Factors affecting engineering student success

A South African perspective

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Abstract— Worldwide at universities student success is high on the agenda; the priority is to introduce interventions to enhance throughput while maintaining high-quality teaching standards. In engineering faculties, we are experiencing pressure to educate and graduate more engineers in the minimum time. In South Africa, where the demographics of our student population have changed in the last ten years, we are facing new challenges in dealing with engineering students from diverse backgrounds. There is a need to reflect on what we have learned in the last 24 years after becoming a democratic republic and to use these lessons in thinking strategically for the future. For this paper we did a systematic literature review to identify factors that have contributed to student success for South African engineering students since 1994. A hundred and forty-nine South African engineering-related papers were identified for the systematic literature review. These were critically evaluated for relevance and reduced to a sample set of 33 papers used for identification of factors contributing to student success. Our results are presented from the school, student, lecturer, university, government and accreditation stakeholder perspective and include themes such as student selection, student support and teaching and learning practices.

Keywords—Engineering student success, South African engineers, success factors for engineering students.

I. INTRODUCTION

Engineers are generally people who are inclined to build or create things or processes and their greatest satisfaction is watching something that they conceived, designed and built being implemented successfully as they intended. Peace engineering can be described as engineers creating things, but doing so with an ethical mindset and having an anticipatory imagination [1]. The future engineer in the fourth industrial revolution, besides having the technical depth to formulate technical solutions for problems, also needs to develop such solutions to be sustainable in social and environmental terms. Hence peace engineering will thrive in a world where social equity, transparency and a culture of quality and excellence thrive. To achieve this in a developing economy such as South Africa, student access and success in engineering are critical. In South Africa education has always been one of the key focus areas of importance and since 1994 we have witnessed a significant growth in enrolment in both the school and higher education sectors. However, there are still concerns about overall numbers, equity and the proportion of the student body that succeeds [2]. Some concerns include that only one out of four students in contact institutions graduate on time, only a third of the registered students graduate within five years and completion rates remain skewed: white completion rates on average are higher than African rates [2]. For engineering degrees, the picture does not look much better. Of the 2006 cohort of engineering students, only 41% of the students completed their four-year degree in five years [3].

Engineering remains a scarce skill and South Africa, similar to other countries, identified the training of more engineers as a priority [4]. South Africa, "at one engineer per 3166 of [the] population, ranks well behind such countries as Brazil (227), the United Kingdom (311), Australia (455) and Chile (681), although well ahead of such African countries as Tanzania (5930) and Zimbabwe (6373)" [4]. It is a priority that the engineers we train are also from previously disadvantaged groups to make the engineering profession representative of the country's demographics. However, although more students from designated groups are allowed into engineering programs, these students from previously disadvantaged groups face unique challenges. For example, poor quality of schooling is pertinent, where many of the students might be in the top of their matriculation group but are under-prepared for the challenges they face when entering university programs [4]. The result is the low throughput mentioned, where students from previously disadvantaged groups perform worse than other students.

In the last 24 years there have been a number of initiatives to address the poor performance of university students. However, there are still numerous challenges and the purpose of this paper is to give an overview of some of the challenges experienced by role players responsible for student success, as reported in literature. Furthermore, we provide some success factors leading to higher student throughput.

The paper is based on a systematic literature review as presented in section II. In section III the challenges and success factors are discussed from different role players' perspectives, followed by a conclusion in section IV.

II. SYSTEMATIC LITERATURE REVIEW

For this research we conducted a systematic literature review. Kitchenham [5] defines a systematic literature review as "a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest". We followed the five

steps for a systematic review, namely to identify resources, study the selection, do data extraction, data synthesis and then write up the study as a report [5-6].

We followed a qualitative interpretive research philosophy with the focus on understanding the content retrieved during the review [7]. The systematic review was conducted using the University of Pretoria library resources that consist of all the prominent journals. We used combinations of four key terms [student, South Africa, engineering, success] in our search and included the titles of articles, keywords and abstracts. The search was limited to English papers only and the period was 1994 to 2018.

We initially started with 149 papers. All papers were screened and we only kept papers that included discussions on student success and solutions for problems experienced by engineering students. We ended with 33 resources that focused on studies related to engineering in South Africa. We used thematic analysis to identify key challenges and student success factors and grouped these problems and success factors together for discussion in section III.

