Master's of Engineering Management: Graduation rates lagging behind growth rate

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***Abstract*—The Engineering Management degree at master's level has been taught at a South African higher education institution for more than 20 years. The student enrollment numbers have seen significant growth over the last decade, with a year-on-year growth varying from 20% to 39% each year. The coursework master's program consists of a number of lectured modules and a research component which accounts for fifty percent of the program. The students are very successful in completing the lectured modules, but they are less successful in completing the research component. The main problem is that students complete the lectured component within the required time, but when they start doing the research component they either take longer than the allocated time or they never reach completion.**

The cohort data from 2006 to 2013 indicate that the students on average take 3.3 years to complete their studies and thus do not complete their studies in the minimum of two years for part-time or 18 months for full-time enrollments. On average there is a 42% drop-out rate, which is high, although still lower than the norm compared to the national benchmark. The South African national benchmark data from the Centre for Higher Education Transformation indicate that the drop-out rate at master's level across all qualifications was 57% for 2013.

The fact that postgraduate student numbers are growing but the graduation rates are not growing at a similar rate has been highlighted by various international authors and research institutions. This research focused firstly on understanding the relationship between the students' performance in the lectured modules compared to their performance during the completion of the research component. Secondly, the research identified the challenges facing the students that prevent them from completing their studies within the allocated time or that delay completion.

The identification of the trends highlights the education needs of the target group of postgraduate candidates who are generally in full-time employment. This information will assist in future planning to accommodate growth, but also in readjusting the approach to teaching and learning during postgraduate studies in order to support specific groups to improve success rates.

Keywords—coursework master's; time-to-completion; Engineering Management

I. INTRODUCTION

One of the main problems in a taught master's degree is that students complete the lectured component within the required time, but for the research component they either take much longer than the allocated time or never complete the studies. When the number of students that take longer than desired becomes too high, additional strain is placed on the educational resources [1].

The national labor market of South Africa has a significant demand for qualified engineering managers. Engineering managers are clustered with manufacturing managers and are listed 37 out of 100 on the 2014 national scarce skills list, as published in the Government Gazette [2], within the South African market.

The service delivery of higher education institutions focuses mainly on outputs, which are graduates and research outcomes to society [3]. To respond to the skills shortages in the African labor market, it is important for South African institutions of higher education to achieve high success rates in the engineering management field. The South African national benchmark data from the Centre for Higher Education Transformation (CHET) indicates that the drop-out rate at master's level across all qualifications was 57% for 2013 [4].

A specific higher education institution has been offering coursework master's engineering management programs for approximately 20 years. The purpose of the coursework master's in Engineering Management is to develop professionals for leadership roles in engineering and related fields. This program enables individuals with a degree in engineering, science or a related field to advance their careers to management positions. The coursework master's degree consists of a set of lectured modules and a research dissertation that accounts for 50% of the program.

In 2015 a quality review was done of the coursework master's program. The review panel consisted of 11 engineering management experts from local and international academia as well as local industry. The international representatives were from Australia as well as the United States of America. It was clear from this review that the students are very successful in completing the required lectured modules, but less successful in completing the research component.

The reason for the low success rates in the research component, as observed by academic staff, is the requirement that the students must prove their ability to do research independently while being in full-time employment. When completing the modules, there is contact time and assessments with deadlines which are enforced. During the research component students are expected to manage the research

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process as an individual and take full responsibility for their performance.

The target market of the program is full-time employed students who typically are enrolled part time. The only full-time students are international students with only a study permit. The international student base has varied between 5 and 12% in the last six cohorts. Taking into account their work pressure, the students do not allocate the required time to the research and this has a negative impact on their success rate. The low success rate for the dissertation has a direct impact on the throughput rates.

The maximum study period is two years for full-time master's program students and three years for part-time students. As the coursework master's degree has a minimum study period of 18 months for full-time and two-years for part-time students, the time to completion for part-time students is expected to be within three years.

