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Physics graduate preparedness: A human capabilities perspective

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Abstract

In South Africa and globally, the preparedness of physics graduates for the workplace and societal challenges is increasingly prioritised. This study, framed by a human capabilities approach, explores physics students' and graduates' perceptions of the development of their graduate preparedness. Findings revealed various interconnected conversion factors that are seen to differently enable or hinder students' ability to transform educational resources and opportunities into desired capabilities and functionings. These included personal factors such as motivation and computational skills; social factors such as teaching approach, opportunities for peer engagement inside and outside the classroom, and career guidance; and environmental factors related to the urban setting of the university. The study highlights implications for teaching and institutional arrangements, including more explicit focus on fostering desired graduate attributes, developing student voice, and enhancing career exposure. The study explores how universities could better equip physics graduates as critical citizens to advance individual and societal well-being.

Keywords: capabilities approach, conversion factors, critical citizenship, graduate attributes, physics,

Introduction

Within higher education, discussions around graduate preparedness and employability tend to focus on meeting labour market demands and equipping graduates with workplace skills. From this "human capital" perspective, a country's economic growth is closely linked to its higher education, suggesting a direct relationship between increased participation in higher education and overall economic development (Tymon, 2013), with graduates equipped with essential skills for the 21st century (Aikman, 2017; Schwab, 2017). However, other researchers (for example, Marginson, 2006; McCowan, 2015) argue that this human capital conceptualisation of higher education is insufficient and that the public good purposes of higher education should be given emphasis. From this perspective, the development of well-rounded, critical citizens is a pivotal purpose of higher education. Authors, such as Walker and Fongwa (2017), contend that in a developing country, like South Africa, university graduates should be equipped to tackle societal inequalities and promote social justice. They advocate for graduate education grounded in an ethical framework that prioritises enhancing the quality of life for all, rather than focussing solely on knowledge and skills. In the context of professional education, Walker and McLean (2015) explore the prospect for universities to educate 'public good professionals', equipped to address social justice and other societal ills, such as poverty.

In the South African context of high unemployment rates and a struggling economy, graduate employability and the economic benefits of higher education cannot be overemphasized. Nevertheless, it is important to foreground the other important roles of higher education stated in national policies, such as meeting the aspirations of individuals and contributing to the 'socialisation of enlightened, responsible and constructively critical citizens' (DHE, 1997). This is especially pertinent since these purposes have been largely overshadowed by the labour market demands of South African higher education (Lange, 2012).

This article seeks to offer insights into how physics students perceive the development of graduate attributes and skills, and how institutional arrangements are perceived to enable or hinder the attainment of graduate preparedness. The first part of the article provides an introduction to graduate preparedness in the context of physics, and then presents an overview of the literature on the human capabilities approach in relation to higher education. The article then goes on to explore students' perceptions of the institutional arrangements that enable or hinder the development of graduate preparedness. From this, we identify intersecting conversion factors (personal, social and environmental) that influence students' perceptions of their graduate preparedness.

Physics graduate preparedness: An overview

In line with global trends in higher education towards a greater focus on promoting employability and workplace skills, there is a similar trend in undergraduate physics education. There is growing acknowledgement that an undergraduate physics degree is not merely a preparation for further graduate studies and research, but that graduates need to be equipped with a broader range of generic skills beyond narrow physics-specific knowledge and skills.

Global physics organisations, including the U.K.'s Institute of Physics (IOP), the U.S.A.'s American Physical Society (APS), the European Physical Society (EPS), and the Australian Institute of Physics (AIP), have outlined the essential skills and attributes that physics graduates should acquire through their education (APS & AAPT 2006; AIP & AAS 2012; IOP 2014). These include problem-solving, critical thinking, research and investigative abilities, analytical reasoning, effective communication, information and communications technology (ICT) skills, ethical behaviour, project management skills, technological aptitude, and personal skills.

