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The South African Engineering Education Model with a European Perspective: History, Analogies, Transformations and Challenges

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The South African Engineering Education Model with a European Perspective: History, Analogies, Transformations and Challenges

South Africa, with its national cultural diversity and post-apartheid challenges and commitments, finds echoes in the European context, especially considering the imperatives of openness and non-discrimination in higher education. With an historical tradition of excellence in engineering education, the emphasis on supporting educationally disadvantaged learners was a notable characteristic, especially in the period of democratic transition from the late 1980s. This evolved into extended curriculum programmes – where the engineering degree is spread out so that it should take an extra year to complete – which are now in place at all universities across the country. This article draws some analogies with the French model and discusses the source and drivers of transformation of engineering education and training. It examines the potential for structural transformation of engineering education and raises the questions of conservatism and interoperability of programmes at an international level.

Keywords: Engineering education; South Africa; transformation; internationalisation; inclusion.

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Introduction

In June 2015, the South African Society for Engineering Education (SASEE) organised its third biennial conference on the theme ‘Retaining the Best and Brightest in Engineering Education and the Profession’. The theme of this conference highlights a problem that persists in South African engineering education in the post-apartheid era: traditionally elite higher education institutions struggle to retain students from socially and educationally disadvantaged backgrounds. As in many European countries, public institutions offering engineering education in South Africa are traditionally among the most prestigious. In fact, from its origins in 1829, in what was then the British Cape

Colony, the trajectory of South African higher education has been heavily influenced by the British model, under the auspices of the British Empire. It was, after all, the discovery of diamonds and gold just before the turn of the twentieth century that provided the impetus for the emergence of the first engineering schools in South Africa which are of major importance to South Africa as a developing economy.

Since 1999, South Africa has been a signatory of the Washington Accord, an international agreement among bodies responsible for accrediting engineering degree programmes, joining countries such as the UK, Ireland and Australia. Bachelor of Science (BSc) degrees in engineering are delivered by prestigious higher educational institutions and graduates classically undergo further training before being accredited by the Engineering Council of South Africa (ECSA), the statutory body for the engineering profession in the country. Although it strives to maintain the quality required by South African professional bodies, several problems face engineering education in the post-apartheid context, such as equality of access and success for black¹ African students, inclusion, registration, studying cost and academically eligible student drop-outs (Ahmed et al. 2015).

Facing such issues, the originality of South African engineering education is in the adaptation of its programmes. In the 1980s, engineering education focused on assisting educationally disadvantaged students, an initiative that was driven by mining companies such as the Anglo American Corporation, as democracy became imminent. The form that this took was an engineering degree that should take an extra year to complete. This model of 'extended curriculum programmes' is the basis for a recent

¹ As is the convention in post-apartheid literature, the term 'black' in this paper refers to those categorised as 'non-white' under the apartheid government. This includes those classified as black African, 'coloured' and Indian. It is acknowledged that 'race' was used as a construct to institutionalise oppression in South Africa and such references are not intended to entrench racial classifications.

proposal for the structural transformation of the entire higher education landscape in South Africa (CHE 2013).

In the context of the internationalization of engineering education, where curricula are to become more open and flexible, it is important to understand how curriculum structure influences student engagement and retention and also how this depends on student socio-economic or cultural profiles. Ongoing challenges in South Africa, even 20 years after the advent of democracy, provide a local urgency that detracts from the internationalism agenda. However, there are echoes at the European level, especially considering the imperatives of openness and non-discriminative education in engineering. The European refugee crisis of September 2015 is perhaps an impetus for higher education sectors to practise the inclusion of disadvantaged learners, including people from immigrant backgrounds, while preventing and combating discriminatory practices.

The main aim of this article is, through an examination of the evolution of the education model for engineers in South Africa and drawing that back to Europe, to generate some insights on the effect of the broader social context on the form that engineering education structures take. The political context in the South African case is of particular interest because of the way in which discrimination on the basis of race became entrenched in society and the profound effect this had on the education system. Through a conceptual lens provided by the French sociologist Pierre Bourdieu, South African engineering education is analysed in order to gain a sense of the how durable and also how malleable – to the forces of curriculum intervention or education policy, for example – educational structures tend to be and in turn how these structures impinge on society at large.

The emergence of engineering education in South Africa

The first university to be established in South Africa was the South African College (SAC) in 1829 in what was then the British colony of the Cape of Good Hope. In its early years, the SAC was a combined primary and secondary school which gradually developed a small tertiary superstructure (Walker 1929). This superstructure broke away from the secondary school which was Since it did not have the power to confer degrees, students at the College were prepared for the examinations of London University (Bitzer 2009). A year after the colony became self-governing, in 1873, the University of the Cape of Good Hope (UCGH) was established. Modelled after the federal University of London (of which London University had become a college), it was a degree-awarding examining board for students from the ‘eight independent, presumptuously-titled “colleges” scattered around the colony’ (Phillips 2003, 123), including the SAC.