The Engineering Management student enrollment numbers have seen significant growth over the last decade. In order to sustain the growth, it must be ensured that the completion rate also grows along with the enrollment rate. It is therefore important to understand the challenges students experience during the completion of the research component.

Research is available to provide insight into the students who undertake a taught master's, their prior learning experiences and expectations that can be considered during the development of student support [5]. As highlighted by Drennan and Clarke [6], the coursework master's degree is one of the least understood or researched academic levels in higher education. There is also very limited knowledge of student performance during a coursework master's in Engineering Management when comparing the lectured component to the research component.

The research objective of this study was to add to the knowledge of the taught master's research component in the engineering management field. The aim was firstly to analyze the students' performance during the lectured component compared to that during the research component. Secondly, it attempted to identify the challenges facing students that prevent them from finishing within the time limit or cause them to never complete.

The first section provides the background on the master's profiles in South Africa as well as the specific engineering management program. Thereafter the review states what literature suggests are the key challenges facing postgraduate students during their studies. In the next section, the students' performance during the lectured component is compared to their performance during the research component. The first section provides results from the data analysis to evaluate the graduation rate and identify student behavior patterns. The second section reports on findings from a student survey in order to identify student challenges during studies, followed by a discussion.

II. Problem Review

The level of economic growth envisaged by South Africa as a country requires the production of a next generation knowledge community. A 10-year plan set out to be achieved by 2018 indicates that South Africa's PhD production must grow fivefold, to about 3,000 science, engineering and technology PhDs per annum [7].

To provide a flow of PhDs towards achieving these targets, the master's graduate rate must be increased while maintaining the quality of the student output. The national statistics as produced by CHET show the throughput rates at a specific point in 2013 for the 2008 cohort. For coursework master's across disciplines in South Africa, on average 54% of the students graduated and 46% of the 2008 cohort had dropped out by 2013, which is six years after enrollment [8]. Further details show that for engineering coursework master's degrees, 55% of the cohort graduated within four years [8]. These statistics confirm that in the South Africa market the actual time to completion for master's studies is more than the expected time to completion, which is three years for part-time studies.

The graduation rates must urgently be addressed in the engineering field to support the country to become globally competitive. The following section presents an analysis of student performance in the coursework master's program at the specific higher education institution.

A. Student Profile and Performance

The Engineering Management student enrollment numbers have seen significant growth over the last decade. At one of the higher education institutions servicing the economic hub of South Africa, the coursework master's program is offered on a full-time as well as a part-time basis. The students are required to complete the modules first, after which they are required to complete the research component. This implies that a part-time student has to complete the program over a minimum period of two years and the maximum time to completion is within three years.

The majority of the students in the programs are working professionals who wish to enhance their knowledge in the field of engineering management in order to advance their careers in different companies, often to managerial positions. As the majority of students are working, they enroll part time.

The program has grown substantially, with a current intake of around 100 new enrollments annually. The growth in the number of students has exceeded expectations, with a year-on-year growth varying between 20 to 39% each year as displayed Table I.

TABLE I. Headcount Enrollment per Year

	Headcount Enrollments							
	2008	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***
Total headcount	59	77	104	138	167	232	261	329
Growth year-on-year (enrollments)	9%	31%	35%	33%	21%	39%	13%	26%

The enrollment growth is compared with the graduation rate as illustrated in Fig. 1.

Fig. 1 shows the steady growth in enrollments. When comparing it to the graduation growth rate, it is encouraging to also see growth in the graduation numbers. The 2015 graduation numbers show a decline. The reason for this is that at the point of analysis not all 2015 graduations had been recorded yet.

Although the graduation rate is growing, the rate is not growing steadily along with that of the enrollments.

