D 4: Telephone Interview Script Honour / 4:41 Yes, actually, will continue with my studies. But the reason why I sto…… (20943:21280) - D 4: Telephone Interview Script Honour / 4:42 But, the thing is back at home, you see; they are still struggling and…… (21282:21589) - D 4: Telephone Interview Script Honour / 4:44 I was equipped with many skills, but for me the lack of programming sk…… (22104:22740) - D 4: Telephone Interview Script Honour

1:34 Early age starts in High School when you choose your subjects at grade…… (7061:7680) - D 1: Telephone Interview Script UnderGrad

Early age starts in High School when you choose your subjects at grades 10. These learners are only 15 or 16 years old; from that point the decision affects one throughout one's life. Because if you don't choose to study Physical Sciences at that time, then you block yourself from a lot of opportunities and career paths. You can't even go to study and you can't do the jobs you want to do in the future. You can't become a pilot, a doctor, an engineer etc. One cannot even become the stuff you want to be, if there is a wrong choice. So, it will end up taking one longer to achieve one's goal, if one is not prepared.

1 Codes:

Spare salient opportunities not taken

Comment: by B.N. AUDU

These are opportunities that were available but, seemingly unseen and untaken by students/graduates during the course of their studies.

1 Groups:

Perceptions of Physics Graduate Preparedness/Environment

6 Quotations:

1:27 maybe not that only, if you ask for help, there is help; but not prese…… (5144:5322) - D 1: Telephone Interview Script UnderGrad / 1:33 Yea, basically just to let them know what it is they can do and what o…… (6826:7028) - D 1: Telephone Interview Script UnderGrad / 1:34 Early age starts in High School when you choose your subjects at grade…… (7061:7680) - D 1: Telephone Interview Script UnderGrad / 3:18 When I was studying, I was only focused on studying physics, and when…… (6856:7409) - D 3: Telephone Interview Script Masters 1 / 3:31 I think all of us were given the same opportunity and platform to lear…… (12664:13036) - D 3: Telephone Interview Script Masters 1 / 4:48 To be honest, yes. Yea everybody had the opportunity to do his own pro…… (22869:23123) - D 4: Telephone Interview Script Honour

The Challenge

Comment: by B.N. AUDU

This refers to the a situation where by the same thing is done differently. Also, the act is focused on being the best, consistent or being the real opposite.

1 Groups:

Coping Strategies

12 Quotations:

1:31 But there was this one, this one guy; he was also making his worth but…… (6081:6414) - D 1: Telephone Interview Script UnderGrad / 1:34 Early age starts in High School when you choose your subjects at grade…… (7061:7680) - D 1: Telephone Interview Script UnderGrad / 1:48 There was other guy that did not study physics but he was a better con…… (11400:11554) - D 1: Telephone Interview Script UnderGrad / 3:9 Actually, the school I went to used to produce average students. They…… (2397:2917) - D 3: Telephone Interview Script Masters 1 / 3:11 Yea, actually, it helps a lot studying things like the masters and goi…… (3329:3881) - D 3: Telephone Interview Script Masters 1 / 3:35 Before, now I have always thought that I wasn't ready for work place.…… (14606:14892) - D 3: Telephone Interview Script Masters 1 / 4:7 You see, my father was an artisan. You see, those people who are doing…… (2750:3260) - D 4: Telephone Interview Script Honour / 4:8 My studies was very difficult at the University of the Zululand you se…… (3262:3334) - D 4: Telephone Interview Script Honour / 4:9 To be honest, I was the first child in my family to go to the universi…… (3335:4220) - D 4: Telephone Interview Script Honour / 4:41 Yes, actually, will continue with my studies. But the reason why I sto…… (20943:21280) - D 4: Telephone Interview Script Honour / 4:42 But, the thing is back at home, you see; they are still struggling and…… (21282:21589) - D 4: Telephone Interview Script Honour / 4:44 I was equipped with many skills, but for me the lack of programming sk…… (22104:22740) - D 4: Telephone Interview Script Honour

1:48 There was other guy that did not study physics but he was a better con…… (11400:11554) - D 1: Telephone Interview Script UnderGrad

There was other guy that did not study physics but he was a better consultant than I was. He left the job now and is doing his own business and he is good.

1 Codes:

The Challenge

Comment: by B.N. AUDU

This refers to the a situation where by the same thing is done differently. Also, the act is focused on being the best, consistent or being the real opposite.

1 Groups:

Coping Strategies

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3:9 Actually, the school I went to used to produce average students. They…… (2397:2917) - D 3: Telephone Interview Script Masters 1

Actually, the school I went to used to produce average students. They always end up S (start-again) or M (merit) due to the village environment code. We that want to be different fight for merit. At my grade 12, we were about 120 learners and learners that get the merit grade are less than 20. That means that many of the learners passed but cannot get offer to go to the university. So, only a few of us who got merit could proceed to university to study and only a fraction of that merit that went on to get a degree.