While there is no doubt that Britain, more than any other country, moulded South African higher education, Phillips (2003) refutes the very idea of a prototypical British university to be replicated in the colonies. He suggests that at least five different ‘breeds’ of university existed in the UK by the end of the nineteenth century and, despite the early imitation of an English model, demonstrates that the South African system was actually patterned after the ancient Scottish universities – Edinburgh, Glasgow and Aberdeen. Compared to the English universities, which were dominated by the unashamedly elitist ‘Oxbridge’ model, students at the Scottish universities were more socially diverse than at the English universities, in part because the fees were lower and bursaries for poorer students were widely available (Anderson 1992). While the curricula in the English universities were narrower and tended to be based on the classics and mathematics (Davie 1986), the Caledonian universities offered more

general, flexible curricula. Other characteristics of the Scottish model that are pertinent to the South African case were the heavy reliance on lectures and the extensive use of examinations to assess student achievement (Phillips 2003).

A comparison of two European models of engineering education

Despite a strong British prejudice in favour of experiential learning and apprenticeship to established practitioners (Engel, 1983), formal engineering training emerged in the UK in the 1870s, around the same time that the UCGH was established in the Cape. Universities in Britain, particularly in England, had for a long time resisted offering vocational preparation for the professions (Anderson 1992) but a number of factors, including the desire for status on the part of growing professional organisations, resulted in the insertion of engineering at universities and some technical degree-endowing institutions. In England, it was the newly established 'civic' universities that accommodated engineering training. In Scotland, the ancient universities developed engineering curricula and even came to establish 'a dominance in training the professional and business leaders of their regions never quite achieved by the English civics' (Anderson 1992, 22).

As will be seen, the curriculum model that was eventually transferred to the Cape was an engineering science Bachelor's degree. As with the emergence of formal engineering education in the USA, the insertion of engineering at the universities in the UK served to *legitimate* engineering in the context of the rise to dominance of what Lundgreen (1990) calls the 'school culture'. As such, it developed as distinctly theoretical and was firmly established within 'engineering science', even if it also contained some degree of practical engineering. In the mid-twentieth century, Britain tried more overtly to emulate the technical and practical higher education model enjoyed by the French and Germans (Marr 2007) but never quite succeeded.

If we focus on comparing the British trajectory to the French model (one that was particularly influential in other countries seeking to build formal structures of technical education) it is notable that institutions dedicated to engineering education were established much earlier in France. For example, *Ecole des constructeurs de vaisseaux* was created in 1672 for ship building engineering, *Ecole des Ponts et Chaussées* in 1747 for civil engineering and the *Ecole des Mines de Paris* in 1783 when mining was the leading high-tech industry in France. These institutions were later called the *Grandes Ecoles* (Lemaître 2010) and, up until today, are distinct from what might be called ‘science universities’.

Contrary to the case in Britain – particularly in England – where universities were much more autonomous, the development of the *Grandes Ecoles* was linked to national development plans. Furthermore, graduates from these prestigious institutions moved into respected positions in the national hierarchy of the French civil service, forming a technocratic elite (Karver 1995) thus playing a key role in the reproduction of French society. In this way, the *Grandes Ecoles* were – and still are today – extremely elitist, with admission taking place after a highly selective two years of preparatory classes with a pre-admission system based on a national-level competitive exam (*concours*). The study of engineering is separated from other science subjects at the *Grandes Ecoles* and is studied at Master’s level and not as a Bachelor degree as in Britain and its colonies.

The Mineral Revolution and war

The impetus for the offering of engineering training in the British Cape was the discovery of diamonds in about 1870 near what was to become the town of Kimberley.

In the mid-1880s, gold was discovered on the *Witwatersrand*², the ore-rich north-facing scarp around what is present-day Johannesburg. While Kimberley was just within the northern border of the Cape Colony, gold deposits were further to the north within the borders of the *Zuid-Afrikaansche Republiek (ZAR)*, one of the small independent republics established by the *boers*³, descendants of the Dutch settlers who had left the Cape Colony decades earlier to escape British rule. The ZAR had neither the manpower nor the industrial base to develop the gold industry and this resulted in a huge influx of immigrants, many of them from Britain, seeking their fortune and employment (Packenham 1979).