In South Africa, there has also been a growing emphasis on the quality and structure of undergraduate physics education, as well as the preparedness of physics graduates for future challenges. The South African Institute of Physics (SAIP) undertook a review of undergraduate physics education in South Africa (CHE & SAIP, 2013) which highlighted the under-preparedness of students entering first-year physics, along with concerns about the proficiency of graduates in applying acquired skills when completing their first degree in physics. This led to the development of the Benchmark Statement of Physics for South Africa, published in 2015 (SAIP, 2015). The Benchmark Statement sets out the core curriculum for an undergraduate physics BSc degree, and outlines the key skills and attributes expected of physics graduates. These are categorised into three main areas: Physics-specific skills, Generic skills (such as problem-solving, analytical skills, investigative skills, communication skills, ICT skills, and personal skills), and Ethical behaviour.

What is notable in all the physics graduate attribute frameworks is that they tend to focus on generic skills that could be seen as useful for the workplace and tend to have a limited focus on wider ethical, social/civic or environmental dimensions. Where ethical behaviour is included, it tends to be framed around data ethics rather than around wider ethical issues in the use of scientific knowledge. For this reason, an expanded framework of physics graduate attributes was developed (Audu, 2023) to reflect a set of attributes and skills not only for the workplace but also for developing critical citizenship. Of course, it is important at this point to note that many of the skills and attributes that are often represented as key "workplace skills" (for example, communication or teamwork) are in fact equally needed for the societal and citizenship roles that students will be called on to play in their future lives.

The human capabilities approach and higher education

The human capabilities approach focuses on the genuine opportunities available to individuals to lead a valued life, or the freedoms they have to achieve the particular life they have chosen and have reason to value (Nussbaum, 2011; Sen, 1999;). Therefore, the capabilities approach provides a critical lens for evaluating what is of value in education, beyond a narrow focus on skills acquisition for the workplace, to encompass wider opportunities to develop individual agency, well-being and human flourishing (Hart & Brando, 2018; Lozano, et al., 2012; Nussbaum, 1997). 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: 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).

The application of the capabilities approach to higher education has given rise to studies examining issues of social justice in higher education. Walker (2006) has used the capabilities approach to examine higher education pedagogies that improve student learning and provide support for first-generation students. This research on pedagogies at the university level has also extended to professional education and the role of universities in developing public good professionals (Walker & McLean, 2015). Various studies in South Africa have applied the capabilities approach to address issues such as unequal access to higher education (Wilson-Strydom, 2015), participation in undergraduate education (Calitz, 2015, 2017, 2019; Calitz, et al., 2016), and graduate outcomes and employability (Walker & Fongwa, 2017). Other studies have used the capabilities approach to explore undergraduate engineering education for sustainable human development (Mathebula, 2018), and the opportunities, obstacles and outcomes of low-income students in higher education (Walker, et al., 2022).

Within the context of this study, the capabilities approach is used to analyse the educational experiences of both undergraduate and postgraduate physics students, focussing on their perceptions of preparedness and evaluating how a physics degree can expand the opportunities for students and graduates to lead lives that they value.

Capabilities and functionings

Capabilities and functionings are two important and interconnected concepts in the capabilities approach, where capabilities refer to what people can do and be (Sen, 1992; Dreze & Sen, 1995). While a capability is a potential functioning, not all capabilities are converted into functionings. As Sen (1985: 48) notes, 'A functioning is an achievement, whereas a capability is an ability to achieve'. So, it can be said that functionings are a subset of the capability set. Functionings are the actualized options or chances of an individual. Calitz (2016) illustrates this concept through an example of a student who develops the capability to express her voice. She then faces the choice of whether (or not) to convert this capability into a functioning, by speaking out confidently in a classroom setting. Walker (2006) offers another example, noting how higher education can provide students with the opportunity to develop capabilities such as analytical thinking or citizenship. However, students have the choice of whether (or not) to apply these capabilities in order to function as analytical young people and engaged citizens.

Referring back to the earlier section on physics graduate preparedness and graduate attributes, a question may arise: how do higher education capabilities differ from a set of graduate attributes? Bozalek (2013) addresses this question in the context of developing the Charter of Graduate Attributes for the University of the Western Cape, a historically disadvantaged university. She contends that the capability approach provides an enlarged perspective on the purposes 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 and human flourishing. As was noted earlier in this article, the SAIP Benchmark Statement has a narrower focus on a disciplinary context and workplace skills for physics graduates. For this reason, a more expanded set of graduate attributes was developed to include wider ethical, environmental and social dimensions, reflecting a more "social good" orientation to education (Audu, 2023).