3 Codes:

A good start (where it all started)

Comment: by B.N. AUDU

> *This define's how Respondent started his/her formal scholling. It may also relate to Respondent's perfomance or experiences at these early stage of formal schooling.*

1 Groups:

Education

9 Quotations:

1:1 I went to the Nuffield Primary School at Nuffield, Overpark and I went…… (206:317) - D 1: Telephone Interview Script UnderGrad / 1:2 In my primary school, I was like among the top 2 students in class; I…… (319:530) - D 1: Telephone Interview Script UnderGrad / 1:5 my marks was always average like 60% like that. (635:681) - D 1: Telephone Interview Script UnderGrad / 1:6 I went to the Nuffield Primary School at Nuffield, Overpark and I went…… (206:682) - D 1: Telephone Interview Script UnderGrad / 3:1 went to Magibe Junior primary school which is about 10 minutes-walk fr…… (496:802) - D 3: Telephone Interview Script Masters 1 / 3:2 I went to Magibe Junior primary school which is about 10 minutes-walk…… (495:802) - D 3: Telephone Interview Script Masters 1 / 3:9 Actually, the school I went to used to produce average students. They…… (2397:2917) - D 3: Telephone Interview Script Masters1
/ 4:3 Yea, I did my primary school in a place called Mpune in Limpopo Provin…… (994:1094) - D 4: Telephone Interview Script Honour / 4:4 after I completed my Primary school, because where I was staying there…… (1237:1427) - D 4: Telephone Interview Script Honour

Beating the odds

Comment: by B.N. AUDU

> *Coming up with a strategy to survive and make headway.*

1 Groups:

Freedom and Agency

10 Quotations:

1:23 I just go to the lectures and I take notes during lectures, I make not…… (3850:4194) - D 1: Telephone Interview Script UnderGrad / 3:9 Actually, the school I went to used to produce average
students. They…… (2397:2917) - D 3: Telephone Interview Script Masters 1 / 3:11 Yea,

actually, it helps a lot studying things like the masters and goi…… (3329:3881) - D 3: Telephone Interview Script Masters 1 / 3:12 I can say, when I started my undergraduate study, I was just aiming wa…… (4025:4657) - D 3:
Telephone Interview Script Masters 1 / 4:4 after I completed my Primary school, because where I was staying there…… (1237:1427) - D 4: Telephone Interview Script Honour / 4:5 After finishing my High School, I spent 3 (three) years unemployed and…… (1429:2341) - D 4: Telephone Interview Script
Honour / 4:6 In-fact, when I was I was primary school, I was living with my parent…… (2352:2749) - D 4: Telephone Interview Script Honour / 4:9 To be honest, I was the first child in my family to go to the universi…… (3335:4220) - D 4: Telephone Interview Script Honour / 4:18 Like the one from Eastern Cape was living with his mother and the moth…… (7572:8050) - D 4: Telephone Interview Script Honour
/ 4:22 For me, what worked well for me was to study very hard. When you are d…… (9179:9712) - D 4: Telephone Interview Script Honour

The Challenge

Comment: by B.N. AUDU

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Appendix G: Sample PGA Embedded in the Module Descriptor

Home Department	Physics and Astronomy
Module Topic	Modern Physics, Heat and Mechanics
Generic Module Name	Physics 151
Alpha-numeric Code	**PHY151**
Year level	1
Main Outcomes	On completion of this module students should be able to: • Demonstrate an understanding of the nature of science. • Demonstrate an understanding of the social, ethical and environmental dimensions of science. • Apply modern physics and heat principles to solve problems. • Apply introductory kinematics and dynamics principles to solve problems. • Apply mechanics theory to everyday life situations. • Work in a laboratory environment and record, represent and interpret data. • Access science texts and communicate in a variety of forms: laboratory report, essay, poster presentation.

Home Department	Physics and Astronomy
Module Topic	Waves, Electricity and Magnetism
Generic Module Name	Physics 152
Alpha-numeric Code	**PHY152**
Main Outcomes	On completion of this module students should be able to: • Apply the physics principles of vibrations and waves to solve problems.
	• Apply the physics principles of vibrations and waves to everyday life situations e.g. Light and sound. • Apply the physics principles of introductory electricity and magnetism to solve problems. • Apply the physics principles of introductory electricity and magnetism to everyday life situations. • Work in a laboratory environment and record, represent and interpret data. • Access science texts and communicate in a variety of forms: laboratory report, essay, poster presentation. • Apply basic statistics to measurement and uncertainty in data.

Main Outcomes	On completing of this module students should be able to: • Have knowledge and understanding of introductory mechanics of kinematics, dynamics and applications. • Be able to apply mechanics theory in everyday life situations. Inferred • Be able to work in a laboratory environment and record, represent and interpret data.

Home Department	Physics and Astronomy
Module Topic	Waves, Electricity and Magnetism
Generic Module Name	Physics 121
Alpha-numeric Code	**PHY121**
Year level	1
Main Outcomes	On completion of this module students should be able to: • Demonstrate knowledge and understanding of introductory vibrations and waves theory and applications in sound • Show knowledge and understanding of geometrical optics and applications of it in everyday life • Be able to work in a laboratory environment and record, represent and interpret data. Inferred