The first mining engineers to participate in the Mineral Revolution were trained abroad but it soon became apparent that a skills training facility was required for the continued development of the national industry (Davenport 2011). To this end, the South African School of Mines was established in Kimberley in 1896 through the co-operation of the De Beers mining company and the Cape government. Buchanan (1986) highlights the importance of the diaspora of British engineers with regard to the development of expertise and the establishment of formal education structures across the empire⁴. Of course, since Kimberley was part of the Cape Colony, these first steps in engineering training were strongly influenced by the British model. In fact, the first two years of training in applied mathematics and physics was to be undertaken at the SAC in Cape Town, and the third year was then to be spent at the School of Mines where technical instruction was to be given (Davenport 2011).

² *Witwatersrand* means ‘white waters ridge’ in Dutch.

³ *Boers* means ‘farmers’ in Dutch.

⁴ The biography of Professor John Orr (1870–1954) gives a fascinating insight into how engineering expertise from Britain (Scotland, in the case of Orr) was transferred to the various contexts in which engineering education evolved in the Cape Colony and the Union of South Africa. See http://www.s2a3.org.za/bio/Biograph_final.php?serial=2080

Towards the turn of the twentieth century, gold mining in the ZAR had already surpassed the diamond mining industry in terms of both size and wealth (Davenport 2011). Students enrolling for a diploma in mining engineering at the School of Mines in Kimberley were to spend their fourth and final year on the gold mines on the Witwatersrand. However, the rapidly growing number of immigrants – called *uitlanders* by the local population – in Johannesburg gave the ZAR government cause for concern and it began to impose heavy taxes on dynamite and required lengthy residential qualifying periods for voting rights for immigrants (Milner & Headlam 1931). This elevated tensions between the boers and the uitlanders, a group that included the mining magnates and engineers who wanted social and political control over their lives. They looked to Britain for assistance and formed a committee to represent their interests which included demands for a stable constitution, a fair judiciary and a better educational system (Milner & Headlam 1931). Initially, the ZAR government had agreed to oversee the fourth year of training on the gold mines but growing hostilities resulted in its losing interest in participating in the training scheme (Davenport 2011). The mining houses took it upon themselves to provide the necessary practical training.

Driven by its imperial interests in Africa, Britain used the grievances of the uitlanders in Johannesburg as a pretext for military conflict. The tensions between Britain and the Boer governments boiled over in the Second Anglo-Boer War of 1899. This ended with a bitter defeat of the boers in 1902 and the absorption of the Boer republics into the British Empire. This brief sketch of the circumstances surrounding the start of engineering training in South Africa demonstrate that it was wholly moulded by the British model.

Engineering Education in South Africa in the Twentieth Century

The School of Mines relocated to Johannesburg in 1903, a year after the end of the

Anglo-Boer War, and was renamed the Transvaal Technical Institute in 1904. In 1910 it became the South African School of Mines and Technology and was established in 1922 as the University of the Witwatersrand (abbreviated 'Wits'). This university is currently one of the leading institutions offering engineering degrees in South Africa. When the four British colonies became the Union of South Africa in 1910, the only two institutions engaged in engineering training were the SAC in Cape Town and the South African School of Mines and Technology in Johannesburg (Murray 1982). By this time the three years of training in mining (with a fourth year on the gold mines) had evolved to a general four-year diploma examined by the UCGH. In fact, from the early 1900s, the general mining engineering qualification contained elements of mechanical and electrical engineering (UCGH 1903). By 1915 the 'subdivisions of engineering were formally recognised by the introduction of diplomas in civil, electrical and mechanical engineering to be achieved at the end of four years of study' (Kilner 1965, 1).

Three bills to restructure tertiary education

In 1916, the Union Government passed three bills concerning tertiary education. One granted the SAC status as a fully-fledged university, re-named University of Cape Town (UCT), in 1918. It is interesting that the birth of UCT is bound up with the acquisition of the land that it occupies today, an estate on the slopes of Table Mountain owned by Cecil John Rhodes, the mining magnate and British imperialist. He bequeathed it for a teaching university at which he envisaged both white 'races' would work together to lay the foundation for future cooperation (Giliomee 2003). The word 'races' in this regard was used to refer to the white English- and Dutch-speakers of the colony and thus excluded people of other skin colours. Unfortunately, the provision of higher education for the black people of South Africa would become a possibility only many decades later.

What the establishment of UCT meant for engineering education was that for the first time students could register for a four-year Bachelor of Science (Eng) degree in either civil, mechanical or electrical engineering. In 1922, a BSc degree in chemical engineering (initially called Applied and Industrial Chemistry) was offered for the first time (Kilner 1965). It is worth noting that although that this Bachelor's degree was a year longer than that in the UK, it followed 12 years of schooling rather than 13. The engineering science degrees awarded by South African universities today are still structured according to the curriculum pattern established in those years.