Conversion factors

The capability approach is grounded in the view that individuals are fundamentally distinct, and that there are *personal*, *social and environmental conditions* at different locations which are the reasons for this diversity (Sen, 1979). This means that since individuals are inherently different, they will need different resources to attain the same functionings. For example, Sen (1979, 1993) notes that a person using a wheelchair will need more resources to achieve the same level of personal mobility as an able-bodied person. As Nussbaum (2011: 20) emphasises, the development of capabilities is deeply influenced by the wider environment in which a person lives:

> [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.

The concept of conversion factors presented by Sen is designed to evaluate how each person is able to convert his/her 'bundle of goods' (resources and opportunities) into functionings (Sen, 1999). These conversion factors are personal, social and environmental differences that explain why individuals benefit differently from the same opportunities and resources (Robeyns, 2005).

Bozalek (2013: 74) notes the usefulness of the concept of conversion factors in higher education for 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 and functionings:

> 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.

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. For some students, safety concerns make commuting home at night difficult, limiting their access to the library and other university facilities. As a result of this environmental factor, students are unequally positioned in their ability to convert educational resources (such as library books or internet access) into educational functionings (in this case, meaningful academic engagement).

Therefore, for any educational context (such as undergraduate physics), there are institutional arrangements (which are social or environmental in nature) that enable or hinder the conversion of resources and opportunities into capabilities and functionings. 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 better equipped to develop additional capabilities in the workplace or in life beyond university. The capability approach helps us to recognise the conversion factors that enable or hinder educational processes, and in doing so, highlight changes needed to societal and institutional arrangements to promote more equitable outcomes.

The research study

This study was conducted at the University of the Western Cape, an urban, research-led and teaching-focussed university, with an institutional slant towards being an engaged university committed to the “social good”. The study was part of a larger project to examine the extent to which the Department of Physics and Astronomy was effectively developing desired physics graduate attributes and capabilities in students, and students’ perceptions of their graduate preparedness (Audu, 2023). Ethical approval was obtained for this study, and standard ethical procedures including informed consent and anonymity were strictly followed. As part of this study, an earlier analysis of the learning outcomes stated in the undergraduate module descriptors had revealed a dominant focus on physics content, with some other skills also emphasised (computational skills, practical skills, problem-solving and communication) (Audu, et al., in press).

The overall research question that oriented this study, framed by the capabilities approach, is:

> What are the conversion factors that enable or hinder students’ ability to convert educational resources and opportunities into graduate preparedness?

The study is interpretivist in nature, aiming to explore the development and fostering of graduate preparedness. The overall study was conducted with a cohort of 3rd year undergraduate, Honours and Master’s students in the department (52 students completed a graduate attributes questionnaire, representing 70% of the students enrolled in those year levels). Open-ended questionnaire questions were designed to elicit students’ perceptions of their level of preparedness on a range of graduate skills and attributes. From the larger cohort, a smaller cohort of students was selected for follow-up focus group interviews (five 3rd year students and six Honours/Master’s students formed two focus groups). The focus group interviews explored further students’ perceptions of their preparedness and the extent to which these skills/attributes had been developed during their undergraduate studies. Students were also prompted to reflect on what aspects of their educational environment had enabled their development and on how this development could have been better supported.

From the cohort of 3rd year, Honours/Master’s students interviewed, five had left the university the following year to take up employment opportunities, and four of these students volunteered to continue to be part of the study. A narrative inquiry approach (Polkingthorne, 1995) was adopted with these physics graduates, who were first interviewed in their final year of study and then again the following year, once in the workplace. The graduates shared the stories of their journeys to entering university, their experiences during their studies, and their transition into the workplace. Likewise, several other higher education studies grounded in the capability approach have used narrative inquiry to explore similar themes: for example, Mkwananzi & Wilson-Strydom (2018) adopted narrative inquiry to gain insight into the lives and educational aspirations of migrant youth; Calitz (2015, 2019) used narrative inquiry to explore students' experiences of participation in higher education, and Walker and Fongwa (2017) and Walker, et al. (2022) analysed the narratives of students' aspirational pathways through university and beyond.