III. Student Challenges and Factors Enabling Student Success

During the thematic analysis, problems and success factors were categorized according to the different role players responsible for or involved in the construct. The role players involved in the student life cycle used in the analysis are modeled in Figure 1.

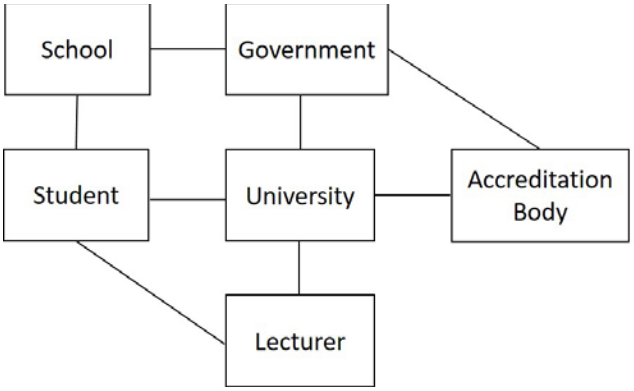

Fig. 1. Role players identified during thematic analysis

The role players in student success include firstly the school that the student attends pre-university. Public schools are funded by government and government prescribes the content taught in schools that is examined in a final examination in Grade 12. Private schools are not financially supported by government and the school has the choice of writing the South African Matriculation examination or an alternative accredited examination acknowledged by South African universities. Universities are financially supported by government and the curriculum is governed by government through registration of programs. Students also contribute part of the funding for studies. For students who are unable to pay for university studies, National Student Financial Aid Scheme (NSFAS) funding is available, granted based on family income. Lectures are directly linked to students enrolled at a university through modules presented to them as part of a study program. Lastly, the engineering programs at South African universities align with the Engineering Council of South Africa (ECSA) accreditation body. In the remainder of this section the challenges and factors affecting student success are discussed according to the themes identified during the systematic review.

A. School

The first school was established in South Africa in 1658 and several years later, in 1839, an Education Department was established in the Cape with a superintendent, James Rose Innes, at its head [8]. In 1948 the National Party won the election in South Africa and the apartheid era started, where the government created an unequal system along rigid racial lines. Education was provided to black children in South Africa through the Bantu Education Act, but the schools were often under-resourced and school attendance [9] was not compulsory. After 1994, where the country moved into a democratic era, education for the masses became central to the changes in South Africa and it remains a key focus area [8].

Government acknowledges the dire need for more engineers and has supported initiatives to grow engineering numbers. At the University of Pretoria the number has doubled from 600 students in 2002 to more or less 1200 new enrollments in 2018. However, we are faced with the legacy of apartheid, namely poor high school preparation [10]. According to the subject report on the 2017 national senior certificate [11], of the 245 103 students who wrote the Mathematics papers in 2017, only 6 726 passed with the 80% needed to guarantee entry into most engineering degrees. Students who obtain senior certificates in the South African schooling system cannot be assumed to be adequately prepared to meet the demands of tertiary education. However, several studies show that even these students who obtain senior certificates satisfying the entry requirements to enter engineering courses are not necessarily adequately prepared to meet the demands of tertiary education [12-17].

Some of the recommendations for the school system include [15, 9, 4]:

- A total overhaul of the school system, both on primary and secondary level.
- Mathematics and Science should receive serious attention at school level – attracting experienced teachers through higher salaries is one suggestion to obtain better results.
- The matriculation or university entry examinations need to be reconsidered.
- Consideration needs to be given to the establishment of an A-level system.
- Career advice on school level needs to prepare the student to make an informed decision on selecting engineering or an alternative career.

B. Student

Student dropout rates are one of the biggest concerns in the South African higher education domain. According to the Vital

Statistics Public Higher Education 2016 report [18], which contains statistics on throughput for the 26 universities in South Africa, about a third of students who enrolled in 2011 for a four-year degree as first-year students had dropped out by 2016.

Until recently one of the key reasons for the low attrition rate was the challenges faced by students to fund their own studies [19-20]. In reaction to the fees must fall campaign in 2015/2016 at South African universities, the then president, Jacob Zuma, announced free education for lower income families in December 2017 [21]. It will take another four years at least for the results of this intervention to become evident.