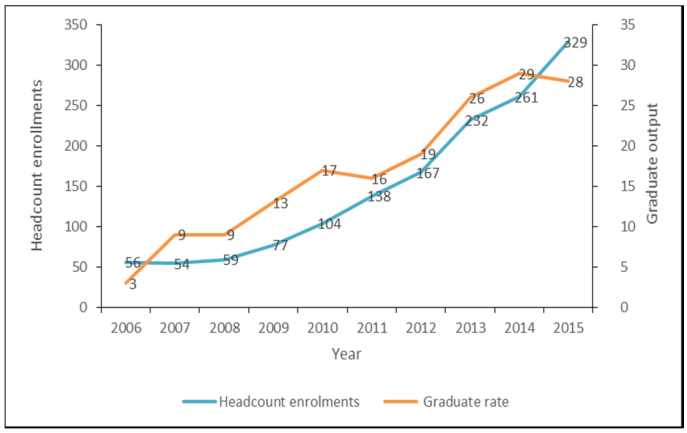

Fig. 1. Enrollments compared to graduations year-on-year

The enrollment headcount of a specific year is compared to the graduation rate two years in advance, as the time to completion is a minimum of two years, as well as the graduation rate plus two years' additional time to completion. The data illustrate that students take longer than the minimum time to completion, as illustrated in Fig. 2.

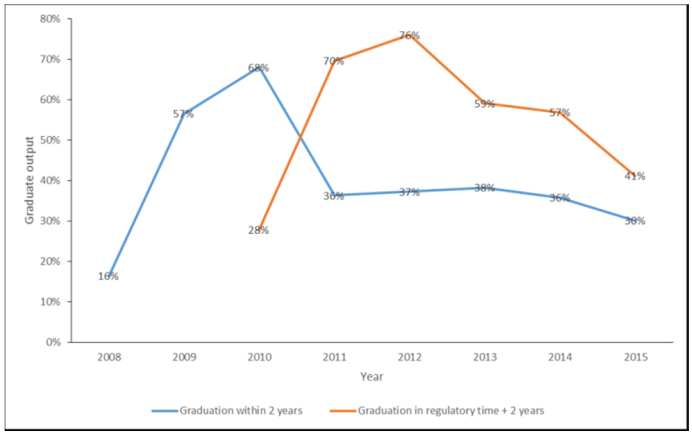

Fig. 2. Graduation rate vs. graduation rate + 2 years

The data from 2006 to 2013 indicate that on average students take 3.3 years to complete their studies. From this presentation it is clear that the students do not complete their studies in the minimum allocated time of two years for full-time or three years for part-time studies. Although there is also a relative percentage of dropouts that never graduate or enroll again to complete their studies, this figure is still lower than the norm of the national benchmark from the CHET data. The 2013 CHET data indicate the drop-out rate at master's level across all qualifications as 57%.

From the data it is assumed that the master's Engineering Management students do not graduate within the minimum allocated time to completion.

The analysis is drilled down to review student performance at module level to identify performance patterns. The success rate of the modules completed per year for the past six years is evaluated first.

The success rate of students of the six lectured modules has been above 60% for the past six years, as illustrated in Fig. 3. The throughput per module per year shows that the students are very successful in completing the six lectured modules.

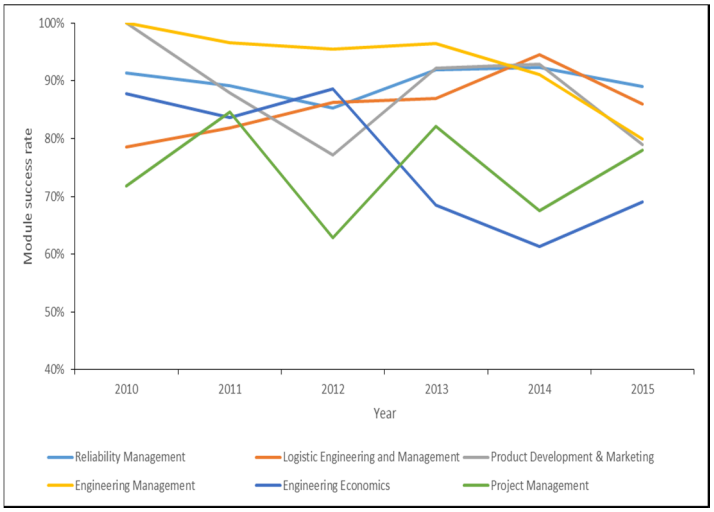

Fig. 3. Success rate for lectured modules

The average mark students obtained for each module of the individual lectured modules as well as the research component has been above 60% for the past ten years, as displayed in Fig. 4.