The second bill made provision for the UCGH to be named the Federal University of South Africa (today known as Unisa). It continued to confer degrees for six colleges in the Union, including the School of Mines and Technology in Johannesburg. As mentioned earlier, this institution broke away in 1922 as the University of the Witwatersrand that, like UCT, began to award its own BSc (Eng) degrees. The third bill, passed in 1916, granted university status to Victoria College, an institution about 50 kilometers outside of Cape Town in the small town of Stellenbosch. It was renamed the University of Stellenbosch and distinguished itself from UCT in that the dominant medium of instruction was to be Dutch or Afrikaans rather than English. This marked the beginning of the language division in higher education in South Africa. When the language of Afrikaans fully emerged from its Dutch substrate later on, Stellenbosch University would be recognised as the oldest of the so-called Afrikaans universities. Although engineering education emerged some decades later at these institutions and the qualification is abbreviated BEng (*BIng* in Afrikaans) rather than BSc (Eng), the basic four-year curriculum structure is also firmly rooted in the Caledonian model (Phillips 2003).

Engineers and technicians

Although it is not possible to go into all the details in this article, another form of engineering training emerged from within the technical college sector (Case 2006). In South Africa, technical colleges play a dual secondary/tertiary role in providing graduates with the knowledge and skills they need to enter specific trades and occupations (d'Almaine et al. 1997). To meet a shortage of skilled personnel in the late 1960s, some of these colleges were designated as Colleges of Advanced Technical Education (CATEs) and a decade later evolved to become 'technikons', often thought of as being similar to polytechnics elsewhere in the world. However, as Case (2006, 4) notes, the privileging of theoretical over practical knowledge in South Africa has resulted in a 'sharp difference in status between these two types of institutions'. Technikon graduates – designated as 'engineering technicians' – qualify with an engineering diploma after two years of theoretical study followed by one year of experiential training at a co-operating, accredited industrial company (d'Almaine et al. 1997).

The segregation of tertiary education

In 1948, the Afrikaner National Party was elected to power under the slogan of *apartheid* – a term meaning 'separateness' in Afrikaans. As suggested already, apartheid simply entrenched the racial inequity that had begun under Dutch and British colonial rule. Although a few institutions were specifically developed for 'natives', universities that had been established in the years prior to the 1950s were reserved for white students. Under the guise of separate development, a bill was passed in 1957 calling for the establishment of separate universities for the different racial groupings. These half a dozen or so hastily-erected institutions were vastly under-resourced

compared to the traditional universities – only one offered engineering. Two years later, the bizarrely-termed Extension of University Education Act of 1959 officially prohibited black students from attending white universities.

The role of the professional body and its relation to the state

Before turning to the events that transformed this bleak political landscape and how this impinged on higher education, it is necessary to briefly discuss the role of the professional engineering body in South Africa. It has already been mentioned that engineering education in Britain arose out of a well-established apprentice system that was linked to strong professional organisations. This was not the case in the rest of Europe where the state generally tended to regulate professional education. As we have seen, the *Grandes Ecoles* in France were – and still are – strongly managed by the state although it must be noted that *Commission des Titres d'Ingénieurs* (CTI) was created by law in 1934 to regulate the awarding of the title 'engineer' following a cause for concern over a proliferation of institutions offering diplomas in engineering (CEFI 1995). Not surprisingly, South Africa tended to follow the pattern of the rest of the Anglophone world where the professional bodies (with significant influence from the corporations) play the leading role. The USA is perhaps the best example of this, where ABET (Accreditation Board of Engineering and Technology) was created in 1932 (pre-dating the French CTI), taking the premier role in regulating technical training in the USA and even developing into an 'energetic international organization' (Lucena et al. 2008, 435).

In South Africa, engineering was recognised as a self-governing profession much later with the passing of the 1968 Professional Engineers' Act and the establishment of the South African Council for Professional Engineers (SACPE). One of the key roles of SACPE was to accredit the four-year Bachelor degrees that were

being offered by a number of universities at the time. Only with such a qualification was – and still is – it possible to register as a professional engineer and then obtain the required certificate of competency. In South Africa, it was only in 1982 that Wits invited SACPE to accredit all its engineering courses (Kruger 2016). This was apparently so successful that all universities subsequently asked for accreditation, a practice which continues until today. In 1991, SACPE was renamed the Engineering Council of South Africa (ECSA). Students graduating from the technikons with a three-year engineering diploma were also able to register with ECSA as engineering technicians but this all changed once apartheid fell in the early 1990s, as will be discussed in the following section.