It was important to get a sense from the interviews of each student's prior education and community background since this plays an important role in their experience in higher education. For example, the undergraduate students were all registered for the same programme (physics) but came to university with different backgrounds and with different social capital, and so what they valued, and the professional capabilities and functionings that they developed during their programmes, varied for each student. This also holds true for the post-graduate students, some of whom joined UWC at the Honours level, each bringing unique undergraduate experiences from other universities.

The data reported in this article is drawn largely from the interviews with students and graduates, though some questionnaire data is also reflected. Thematic analysis was used to analyse the qualitative data using ATLASti, uncovering nuanced themes related to factors that enabled or hindered students' perceptions of their preparedness. Illustrative quotes from the raw data, capturing respondents' reflections in their own words, strengthen the research credibility.

Findings

The interviews with students and graduates provided insights into how they perceived the development of graduate skills and attributes, and how institutional arrangements enabled or hindered the development of graduate preparedness. As noted above in the discussion on conversion factors, for any educational programme, the conversion of resources and opportunities (for example, those on offer in the undergraduate physics programme) via capabilities into functionings will depend on the interaction between a student's background and personal traits, social and institutional arrangements, and environmental factors. From the analysis of this data, we identify intersecting conversion factors (personal, social and environmental) influencing students' perceptions of graduate preparedness. These conversion factors are discussed below.

Personal conversion factors

Personal conversion factors are the individual's attributes that play a role in how the resources (in this case, those on offer in the undergraduate physics) are differently converted via students' capabilities into functionings.

For most students, ***motivation and aspiration*** were seen as enabling student learning and enhancing the development of graduate attributes. This motivation was linked to a passion for the discipline of physics and a desire to learn about the world around them:

> I think, what kept me … was that it was very interesting, and it equips one with problem-solving skills and the knowledge of the physical world. (Josh, postgraduate student)

Another motivation expressed was the perception of physics as a 'scarce skill':

> My study of physics is based on interest. The advantage is in the number of those students studying the subject; that is, they are few. (Siya, 3rd year student).

> 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, 3rd year student)

In many cases, students describe how motivation and aspiration kept them overcoming challenges in navigating the university system. For example, this student describes the challenges that he and his group of classmates faced:

> 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. (Ukwesinde, interviewed first as postgraduate student, here as a working graduate)

Motivation is also seen as an enabling conversion factor, empowering Ukwesinde to persist through his undergraduate studies to completion, despite very inadequate resources (no books or a laptop). Wilson-Strydom (2015), likewise noted the significance of motivation or the 'will to learn' for student success in such environments. In addition, a study of graduate employability in sub-Saharan Africa found that 'attitude and personal motivation (to work hard; to take advantage of university opportunities …)' (McCowan, et al. 2016: 23) were important personal conversion factors for fostering graduate success in entering the workplace. Walker, et al. (2022), equally, found in their study that low-income students demonstrated strong aspirations and resilience in overcoming the obstacles they encountered.

On the other hand, a lack of motivation can serve as a constraining conversion factor, limiting students' ability to convert opportunities and resources on offer into functionings, which in this case are desired graduate attributes. For example, one graduate reflecting back on his undergraduate studies felt that his lack of motivation led him to disengage in class and do the bare minimum to get by. Looking back, Albert felt that if he had only taken up opportunities to engage effectively in class, he would have developed more confidence in his communication skills (which he now experiences as a lack in his current workplace). He also felt if he had had a clearer sense of career options, he would have been more motivated to attain the grades needed to enter an Honours degree, and would not now be working in an unsatisfying job:

> If this 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, interviewed first as a 3rd year student, here as a working graduate)

A second personal conversion factor identified was ***confidence in computational skills***. Many students come to university with little or no computer skills from high school, and some were not fortunate to use a computer at all before enrolling in university. Lecturers often assume computer proficiency from the outset for all students. Students perceived that a lack of computational skills hindered their graduate preparedness:

> 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 (Ukwesinde, postgraduate student),

In this example, 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. The students would be limited in their ability to convert educational resources and opportunities (in the practical lab) into functionings (for example, developing practical skills or writing a report). Similarly at Honours level, it was assumed that students entering from various universities all had the same computational physics background; in reality, some are unequally positioned in relation to their classmates.