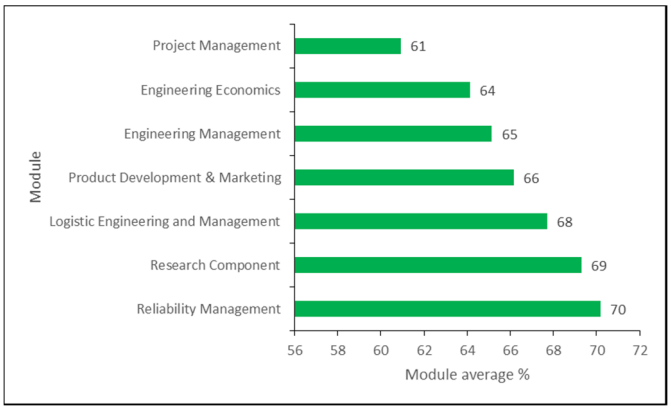

Fig. 4. Module averages

The average of each module including the research component indicates above average student performance.

The reason is that the student end results are considered. If the time taken to complete the modules is examined, it becomes clear that this is longer than expected. For example, the students are expected to complete the research component within one year. An analysis of the behavior of the students who have graduated shows that it took them on average 1.86 years to complete the research component. This adds at least an additional year of study to their time to completion, which excludes any additional time taken to complete any of the other modules.

To determine if there was a difference in student performance between the success achieved by students who graduated in the modules to that of students who did not graduate, each group was analyzed separately.

The analysis, illustrated in Fig. 5, indicates that the average performance of students who graduated was higher than that of students who did not graduate.

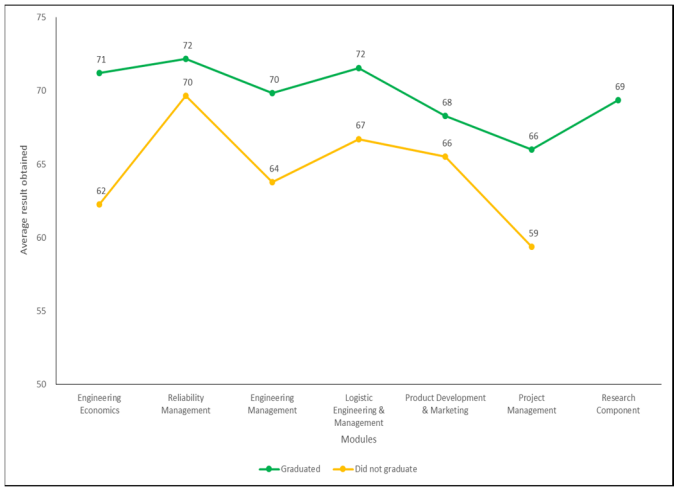

Fig. 5. Averages of students who graduated vs. those who did not

The difference in averages when comparing the group which graduated with the group which did not is shown in Table II.

TABLE II. AVERAGES OF GROUP THAT GRADUATED VS. THOSE THAT DID NOT

Average Difference	
Modules	***Average differences***
Engineering Economics	8.9%
Reliability Management	2.5%
Engineering Management	6%
Logistic Engineering & Management	4.8%
Product Development & Marketing	2.8%
Project Management	6.6%

This data indicate that students with a higher average obtained during completion of modules are those who completed the program. Engineering Management as well as Project Management are two of the modules where there are differences in the averages between graduates compared to those who did not graduate. Both these modules make use of assessments to test the students' ability to write academically.