Discussion

The emergence of the South African model of engineering training corresponds with the British model – with a Scottish flavour – in line with its colonial history. It thus evolved more along the lines of the Anglophone countries which entailed the insertion of engineering into traditional universities, differing from training models of nineteenth and twentieth century Europe such as the French *Grandes Ecoles* or Germany TU9 institutes of technology.

As suggested in the recounting of the history behind the establishment of South Africa's engineering training, the factors driving engineering education are not unique. Geopolitical issues (such as maritime discoveries, colonisation and access to minerals) were major development factors for European nations in supporting commerce and industrial revolution, at national and global levels. In this way, engineering training is intimately related to national economic development.

The high-level positions occupied by engineering graduates from South African universities tend to reinforce the notion of the 'nobility' of the engineer rooted in

institutionalized cultural capital (Bourdieu 1986). This notion is also prevalent in the French *Grandes Ecoles* system. In South Africa such issues of inclusiveness became controversial towards the end of the twentieth century when the edifice of apartheid began to crumble and the consideration of students' educational and cultural backgrounds was important in terms of student performance and retention. A study of the South African university system during the period of transition (Naidoo 2004, 462) used the framework of Pierre Bourdieu to argue that at an English-medium white university that she calls Mount Pleasant, the traditional admissions policy was 'maintained and strengthened', which had the effect of insulating prestigious programmes from a large intake of black students.

Engineering education models in post-apartheid South Africa

The 'miracle' of South Africa's transition to democracy can be understood in the terms of wider political and economic factors (Guelke 1999). Manzo (1992) argues, for example, that the demise of communism in Eastern Europe had specific consequences for South Africa in terms of the reassertion of the hegemony of the USA and the absence of any viable alternative to capitalist democracy. Other factors such as South Africa's economic isolation due to sanctions, the explosion of national social and economic problems and the growing threat of civil unrest from the disaffected black majority added to the pressure for change (Guelke 1999). In 1990, the unbanning of the African National Congress (ANC) – the majority political movement in South Africa by this time – and the release of Nelson Mandela from prison marked the beginning of the period of transition to democracy.

Extended curriculum programmes

However, it is interesting to note that efforts to democratise higher education, and

engineering education in particular, began in the early 1980s. Although not as radical as the so-called black universities, the English-medium white universities like UCT and Wits had positioned themselves against the government's policies of separate education since the 1950s (Du Toit 2001). When the Ministry of Education began to relax the legislation prohibiting black students from attending white universities in the 1980s, these universities began to admit students of colour, sometimes defying the orders of the apartheid government (Scully and Desruisseaux 1986). At this stage, initiatives to provide academic support for black students, most of whom came from poorly-resourced schools and low-income families, arose at these universities under the banner of 'academic development'. Although there are some parallels with the educational development projects that arose in the 1960s in the UK, the USA and Australasia (Clegg 2009), academic development in South Africa focused more on curriculum development and specifically targeted black students. The initial form that this support took was stand-alone bridging programmes but this approach was discarded in favour of a holistic curriculum approach that aimed at extending existing qualifications by a year in order to build in appropriate 'foundational' material (Kloot, Case and Marshall 2008).

In light of the history sketched above, it is especially interesting that the development of these programmes in engineering was well supported by 'big business' in South Africa. The Anglo American Corporation in particular, a major stakeholder in the De Beers diamond mining company that was started by Cecil John Rhodes in 1888, supported the development of the extended curriculum programmes at UCT, Wits and the University of Natal in Durban. Anglo American worked with academics at these institutions to develop appropriate foundational courses, donated millions of rands in scholarships, provided bursaries for black students and contributed financial resources to identify the most talented students for these programmes (Hofmeyr and Spence

1989). Probably the most successful of these is the Academic Support Programme for Engineering in Cape Town (ASPECT) which was started in 1988 and is still an integral part of engineering education within UCT. The ASPECT programme has evolved over the years and today aims to extend the first two years of an accredited BSc (Eng) degree into three years by focusing attention on maths, physics and communication skills in the first year (Pearce et al. 2015). The duration of this alternative undergraduate degree is thus a minimum of five years.

Education for all

The year that marked the beginning of the transition to democracy, 1990, is also notable because it coincides with the publication of the first of a number of higher education policy documents (Bunting 1994). These attempted to grapple with the question of how to transform a sector grossly divided on the basis of language, knowledge type (theoretical vs practical) and race. In April 1994 the first democratic elections took place in South Africa, the ANC won the majority of votes on the basis of their Freedom Charter (ANC 1955) and Nelson Mandela was elected as the first president of the 'new' South Africa. One of the slogans used in the 1994 elections was 'Education for All' which drew on the following statement in the Charter:

The Doors of Learning and Culture Shall be Opened!...Education shall be free, compulsory, universal and equal for all children; Higher education and technical training shall be opened to all by means of state allowances and scholarships awarded on the basis of merit.