Social conversion factors

Social conversion factors involve the social structures and institutional arrangements that either enable or hinder the conversion of available opportunities and resources to capabilities and functionings.

The first social conversion factor that emerged as relevant to the development of graduate capabilities was ***peer academic engagement*** (both with classmates and senior peers). Working in groups in the lecture classes, as well as in tutorials and the laboratory, is an important feature of the academic programme in the Department. Students noted that working with their peers had been a helpful 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, 3rd year student)

Students 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 amongst the students is a major feature, the classroom environment and the few number of physics students has helped my learning. The environment is very conducive for learning. (Sandra, postgraduate student)

Students also noted the benefits of engaging with more senior peers and with students from a range of different countries. The value of peer engagement for physics learning is well supported by physics education research (Hake, 1998; Mazur, 2007); in addition to its academic benefits, peer engagement was seen to develop graduate attributes of collaboration and teamwork, exposing students to diverse peers and engaging across difference.

The ***teaching approach*** adopted in the undergraduate programme was another aspect of the institutional arrangements experienced as positive by the participants. Here, teaching approaches were grounded in researched-based STEM undergraduate approaches, in particular an explicit multiple representations problem-solving approach (Etkina & Van Heuvelen, 2007; Rosengrant, et al., 2009), where students are guided towards adopting a clear problem-solving approach that models 'thinking like a physicist' (Van Heuvelen, 1991) when tackling physics problems. This approach is complemented by the use of collaborative group work in classes. In this case, first year classes are held in flat-space venues which are conducive for groupwork and enhancing interactive engagement between lecturers and students:

> The in depth … 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, 3rd year student)

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 have the freedom and choice to engage with educational opportunities offered in classes, and in doing so develop their problem-solving skills (and other physics graduate attributes, such as teamwork and communication skills), through academic interactions with peers.

As part of the enabling teaching approach, students describe valuing 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 and teamwork are encouraged. Relational affiliation with lecturers and lecturer approachability are seen as important for student success (Calitz, 2015; Walker, 2006).

In summary, two social conversion factors - peer academic engagement, and a teaching approach that fostered student engagement and lecturer approachability - were considered enabling conversion factors. On the other hand, the focus group discussions also highlighted several social conversion factors that students perceived as hindering the develop of capabilities and functionings.

The first hindering conversion factor was the **lack of opportunities for student engagement and affiliation with peers outside of classes**. This was in contrast to students' positive experiences of peer engagement inside the classes. Students expressed the need for more spaces for students to meet across year-levels:

> With my experiences as a tutor, I can say that there are no formal spaces, which students own, for interaction around the department … except for the honours and higher degree programmes. The spaces can be made to enable the 1st and 2nd years to interact. (Ukwesinde, postgraduate student)

The participants acknowledged that interactive student spaces for cross-level engagements in the department would enable students to support each other academically:

> 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. (Desiree, 3rd year student)

> We need interaction spaces, that students can access for constructive use … where postgraduate and undergraduate students can meet. (Nzukwen, postgraduate student)

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 (Kuh, 2007; Pym, et al., 2011; Tinto, 2012). Students envisage spaces where they can express themselves freely:

> A normal space, owned by students, 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. (Sandra, postgraduate student)

The students' quotes above reflect a need for institutional arrangements that enhance student voice and opportunities for affiliation. Here, 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: 695) put 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.

The lack of a dedicated space and platform to convert educational resources and affiliation opportunities into capabilities and functionings hinders students' ability to cultivate physics graduate attributes and skills, including teamwork and collaborating with diverse peers, social awareness and communication.