In a study conducted among engineering students at the University of KwaZulu-Natal [20], financial constraints were the top indicator for leaving university. Other factors identified were transition to "university study (lectures rather than lessons, larger class numbers, the lack of staff-student interaction and an inability to understand the lecturer) and the level of material covered" [20]. Similarly, Mpanza [19] found factors causing students to leave engineering programs to include the tight timetable followed at university, lack of learning skills and thinking capacity and difficulty in adapting to university studies. Furthermore, Graham [22] found that students who performed poorly focused mainly on past papers and did not complete assigned tutorials, for example. According to his study the students could cope in this way with lower levels, but when more was expected from them on higher levels they could not cope. Another factor that emerged was that students felt disengaged because of being overwhelmed by the course content [23]. One pertinent contributor to student failure is that students do not understand what engineering really is and therefore do not always make the right study choice in selecting engineering as first choice [4]. They then often only realize too late that this is not what they wanted to do and leave the study programs to start working or to study something else.

One last observation was that the class attendance of successful students is better than that of poorly performing students [17]. Several reasons can be offered for this phenomenon, but the most pertinent one is probably the freedom associated with university, where time management skills become the responsibility of the student.

Several challenges were identified above, and limited resources have to be employed optimally to find solutions for these challenges faced by students. Some of the solutions are student-centered and need action from the student. These include:

- Focus on development of skills to cope at higher education institutions, including for example study orientation in Mathematics.
- Class attendance should be a priority for successful completion of studies – even though materials might be available online, student-lecturer interaction still proves to be the most effective way to develop the conceptual thinking skills engineers need.
- Students should use opportunities provided by universities to ensure success in studies. These include for example workshops on topics such as time management or the assistance provided by faculty student advisors [13].
- Students should develop high-level thinking skills through class attendance, attendance of tutorials and doing exercises independently – they have to be careful of falling into the trap of learning by studying examination papers.

C. University

As mentioned previously, there is a growing demand for more skilled engineering professionals. According to Case [9], the greatest challenges arise on the supply side of the equation, but universities have a responsibility to ensure that the throughput is increased without lowering standards. Engineering programs are already costly for institutions to run and in recent years, with budget cuts, it has been a challenge for many universities to introduce interventions to grow student throughput. A danger in chasing numbers is that universities may fall into the trap to lower standards [15] and in the process suffer long-term effects when graduates are produced who cannot cope with the engineering problems for which industry needs to find solutions.

One of the challenges universities face that affect students are the late payment of student subsidies and grants to universities. A significant number of students receive help from government in the form of NSFAS grants and if these are received late, the universities need to stand in to support students. This constrains universities from operating effectively at the beginning of the academic year [14]. Many universities had to close down some of their essential services to students in order to balance the books; for example, Mpanza [19] reported on the early closure of libraries to students, an essential service to enable a vibrant study environment.

Several suggestions have been made in literature for universities to embark on ensuring student success. Some of these include:

- Offer workshops for students on "examination preparation, planning, including examination question analysis (Test Strategies) and relaxation techniques before and during the examination" [24, 25, 19].
- Introduce bridging programs for students who want to complete the course in the allotted time but might need additional support [26, 19].
- Introduce co-curricular interventions to prepare students for the world of work [25].
- Provide additional tutoring to students who struggle without creating a stigma of being a struggling student [10, 17].
- Establish international partnerships to expose students to international role players for development purposes [25].
- Create more opportunities for career guidance and develop better screening methods for students before they make a final decision to study engineering to prevent wrong study choices [19, 4].
- Expose female engineering students to strong female role models [25].
- Provide grant support to students receiving grants to allow them to develop grant management skills [4].

- Value the power of technology and use it in the recruitment of students [25].
- Develop strategies to reward excellent lecturers to prevent staff from feeling undervalued for good teaching and learning initiatives [4].
- Constantly make government aware of staff-student ratios to improve student-lecturer interaction [4].
- Work on improvement of throughput without lowering standards [15].
- Value the role of class representatives, teaching assistance, academic development lecturers and mentors during the study period [3, 17].
- Adopt a positive outlook; the institution should be open to critique and listen to industry demands [16]

D. Lecturers

Skilled, trained engineers have a scarce skill in South Africa and engineering is one of the careers in the top paying band [27]. Engineers who choose education as a career are mostly passionate about education and are good educators. The lower salaries paid by universities are a challenge and often result in losing top educators to industry [9]. In recent years the emphasis in universities has also shifted, placing more focus on research, which has resulted in demotivating staff who joined universities firstly to be educators [9]. In addition, student numbers have grown in the engineering departments, resulting in a higher student-staff ratio, which poses new challenges to the engineering lecturer [14]. Staff are also confronted with students from different demographics and with different needs and need to adapt to this new student profile. As a result of an inadequate school system students 'learn to pass' and not always to understand content properly, which results in students on higher levels often not even remembering what was done on lower levels during their training [28].