The policy initiative that had begun in 1990 culminated in the publication of the 1997 Higher Education White Paper (DoE 1997). This document set ambitious goals for the transformation of the higher education sector in terms of structure, governance and funding with equality and social inclusion as pillars. However, the response of the

higher education sector, and in particular the (now ‘historically’) white universities was slow. While the intake of black students to the historically English-medium universities increased substantially after 1994, those universities designated as Afrikaans-medium under apartheid have largely remained white. Some have blamed the lack of transformation on the nature of the political transition in South Africa (called ‘transplacement’ in the literature). The effect was that while the ANC dominated the political arena after democracy, whites still largely controlled the economy (Guelke 1999). Reddy (2004) suggests that this mode of transition meant that civil society and therefore higher education were relatively unaffected by the substantial changes in the political realm. From a 2004 perspective, he notes that the impressive gains made in higher education ‘sit alongside old patterns reproducing themselves both within the higher education sector and in the relations between this sector and society’ (Reddy 2004, 39).

The National Plan

In 2001, the South African Department of Education decided to take a stronger hand in matters and unveiled the National Plan (DoE 2001, 6) to restructure higher education in order to deal with ‘the racial fragmentation of the system’. This involved the re-grouping of 36 universities and technikons into 23 higher education institutions. In the process, the technikons were renamed ‘universities of technology’ and, in the cases where traditional universities were merged with technikons, they formed ‘comprehensive universities’. The National Plan also made provision for the introduction of a Bachelor of Technology (BTech) qualification. This entails a year of academic work beyond the diploma and such graduates are designated ‘engineering technologists’. Along with the ‘engineer’ and the ‘engineering technician’, this is the third and final category of engineering qualifiers in South African higher education

whose members, after graduation, are eligible to be registered with the professional body ECSA.

Qualification variety and compatibility

While both the BTech from a university of technology and the BSc (Eng) from a traditional university are rated as '+4' qualifications, a BTech does not normally allow entry into a Master of Science (MSc) degree (+6) offered by the universities and this in turn has implications for entry into doctorate (PhD) programmes. This is because the BTech is more pragmatically oriented than the BSc (Eng) due to the experiential training component in the national diploma (d'Almaine et al. 1997). Students graduating with a BTech may gain access to an MTech and then a DTech programme, both of which also have a more practical emphasis than do their university counterparts, the MSc and PhD.

Case (2006) notes that the restructuring of higher education in South Africa has done little to change the pecking order: the more theoretically-inclined traditional universities remain more prestigious than universities of technology. There have been numerous attempts to build bridges between the two types of programmes but these have not been successful.

The situation is more hopeful in France. In 1966, +2 technical degrees were introduced thanks to the creation of French University Institutes of Technology (UITs). These institutes offer +2 professionally-oriented university degrees to ambitious students at K-12 level to pursue engineering. Although designated *diplôme*, the first qualification obtained through the UITs is different from a diploma in South Africa in that there is no experiential training component. There are, however, more options available for *diplôme* graduates: entering the workplace, completing another year of professionally-oriented study to obtain their '*Licence Professionnelle*' (similar to the

South African BTech) or furthering their studies at a university or *Grandes Ecoles*. As of 2008, there were 116 UITs attached to 80 universities across the country.

Another bridge exists in France. Although it only comprises of three institutes, the ‘University of Technology’ system was established in 1972. There is no national *concours* for entrance into this system which combines attributers from *Grandes Ecoles* and the universities to offer a five-year *diplôme d’ingénieur(e)* which is equivalent to the Master’s level degree and thus allows the candidate entry into PhD programmes.

Analysis of the impact of extended curriculum programmes

What can be seen as unique in South Africa is that in extended programmes, student preparedness is taken into consideration in order to facilitate transition. Students from extended programmes are considered to have the same engineering degree as mainstream students on graduation. As mentioned above, a number of these programmes were established in the 1980s at the previously white English-medium universities. Although it has taken some time, favourable educational policy and earmarked government funding have allowed extended programmes to be introduced into just about every engineering department in the country since the mid-2000s (Kloot, Case and Marshall 2008). This has culminated in a recent proposal by the Council on Higher Education (CHE) for the structural transformation of the entire higher education landscape based on the notion of extending all higher education curricula by one year (CHE 2013). Regarding students admitted into extended programmes, the proposal notes that the ‘great majority of these students would not have qualified for admission to the corresponding mainstream curriculum, and according to school-leaving grades and entry-level assessments, were underprepared for conventional higher education programmes’ (CHE 2013, 90).