The absence of career guidance also emerged from the data from the student focus groups and graduate interviews as a strongly highlighted concern. Students and graduates were uniformly disappointed with the limited career guidance and information available during their undergraduate studies. They emphasized the need for greater exposure to career pathways, suggesting that industry visits, departmental talks, and interactions with alumni could enhance awareness of employment opportunities and possibilities:

> I have been exposed to some talks and seminars on career choices, but nothing specific on employment opportunities. (Desiree, 3rd year student)

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

For one graduate, Albert, the lack of career guidance was perceived as a key hindrance. As we saw earlier, Albert links the lack of career information to his lack of self-motivation or clear career goals. He felt that this lack of motivation led him to do the bare minimum to pass, and not attaining the grades needed to proceed to an Honours degree. While Albert attributes his lack of self-motivation during his studies to his lack of a career goal, Josh also noted the lack of career guidance and felt that lecturers focused too exclusively on content in 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. (Josh, postgraduate student).

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 – instead, they had found the information online or via friends.

The final social conversion factor identified was ***inadequate development of broader 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, 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. Many of the graduates only came to recognise the importance of additional skills - such as teamwork, communication skills, and ICT proficiency – after transitioning into the workplace. As Nzukwen noted, 'it is not only the physics that you know that matters' outside the university. In addition to physics knowledge, graduates found that the workplace required a range of other skills. They also observed that job advertisements often specified additional competencies, such as programming, alongside a physics qualification. In their study of conversion factors influencing employability, Walker and Fongwa (2017), likewise, recognised "misalignment of theory and practice" as a social-university conversion factor that students perceived as influencing their prospects of employment.

Josh suggested more emphasis on the link between theory and practice, and more focus on developing students' presentation skills and technological proficiency:

> 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 … as well as technology. Technology is advancing by the day. (Josh, interviewed first as a post-graduate student, here as a working graduate)

Nzukwen was one of the 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 workplace I realized that no, it is not only the physics that you know - or the problem that you are solving - that matters. One also needs to know how to work with people … It helped me understand that working with people is important, such that one may be good at physics but if 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. (Nzukwen, interviewed first as a post-graduate student, here as a working graduate)

Besides teamwork skills, other skills that students and graduates felt should have been more explicitly addressed included oral communication skills. For example, this student noted the importance of developing oral communication skills for further post-graduate studies:

> For me, oral communication needs to be developed more as this will be necessary in the honours and postgraduate levels. (Desire, 3rd year student).

The analysis also revealed that a focus on developing social, environmental, and ethical skills and awareness was largely absent in the undergraduate curriculum. As one student noted:

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

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. Students and graduates noted the benefits of the urban geographical location of the university in enabling collaboration across local institutions as well as international collaborations. One of the graduate students, Nzukwen, came up with the term ‘exposure difference’ to contrast UWC with the rural university he came from:

> At UWC … we were always taken to iThemba labs … for us to meet people on the job. We met 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 for the exposure difference and how it impacted on me is the location of the two universities. [My previous university] is in a very rural area. There were no excursion visits to companies or research centres, you see. That is part of what was lacking seriously in my undergraduate training. (Nzukwen, interviewed first as a post-graduate student, here as a working graduate)

Students felt that being at an urban university allowed them to gain valuable opportunities through interactions with experts and visits to industries or research centres. Similarly, Walker, et al. (2022) highlighted disparities in career exposure and access to information, noting that graduates from rural universities often had fewer such opportunities compared to their urban counterparts.

Conversely, the university’s urban setting, with a large population of commuter students, was a hindering conversion factor for some of these students. Many lack suitable study environments at home and struggle to find time for academic work off-campus due to factors beyond their control (such as long travel times and household responsibilities). Students suggested that dedicated study spaces on campus would create supportive environments for studying and engagement with peers:

> My ideal environment to interact would be small, partitioned rooms for studying, and designated sitting space for social interactions. (Duun, 3rd year student)

Such spaces would foster the engagement and affiliation described earlier, helping students to build confidence and further develop essential physics graduate attributes. In addition, students felt that this would also help students in transition periods (from high school to first year, or from first year to second year) by providing a structured environment where consultations and academic assistance could be easily accessed.