The data analysis confirmed that students are not finishing within the required time to completion, although student performance is good during the lectured modules. When they have to complete the research component and if they do complete it, their performance is also good.

It was therefore decided to identify from the students' perspective what challenges they experience and to identify trends for the time to completion exceeding the allocated time, or reasons for students dropping out.

A student survey was conducted to understand what challenges students experience during the coursework master's program. This was done to identify external trends that impacted negatively on their performance. The findings from the students' perspective are discussed in the following section.

III. STUDENT SURVEY RESULTS

Literature was first reviewed to identify the known challenges experienced by students. This was used to compile the questionnaire to be used as a measuring instrument.

Research has been published by Fook and Sidhu [9] on what challenges are experienced by students in higher education. Their research covered a cross-section of the student population and included undergraduates as well as postgraduates [9]. They identified eight common challenges faced by students in higher education, namely the cognitive challenge, becoming an active learner, coping with reading materials, instructional problems, language barriers, time management, burden of assignments and cultural differences in higher education. In a study conducted by Liu [10], three main challenges were identified when postgraduate students study abroad. These were understanding of learning (some students have an "inquiry" approach and apply critical thinking versus memorization), language barriers as well as the pressure of course demands that impact on completion within the minimum time.

In order to identify external trends that impacted on student performance, a survey research method was utilized to produce quantitative descriptions on some aspects of a studied population [11]. As adequate data were not available to identify the student challenges, the target population for the survey was all students who had been enrolled for the coursework master's program between 2009 and 2016. A total of 531 participants were contacted directly via online platforms as their email addresses were known to the researchers. A response rate of 32% was achieved with 168 responses received.

As the survey had multiple purposes, the survey posed different questions to different participants:

- *Graduates:* Identifying if the student had graduated already or would soon graduate with a coursework master's in Engineering Management (Responses: 21).
- *Dropped out:* Identifying if the student had dropped out of studies and had not yet completed the studies (Responses: 1).

- *New 2016 registration:* Identifying if the student had registered for the coursework master's for the first time in 2016 to start the degree studies (Responses: 83).
- *Currently in progress:* Identifying if students completed all or some of the required modules (Responses: 63).

One of the objectives of the survey was to identify the challenges students faced. The challenges presented in the survey were based on the existing challenges identified from literature [9, 10]. A five-point Likert scale was provided and the respondents were asked to rate the effect of the challenges on their performance [12], with 1 = No affect; 2 = Minor affect; 3 = Not applicable; 4 = Moderate affect; 5 = Major affect).

The challenges which students experienced during their studies that could prevent them from completing or that could cause a delay in completion are now discussed. Newly registered students were not questioned on the challenges experienced as they had only just started the program. As only one response was obtained from a student who had dropped out, this response was not used.

First, the students currently busy with their studies were analyzed. The three top challenges that stood out from the responses, as illustrated in Fig. 6, were time management, employment challenges and cognitive challenges.

The respondents indicated they had difficulty in managing their time and finding a balance between employment, study and home demands. 39% of the current students indicated that time management had a major effect on their performance and 34% were moderately affected. In total 73% stated that time management had an effect on their performance.

Following on time management was employment demands. Students indicated they were allocated to a project that required travelling. 25% of the current students indicated that work demands had a major effect on their performance and 12% experienced a moderate effect. A total of 37% of the students experienced an impact on their studies due to work demands.

The students also rated the cognitive challenge to develop skills to think in scholarly terms and write academically to have a significant impact on their performance. 24% of the students indicated that this had a major effect, and 34% a moderate impact. A total of 58% of current students experienced an impact due to this factor.