While there is ample evidence of individual students who have succeeded after being given a chance to study engineering via the extended programme route (Garraway 2009) there are also worrying signs that the widespread adoption of extended curriculum programmes across the sector has not brought about the desired change. The graph below shows engineering enrolments vs graduation from about the time of the democratic transition.

[Figure 1 to be inserted here]

Figure 1. Undergraduate engineering enrolments vs graduation in South Africa: 1989–2010.

While both enrolment and graduation patterns were fairly constant during the 1990s, the 2000s saw enrolments increase by 95% while graduations increased by only 50%. A closer investigation reveals that performance patterns in all programmes, including engineering, are racially skewed. In fact, an analysis of the undergraduate engineering cohort entering all programmes in 2006 shows that while 55% of white students successfully graduated within five years, only 23% of black African students did so (CHE 2013, 50). This suggests that the historical effects of apartheid education are persistent, since they are bound up with wider social and economic factors. It appears that while *political* apartheid collapsed in 1994, social and economic apartheid continues to play a significant role in student performance. As a result of a lack of enthusiasm towards the CHE proposal from the universities, the envisaged structural transformation has been put on hold but it appears as if the Department of Higher Education and Training (DHET) will increase funding to extended programmes.

Unfortunately, there is also substantial qualitative evidence that the devastating effects of apartheid still linger at South Africa's universities. An investigation conducted by the Department of Education in 2008 aiming to eliminate discrimination

revealed that ‘discrimination, in particular with regard to racism and sexism, is pervasive in our institutions’ (DoE 2008, 13). The report noted that there is an apparent disjunction between institutional policies relating to transformation and the real-life experiences of staff and students.

The resentment that this state of affairs has generated was vividly demonstrated by the student protests that erupted at South African universities recently. It is interesting to note that these protests, which started in March 2015 and have continued into 2016, began with formation of a student movement called ‘Rhodes Must Fall’ which demanded that a statue of Cecil John Rhodes at UCT be removed (Hall 2015). The protests gained momentum, leading to a wider movement calling for the ‘decolonisation’ of education in South Africa as well as free education, with students recalling the promise in the ANC’s Freedom Charter (1955). This roused the sympathies of students around the world and even prompted an anti-colonialist march in Oxford in England to demand the removal of a statue of Rhodes at Oriel College (Elgot 2016).

Conservative and transformative forces

As in South Africa, some traditional engineering education models in Europe take into consideration student transition factors (Holmegaard 2015) in line with recommendations *via-à-vis* social inclusion and equal opportunities. To be sure, many obstacles have to be overcome to effectively implement social openness in programmes of excellence for all students who have the potential to succeed. Repeating a year or semester in order to limit student dropout has been shown to have a negative impact on self-efficacy and self-confidence in a period of transition. On one hand, for under-prepared students, vacation ‘boot camps’ allow for extra time on task for those who need it, for example between semesters. Open education opportunities (Munoz et al. 2016) also offer resources for extra work although these demand extra time.

An example of a meaningful initiative is the *cordées de la réussite* (literally ‘success ropes’) launched in France in 2008. This involves the setting up of partnerships between secondary schools and higher or engineering programmes in order to promote access to higher education for young people irrespective of their socio-cultural background. It gives young students some keys to successfully engaging in the higher educational sectors of excellence. In practice, such networks of solidarity are stimulated via structured actions between regional institutions, like tutoring and cultural and academic support. These actions are expected to reduce psychological or cultural barriers by paving a bridge between secondary and tertiary education. Operated by volunteer undergraduate students, who have often had to overcome the same kind of difficulties, the initiative makes it possible to transfer appropriate codes and to change young peoples’ attitudes and preconceptions, facilitating the transition between education levels and improving the prospect of success.

All these initiatives do not impact on the architecture of the programme.

South Africa as a social laboratory

Without in any way minimising the human suffering that apartheid brought about and continues to inflict on the people of South Africa, this society may be thought of as one of the world’s major social laboratories. As expressed in the report on the elimination of discrimination referred to earlier, South African higher education is ‘unrivalled, in the kind of material it offers that may be used to understand the human condition and the environment in which people live’ (DoE 2008, 6). It is possible to draw some analogies from the South African case about engineering education in other countries.