Following the discussion above on conversion factors, Table 1 below summarises the personal, social and environmental conversion factors that students perceived to be enabling or hindering the development of their graduate preparedness.

Table 1. Summary of personal, social, and environmental conversion factors perceived by students and graduates

Conversion factor	Enabling	Hindering
Personal	Motivation and aspiration	(Lack of) Motivation and aspiration (Lack of) Confidence in computational skills
Social	Peer academic engagement Teaching approach (problem-solving and groupwork; approachability)	(Lack of) Opportunities for student engagement and affiliation with peers outside of classes (Absence of) Career guidance (Inadequate) Development of broader graduate attributes and skills in the curriculum
Environmental	Urban university – exposure and opportunities	Urban university – commuter students

Discussion

The capabilities approach takes the view that every person is differently positioned to make use of resources and opportunities. As a result, individual students may benefit differently from the same educational resources and opportunities. This study found that a range of personal, social and environmental conversion factors played a different (enabling or hindering) role for different students. For instance, prior experience with computer skills functioned as a personal conversion factor that positioned some students as better able than others to convert educational resources (for example, a physics experimental laboratory session) into capabilities and functionings (for example, developing experimental skills or report-writing skills). Another example was the environmental conversion factor of being at an urban university, which meant that commuter students would be less able to participate in group work with peers after classes, or extracurricular activities such as clubs and societies. This in turn, would restrict their opportunities to further develop key physics graduate attributes such as teamwork, social awareness and communication skills.

The data analysis also highlighted the interconnected nature of conversion factors, where conversion factors (personal, social, and environmental) shape how individuals convert resources and opportunities into valued functionings (e.g., academic engagement, skill development, or work preparedness). These conversion factors are interconnected and mutually reinforcing, creating feedback loops that amplify hindrances or enablers. In the case of Albert, insufficient career guidance (a social conversion factor, tied to institutional support) erodes his motivation (a personal conversion factor). This diminished motivation then hinders peer engagement (another social conversion factor), which in turn limits confidence in communication skills (a personal gap affecting work preparedness). Similarly, Wilson-Strydom (2015) notes that motivation (or a 'will to learn') can function as a hindering personal conversion factor, but argues that it could also be regarded as a capability needing to be developed by the institution throughout students' undergraduate studies.

Another example of the interconnected nature of conversion factors is the role of institutional arrangements, such as lack of communal spaces for students to meet and study after hours. This hinders opportunities for peer engagement (a social conversion factor), which in turn links to personal factors like diminished motivation or sense of belonging. Communal spaces facilitate spontaneous peer interactions, and the development of attributes such as teamwork, social awareness and communication skills. They also foster informal networking which is key for building social capital in undergraduate settings.

Having identified the range of personal, social and environmental conversion factors that enable or hinder students in converting resources and opportunities via capabilities into functionings, what are the implications for undergraduate teaching approaches and institutional arrangements? Some implications of the study are discussed below.

Explicit development of graduate attributes and skills in the curriculum

Although the graduates interviewed believed they were well-prepared in certain areas, they generally felt that the undergraduate curriculum should have placed greater emphasis on cultivating broader graduate skills and attributes. This perception that broader skills are important for employability prospects is noted in other studies such as Walker and Fongwa (2017) and McCowan, et al. (2016). More explicit development of graduate attributes would require a process of 'graduate attribute mapping' (Lowe & Marshall, 2004) of the curriculum from first year to Honours, and beyond, to ensure that desired graduate attributes (such as communication skills, teamwork, technological proficiency, problem-solving and social awareness) are addressed. This would entail a deliberate, scaffolded development of these skills across the year levels. It would also be important to stress that these attributes, often framed as “workplace skills”, are in fact also crucial to prepare students for wider societal and citizenship roles.