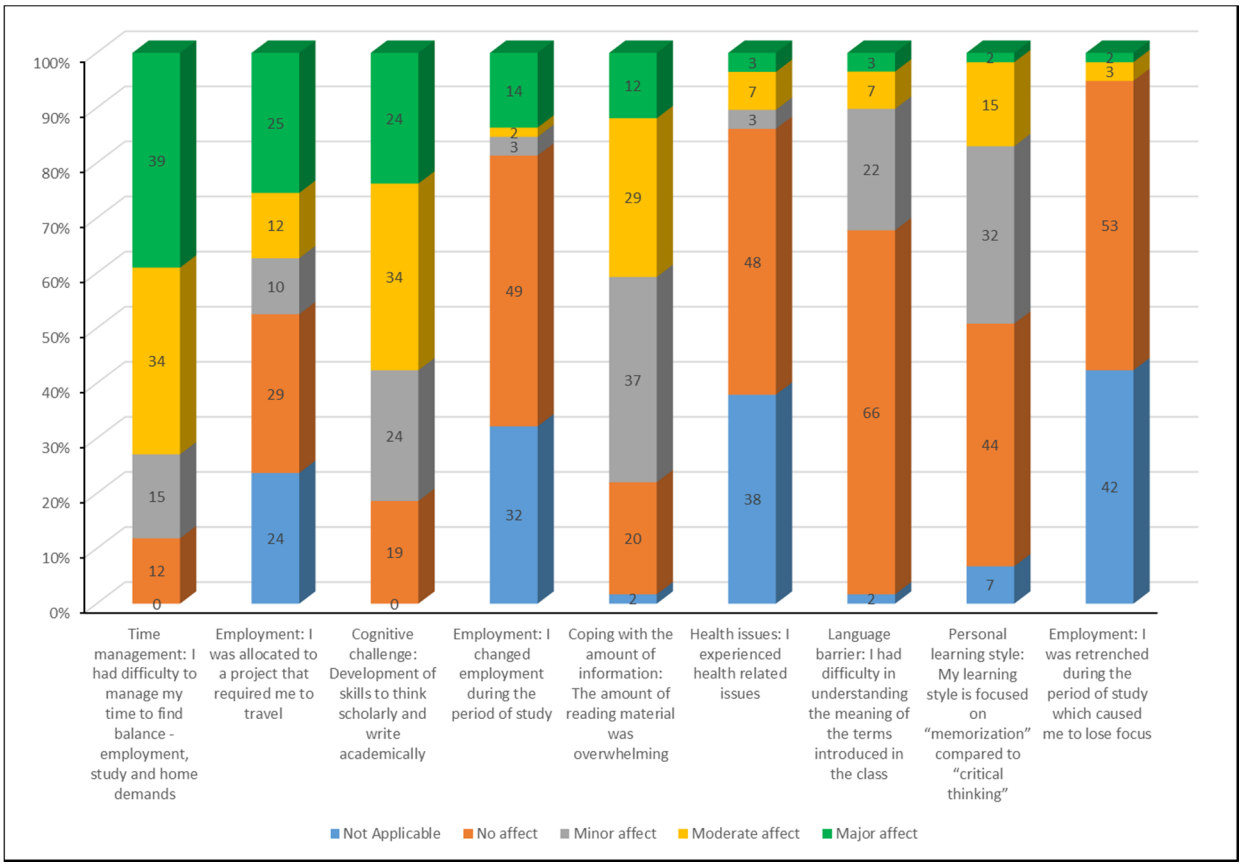

Fig. 6. Challenges of current students

The challenges identified by students who had graduated already were in line with those of the students who were currently still studying. Two of the challenges in the top three are similar, as illustrated in Fig. 7.

Time management was identified by 20% as having a major impact and 25% reported a moderate impact, totaling 45% of the students who responded that it had an impact on their performance.

The cognitive challenge to develop skills to think in scholarly terms and write academically had a major impact on 15% and a moderate impact on another 15%, totaling 30% who responded that it had an impact on their performance.

Coping with the amount of work had a major impact on 10% and a moderate impact on 20%, totaling 30% of students who responded that it had an impact on their performance.