It is abundantly clear from the South African scenario that education systems are incredibly difficult to transform. If we take the view that education systems play a major role in the reproduction of society, then this is an extremely important issue. Contrary to

what might be expected, Bourdieu suggests that rather than aiding transformation, the school is actually a conservative force (Bourdieu 1974). In the South African case, the racial rhetoric behind the student protests and the calls to decolonise the curriculum prompt an investigation into whether the patterns of privilege laid down in the time of Cecil John Rhodes are in fact still with us. Perhaps these patterns were embedded in the system by the colonisers and remain entrenched by contemporary economic and social affairs?

In their analysis of the French schooling system, Bourdieu and Passeron (1977) employed the notion of 'cultural capital' to explain the tendency of students from privileged backgrounds to outperform working class students in assessment tasks because of their familiarity with middle class culture. If we think of South Africa as a kind of social laboratory, it enables us to see the effects of deliberately relegating a segment of the population to the working class by denying them access to educational and economic opportunities (which is what took place for people of colour under the apartheid regime for about 40 years) and then suddenly granting them access (what ostensibly took place in 1994). Through this lens, we can understand the poor performance of black students, especially in prestigious engineering programmes as illustrated in Figure 1, in terms of social class rather than race. In other words, the use of race as a proxy for class illustrates that the patterns of performance in an education system rely heavily on wider socio-economic factors.

In *The State Nobility*, Bourdieu (1996) investigates how the *Grandes Ecoles* function to produce France's technocratic elite and how this reinforces the elitist structure of French society. Students entering the *Grandes Ecoles* typically come from families well-endowed with cultural capital and the system, Bourdieu suggests, works to 'consecrate' the mental structures that such schools inculcate. Since the *Grandes Ecoles*

are mostly engaged in engineering education, this has important lessons in other national contexts. In his foreword to *The State Nobility*, Loïc Wacquant suggests that the analytical framework that Bourdieu employs has a wider applicability than the peculiarly elitist case of French education. He maintains that elite schools function in much the same way in every country but that the specific form that this elitist structure takes depends 'on a number of intersecting factors, including the historical trajectory of (upper) class formation, state structures, and the shape of the system of education in the society and time under consideration' (in Bourdieu 1996, xiii).

If we once again return to South Africa as our case study, it is clear that the influence of British education on that offered in the Cape Colony and the establishment of the School of Mines in Kimberley, and later in Johannesburg, played an important role in the formation of the upper class. It is beyond the scope of this article to comment on how this intersected with state structures during the years of apartheid and how the interests of 'big business' – in particular the mining companies – were served by the elitist education system that was laid down a century ago. However, the evidence on the ground in South Africa certainly seems to corroborate Bourdieu's assertion that educational systems act as a conservative, rather than a transformative force in society.

Conclusion

This article has shown that the basic pattern of engineering education that found its way to the shores of the British Cape Colony at the turn of the nineteenth century has remained largely intact until the present time. The form this took was a rather theoretically oriented engineering science degree at Bachelor's level, mostly inspired by the ancient Scottish – rather than the English – universities. Although quite different to the French model in terms of its practical orientation and qualification level, as well as the overall architecture of the system in terms of its relation to the state, and to the

professional body, there are remarkable similarities in terms of the role of engineering training in the development of a technocratic elite.

How this played out in the context of the formation of the nation of South Africa, with its economy built on gold mining and the establishment of a political system designed to oppress the majority black population is certainly unique. However, this article highlights the astonishing durability of the patterns of privilege that these educational structures reinforce, now more than two decades after the fall of apartheid. What is interesting is that these patterns appear to be grounded in social class rather than race *per se* which has implications for engineering education in other parts of the world, such as in Europe where combating discrimination and including disadvantaged learners, such as those from immigrant backgrounds, is a declared priority.

The sustained focus on curriculum modification in the South African case, and the apparent lack of success of this approach, also has broader implications. It suggests that, while the programme architecture may be altered to cater for certain groups of students, it is more difficult to ensure that the learning outcomes are equivalent. This is relevant with regard to attempts to ensure comparability of engineering qualifications across Europe as articulated by the Bologna process. On one hand, it may be that the particular national trajectories of engineering education systems are simply incompatible with others that have developed on a different path. Attempts to adapt the learning outcomes by altering the curriculum structure of the programme – or even through other means that do not impact on programme architecture – may simply be window dressing. On the other hand, it may be that the particular local context of South Africa, and the problems being encountered in the post-apartheid period, are more than a system rooted in the British model can deal with. If this is the case, then the similarities of the different European models of engineering education and training,

coupled with the relatively similar socio-economic contexts in Europe, may be favourable enough to ensure the comparability and interoperability as envisaged by the Bologna process.

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