Creating platforms for student voice and affiliation

What is termed “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 significant gap in student engagement in activities that foster social, community and leadership roles. This trend is further supported by institutional data which indicates that UWC science students have minimal participation in extracurricular activities (SASSE, 2017). Reasons for the lack of involvement in extracurricular activities could be many, but studies such as that of Walker and Fongwa (2017) identified the need to focus time on academics, and the travel needs of commuter students. This limited participation in extracurricular activities may also be linked to other institutional structures that enhance or limit student engagement. Nevertheless, encouraging involvement in such activities is important, as employers often regard them as valuable for enhancing employability (Kinash, et al, 2016). Researchers argue that participation in campus-based democratic structures and processes is also important for developing citizenship capabilities (McCowan, 2012). Preferably, students should begin experiencing real-life civic responsibilities, such as voting or consensus-based nominations for student representation, while still in a university setting.

One of the important implications of this study is the need for creating departmental platforms for students to develop ‘the capability for voice’ (Bozalek & Boughey 2012: 695) and for exercising agency in relation to their educational experiences (Sen, 1999). These opportunities 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 collaborative groupwork 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.

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 (Kuh, 2007; Kuh, et al., 2007; Tinto, 2012), as well as citizenship capabilities (McCowan, 2012). Participation in such activities is also important for developing students' graduate preparedness and employability (Kinash, et al, 2016); Walker & Fongwa, 2017). 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).

Career guidance and exposure

The need for career exposure and guidance emerged strongly in the data from the students and graduates. From a capabilities approach perspective, career guidance expands the students' scope to make well-informed choices about their futures. This is particularly important for first generation students who cannot draw on their parents' social capital or networks to explore career options and workplace links (Case, et al., 2018; Walker & Fongwa, 2017; Walker, et al., 2022). Students would have appreciated career exposure from first year, through a range of avenues: discussion of physics-linked career information during classes, exposure to career fairs, and invited talks given by alumni. In addition, the Department could explore working with industries for student visits or collaborative internships 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 (Kinash, et al., 2016; McNeil & Heron, 2017).

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 support such as job search strategies, CV writing or mock job interviews would also be beneficial, tailored for physics students in consultation with the university's Career Service. It was significant that none of the graduates had found their jobs through the benefit of departmental or university career services.

Assessing and meeting students' needs

As the earlier examples illustrate, students come to university with different prior experiences and different motivations for being in higher education, which means that they are differently positioned to convert the educational resources and opportunities on offer into functionings (for example, students confident in computer skills will benefit more from an experimental laboratory 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, it is not enough for a department to focus solely on providing equal access to resources for its students; individuals require differing levels of resources if they are to reach to the same level of capability to succeed in developing functionings (Nussbaum, 2011). Since each student enters university differently positioned to make use of resources, students' unique needs should be identified and addressed. One approach could be conducting a needs assessment for first year physics students to evaluate their computer literacy, access to technology, confidence in communication, and so on. Based on the findings, interventions could be put in place, tailored to students' needs. Additionally, student advisors could play a key role in guiding students through this process.

Conclusion

This article has explored physics students' and graduates' perceptions on the development of their graduate skills and attributes. An analysis of interviews revealed a range of intersecting conversion factors (personal, social and environmental) that were perceived as either enabling or hindering the development of their graduate preparedness. These included personal factors such as motivation and computational skills; social factors such as teaching approach, opportunities for peer engagement inside and outside the classroom and career guidance; and environmental factors related to the urban setting of the university.

The study was framed by the capabilities approach which recognises that individuals are differently positioned to make use of resources and opportunities, and therefore may require different levels of resources if there are to achieve the same capabilities and functionings. A key strength of the capabilities approach is its broader perspective - it goes beyond focusing solely on the *individual's* characteristics (for example, abilities, knowledge, motivation), 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 capabilities approach is focused on the entire process that leads the individual to acquire a particular set of capabilities, and how pedagogical and institutional arrangements can enable or hinder this process. This study highlights several key implications for teaching and institutional arrangements, including assessing and addressing students' individual needs, integrating graduate attributes more explicitly and systematically into the curriculum, establishing platforms for student voice, and enhancing career guidance. Finally, the capability approach also points to the importance of taking a broader perspective on physics graduate preparedness, preparing graduates not only for the workplace but to take up societal roles as well-rounded, critical citizens.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used no generative AI/AI assisted technologies.

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