The South African Institute of Physics (SAIP) Benchmark Statement and physics graduate preparedness: A case study of the University of the Western Cape

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Abstract. Worldwide, there is a growing focus on physics graduate preparedness, with physics bodies such as the IOP (UK), the APS (USA) and the AIP (Australia) listing the skills and attributes that graduates should develop during their undergraduate education. In South Africa, similarly, the SAIP Benchmark Statement was developed in 2015 to address concerns about the quality and skills of physics graduates. The Benchmark Statement identified important skills for physics graduates in South Africa but left it up to individual institutions to implement. This study examines 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. Implications for curriculum review and the mapping of graduate attributes across the curriculum are discussed.

1. Introduction

Internationally there is renewed debate on the purposes of higher education in contemporary times. One important function of higher education is to develop the skills needed for economic growth (this is referred to as human capital theory); another is the aim of developing citizenship, and the capacity to lead a meaningful life [1, 2, 3]. In a developing country context like South Africa, it is argued that university graduates also need to be equipped to address inequalities and social justice in society [4].

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 active at work and be good citizens in the society at large [5, 6]. Many universities address this through 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. 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.' [7]

Graduate attributes are broad and generic, and are often developed at a university-wide level, but then need to be adapted for specific disciplines.

2. Graduate attributes in the context of physics

In Physics worldwide, there has been a greater emphasis on the skills that physics graduates are 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) and the Australian Institute of Physics (AIP), have listed the skills and attributes that physics graduates should develop during their undergraduate education [8, 9, 10]. These include problem solving, investigative skills, analytical skills, communication skills, ICT (information and communication technology) skills, ethical behaviour and personal skills, technology aptitude, etc (see table 1).

There is a recognition that physics graduates require a range of physics-specific knowledge and skills, as well as broader skills. For example, the report *Preparing Physics Students for 21st-Century Careers* [11] argues that preparation of physics students currently needs to go beyond the 'standard model' of getting them ready for graduate school. The report recommends ways to improve physics programmes to prepare students for the diverse careers they will embark on. Such preparation would include working well in teams, understanding how science and technology are used in real-world settings, writing and speaking well, and understanding the workplace context.

In South Africa, the South African Institute of Physics and Council for Higher Education (SAIP-CHE) report [12] raised concerns about the quality and skills of physics graduates, and this in turn yielded the Benchmark Statement of Physics for South Africa, which was published in 2015 [13]. The SAIP Benchmark Statement sets out the core content aspects of an undergraduate physics Bachelor of Science (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' [13]. These skills are listed as follows:

1. **Physics skills**
2. **Generic skills**
   - Problem-solving
   - Analytical skills
   - Investigative skills
   - Communication skills
   - ICT
   - Personal skills (work independently and in groups)
3. **Ethical behaviour**

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 (HEQF), Level Indicators, and the generic Qualification Standard for the Bachelor of Science degree, as well as the respective university rules' [15].

3. A framework for Physics Graduate Attributes (PGAs)

In developing a framework of desired physics graduate attributes, I examined 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), APS (USA)). I also drew on the South African Quality Agency (SAQA) Critical cross-field outcomes for South African higher education

[14], and the UWC Charter of Graduate Attributes. Absent in the SAIP Benchmark Statement were some attributes in the SAQA and UWC documents (eg. teamwork, technology aptitude, social/civic awareness and environmental awareness). These were therefore combined with the skills specified in the SAIP Benchmark Statement, to form a broader framework for Physics Graduate Attributes (PGAs) – see Table 1 below.

Table 1. A framework for Physics Graduate Attributes (collated from physics organisations internationally, SAQA and the UWC Charter of Graduate Attributes)

Physics Graduate Attribute	
Category	**Specific Skill**
Transferable 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

4. Graduate attributes in the undergraduate curriculum – espoused or enacted

Graduate attributes can be said to be *espoused* (for example, in institutional documents, such as a Charter of Graduate Attributes or the SAIP Benchmark Statement) or *enacted* (through being embodied in teaching and learning activities and assessment). In other words, sometimes graduate attributes might be espoused in institutional mission statements or even module descriptors, without actually being enacted in the curriculum. Alignment between attributes espoused and attributes enacted in the curriculum is difficult to ensure [15]. As a starting point, this study looked at the *espoused graduate attributes* (through analysis of physics module descriptors from first year to Honours level). Espoused graduate attributes were examined first, because if graduate attributes are not espoused, then they are unlikely to be enacted; or the enactment in the teaching and assessment will likely be dependent on individual lecturers, rather than being formally specified [15].