From a student perspective, a challenge is that lecturers are not always clear on learning outcomes in their courses [29] and students often do not understand the lecturers because of their teaching styles [19].

Several guidelines for lecturers to enhance student success are provided in literature, including:

- Use more experienced lecturers for complex subjects with a student-centered approach [29].
- Use designated staff members as part of bridging programs so that students receive the necessary support to enhance their chances of success [26].
- Use one single platform for teaching and refrain from using different technologies that may confuse students [29].
- Recognize the different identities held by students; the lecturer can then provide an authentic range of engineering-focused activities through which students can develop engineering-focused identities [30].
- Create collaborative student groups [17], especially on first-year level where students are still struggling to fit into the university system. These groups have proven to be of value.

E. Goverment

In 2009 the Department of Higher Education and Training (DHET) was established to manage post-school education and training in South Africa. Training includes all education and training for learners completing school, those who did not complete school and children who never attended school [31]. The current higher education system is based on a White Paper published in 2013 [32], in which the policy gives directions to DHET to build "a developmental state with a vibrant democracy and a flourishing economy".

The DHET in South Africa faces a number of challenges, many of which we have already mentioned in this paper. Sehoole [33] adds to those already listed the importance of DHET defining its own roles and strategies in the internationalization process. However, DHET faces a legacy of problems, including the quality of education at primary and secondary levels that is supposed to prepare individuals for tertiary levels [34]. Furthermore, Chetty and Pather [34] highlight that the quality of school education remains a problem, linked to the teacher attrition rate and the shortage of teachers in the country. Moreover, government is now faced with providing free education for low-income families, a requirement that will necessitate financial cuts in other government domains [35].

Linked to these challenges, some directions that should be pertinent for government include:

- Revising of the school curriculum to ensure that children follow a proper Mathematics and Science curriculum that stimulates conceptual thinking [4].
- Providing funding to universities earlier in the year to ensure distribution to needy students [4, 9].
- Providing additional funding to schools to enable children to make an informed choice in selecting what to study.
- Revising the university subsidy funding model; many engineering schools have doubled their numbers without additional funding for staff, which put an enormous burden on the lecturers [15].

F. Accreditation bodies

The last construct that we consider in this paper is the role of the accreditation body. In South Africa engineering programs are accredited by the ECSA a statutory body established in terms of the Engineering Profession Act, 46 of 2000 [36]. The role of ECSA is to arrange visits to universities for accreditation of their programs, registration of engineers as professionals and the monitoring of the practice of registered engineers.

ECSA should continuously revise the requirements of the curriculum and ensure that the challenges identified by industry, such as problem-solving skills, are included in the curriculum and taught as part of the subject content for all subjects [37, 4].

With regard to the interaction between government and ECSA, Mpanza [19] argues that there needs to be more interaction between the Departments of Basic Education and Higher Education to support the development of students' capability. According to him, ECSA should facilitate this process between key stakeholders and role-players. Blyth [15] supports this notion and argues that accreditation bodies should play a role in addressing the issues in the school system.

IV. Conclusion

In this article we give an overview of the challenges and make some recommendations from a role player perspective. From the analysis it is clear that the biggest responsibility for student success resides at universities. However, universities will not be able to reach higher throughput without a better pipeline of students with competency in Mathematics and Science. Furthermore, these students should make an informed decision when selecting engineering as career choice to prevent early drop-out from the degree programs. Government plays a pertinent role in creating an enabling environment for universities. The roles of the lecturer and student are emphasized; students need to take responsibility for their learning activities and lecturers should create a supportive environment for students to enable learning in the different modules. Lastly, the role of the accreditation body, ECSA, is emphasized, since the governance of programs is pertinent to maintain standards.

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