With regard to employment demands, students indicated they were allocated to a project which required them to travel. Of these students, 10% indicated that it had a major impact and 5% a moderate impact, totaling 15% who indicated that it had an impact on performance as per Fig. 7.

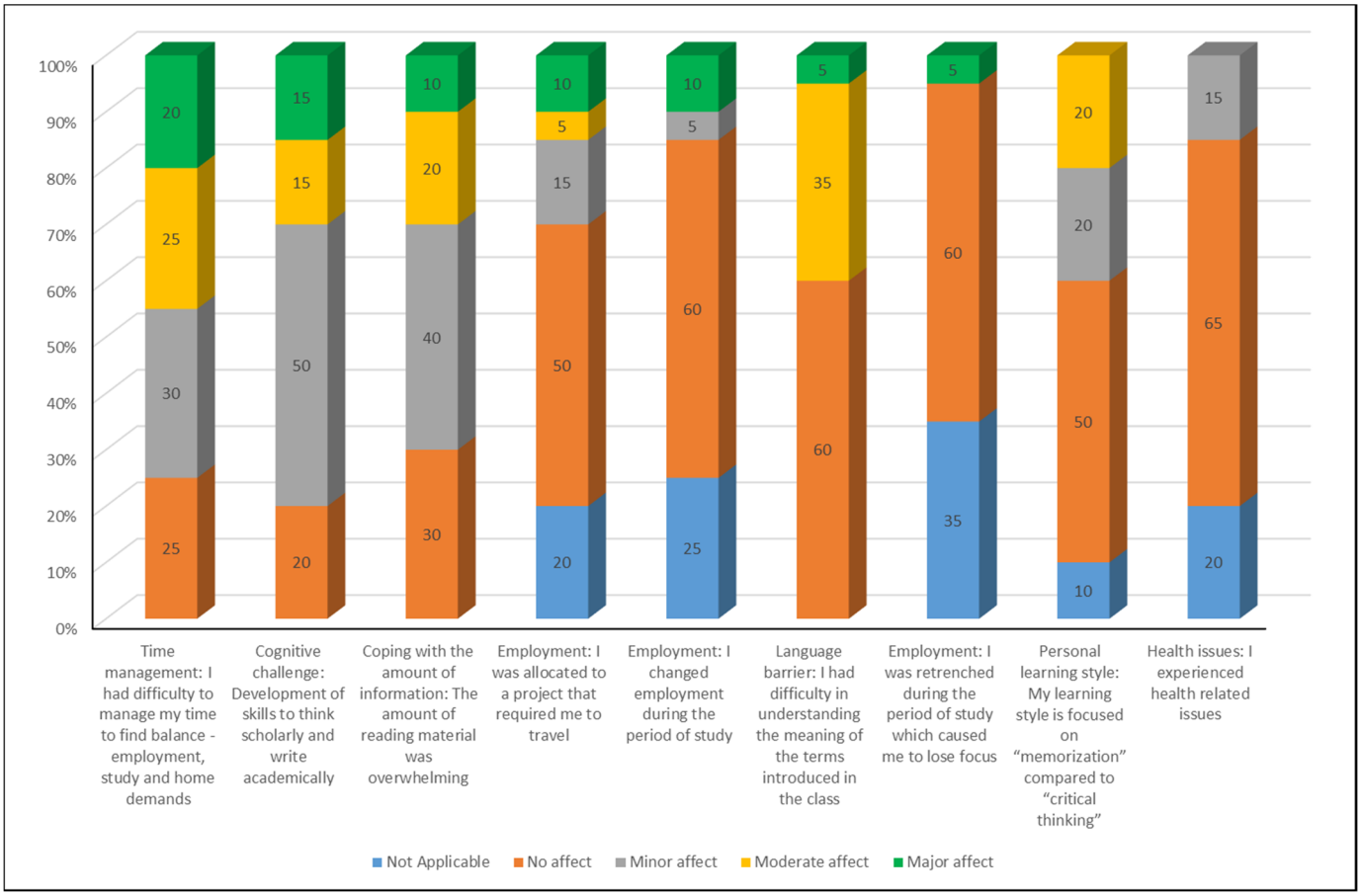

Fig. 7. Challenges of graduates

The employment challenge is an external challenge, which the higher institution has no control over. Two of the challenges identified, namely time management and cognitive challenges, can be mitigated by additional education services. These are discussed in the following section.