5. Research design and methodology

The research question that framed this study was "How are espoused physics graduate attributes (as specified by SAIP and UWC graduate documents) embedded in the UWC undergraduate physics curriculum?". Document analysis was undertaken of the UWC Physics programme module descriptors (using the Physics Graduate Attributes framework as analytical tool).

6. Findings

Table 2 displays the extent to which physics graduate attributes are explicitly embedded in the module descriptors (which act as a guide or compass for both lecturers and other team players in framing an undergraduate physics programme). The academic year is scheduled in 2 semesters across all levels for all taught courses. A total of 18 physics modules were examined (Extended Curriculum Programme PHY 151 and PHY 152 captured as one module) and the First Year (PHY 111 and PHY 121 captured as one module). Others constitute the modules of the undergraduate programme and honours programmes respectively.

Table 2: Mapping of Physics graduate attributes as identified in undergraduate module descriptors

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 (indicator)
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	√					√													2
Summary	*Total*	9	3	5	4	1	2	5	4	2	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.

The furthest right-hand column indicates the number of times a physics graduate attribute (PGA) is stated in module descriptors over the undergraduate modules from year 1 to year 3. 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). Table 3 summarises the PGAs in Table 2 for the BSc and BSc (Hons) levels. 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, Team work, Personal skills

The bottom row of Table 2 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 (as specified by SAIP and UWC graduate documents) are embedded in the module descriptors of this case-study Department. The analysis shows that there are gaps in the physics graduate attributes and skills embedded, with skills such as investigative skills, analytical skills, teamwork, social and environmental awareness not explicitly embedded much in the module descriptors. Despite the SAIP Benchmark Statement being published in 2015, the case study Department had not adapted the module descriptors based on this.

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 and learning outcomes of a module. In this case, their presence or absence could be lecturer-dependent and vary from year to year.

7. Discussion

The SAIP Benchmark Statement arose out of concerns about the quality and skills of physics graduates, and how to best prepare students for changing world of work and society. To address these concerns, the SAIP Benchmark Statement identified important skills for physics graduates in South Africa but left it up to individual institutions to implement. This case study suggests that leaving 'it up to each institution to formulate the precise measurable indicators that apply to its situation' [13] could have led to universities not engaging adequately with the Benchmark Statement. Would it have been beneficial to specify some basic implementation standards and processes?

A threshold for the embedding of the physics graduate attributes in the physics curriculum or module descriptors might offer a baseline to which various departments of physics could aim. For example, a minimum threshold might suggest that a specific skill (eg. communication) be embedded in several modules as various stages of an undergraduate programme (because skills take time to develop, across years of study, and cannot be 'fixed' in a single module). It might also be useful to look to other professional bodies for implementation guidance (for example, the Engineering Council of South Africa). Such professional bodies require the mapping of graduate attributes across modules in a programme as part of their accreditation processes.

For the case-study Department, the findings from this study suggest that a 'graduate attribute mapping' [16] or 'backward design' process [17] 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 for research would be to examine how *espoused* graduate attributes are actually *enacted* in the curriculum through teaching activities and assessment.

8. Conclusion

The SAIP Benchmark Statement identified important skills for physics graduates to develop. This case-study examined the extent to which espoused physics graduate attributes (as specified in the SAIP and other institutional 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, social and environmental awareness largely absent. This case-study suggests that the SAIP's stance of leaving the implementation of the Benchmark Statement up to individual institutions could have led to universities not engaging adequately with it. Instead, it is suggested that implementation guidelines be developed (as with other professional bodies) and that measurable indicators or thresholds of skills embeddedness be formulated for undergraduate physics programmes.

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