IV. Implications for Teaching

Aligned with the program outcomes, the academic staff expect the students to take full responsibility for the execution of the research project. One of the outcomes of the program focuses on the planning and management of engineering management research projects. The findings of the student survey indicate that the biggest challenge of 73% of the students who were currently studying and 45% of graduates was time management.

Time management is noted as a competency which is very important for engineers, but lacking in many [13, 14]. It could be assumed that for the duration of the program, this competency is still under development. Each individual student could also operate at a different level of competency with

regard to their time management ability based on the individual's experience. It is therefore suggested that alternative approaches be implemented by the academic support staff of the program to facilitate the desired development of the time management competency in the student.

As the program is targeted at employed engineers or technologists, it is important for graduates to develop time management skills to support the industry needs. To be recognized as a professional engineer or technologist in industry, a person is required to be assessed through the Engineering Council of South Africa (ECSA). In the policies documenting the acceptable engineering work required to register as professional engineers or professional engineering technicians, it is emphasized that the person must have the knowledge and skills to be able to manage engineering activities [15, 16]. The outcomes relating to managing the engineering activities of the professional engineers or professional engineering technicians are compared in Table III.

TABLE III. ECSA RANGE STATEMENTS [15, 16]

ECSA Range Statements for Outcomes of Managing Engineering Activities	
Professional Engineer	***Professional Engineering Technologist***
Manage part or all of one or more complex engineering activities. Management is directed at achieving engineering results through management of people, resources, processes, systems and money and involves: • Planning complex engineering activities • Organising complex engineering activities • Leading engineering activities • Controlling complex engineering activities	Manage part or all of one or more broadly defined engineering activities. Communicate clearly with others in the course of his or her engineering activities. • Planning activities • Organising activities • Leading activities • Implementing activities and • Controlling the activities

From Table III it is noted that the professional engineers are expected to manage complex activities, and the technologists are expected to manage broadly defined activities. Although there is a difference in complexity, the importance of the time management capability in the industry is no different. The implications for teaching are that consideration should be giving during the research component to enhance the development of this capability and the assumption should not simply be made that the students have already mastered it.

The second challenge highlighted by students was related to the cognitive challenge, which entails the development of skills to think in scholarly terms and write academically. When the outcomes of the foundational qualifications of the students are evaluated, which is typically either an accredited Engineering Technology program or a four-year Engineering degree, all the students are expected to have some ability to communicate effectively [17, 18]. They are also expected to know how to use knowledge in a cross-disciplinary context and apply it in problem solving. However, academic scholarly writing is different and cannot be compared to their engineering written communication ability. Currently two of the modules' assessments are focused on academic scholarly writing. It is recommended that additional content be introduced in these modules to prepare students more for academic scholarly writing.

Additionally, students must be assisted in developing time management skills during the study period. This can be done by having an induction session prior to contact time and discussing the impact of the studies on their life. By monitoring the individual component of the research process and providing feedback on expectations, the students will be guided through the process to understand the academic expectations. This element links to time management where the research process is divided into components.

V. CONCLUSION

Engineering Management education deals with a diverse group of students. The students have a diverse educational foundation as well as diverse work experience. The challenge is to provide them with academic support that facilitates the development of the expected capabilities to complete the qualification, but also to meet the differing needs to facilitate this development.

If the development of the time management capability is fast tracked successfully, it is expected to result in a positive impact on the time to completion.

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