DESIGN OF THE ENGINEERING AUGMENTED DEGREE PROGRAMME AT THE UNIVERSITY OF PRETORIA

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Introduction

According to the Royal Academy of Engineering (June 2007),

No factor is more critical in underpinning the continuing health and vitality of any national economy than a strong supply of graduate engineers equipped with the understanding, attitudes and abilities necessary to apply their skills in business and other environments.

If this is true in developed countries, how much more important is it in a country like South Africa that has an enormous backlog in the infrastructure needed for a decent standard of living, including clean water supply, sanitation, housing, food, transportation and electricity? South Africa has far too few engineers to meet these needs for the whole population. According to Lawless (2005), the ratio of registered engineer to population is 1:3166 in South Africa, compared with 1:543 in Malaysia, 1:389 in the USA and 1:130 in China. Nor is this situation likely to improve any time soon if we continue to run our engineering programmes in the future as we have in the past. According to the Council on Higher Education (October 2009), the graduation rate for Science, Engineering and Technology in 2007 was 17.0%. Although this is an increase over the 2004 figure of 15.0%, in terms of the *number* of graduates with engineering qualifications, there was a change from 6 032 in 2004 to 8 381 in 2007, a miniscule fraction of South Africa's population of nearly 50 million people.

In the late 1980s and the 1990s, most universities in South Africa ran some sort of access programme in science and/or engineering (NARSET, 1997). These programmes fell into three main categories—foundation year, extended degree and augmented. In 2006 the Department of Education informed universities to restructure their access activities into credit-bearing extended degree programmes with a certain minimum number of foundation modules (equivalent to 0.5 HEMIS credits).

In 1994 the School of Engineering at the University of Pretoria initiated a 5-year programme in which students spread the course load of the first two years over three years. Extra tutorials were available in certain first year subjects. A subset of the students, those who needed the most mathematics and language support, took a foundation course in the first year called Professional Orientation. This 5-year programme did not meet the Department of Education's requirements to be classified as an extended degree programme. It also had the disadvantage that students struggled to cope with a full, mainstream course load in their fourth year after having had a much lighter load in their first three years.

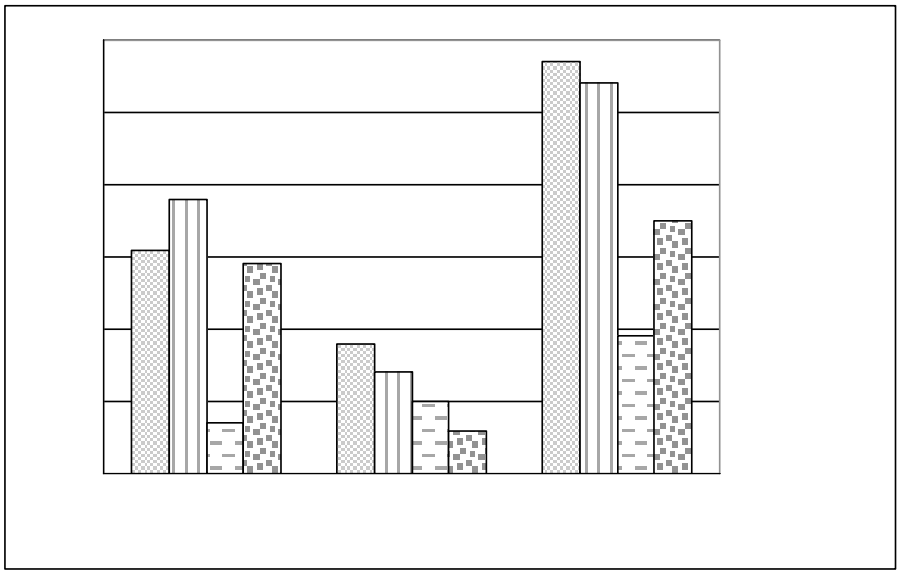

Figure 1: Graduation rates in Engineering for the 2002 cohort of students

An analysis of the 531 (34 black) students who first enrolled for Engineering in 2002 (Figure 1) showed that while the overall graduation rate for students on the 5-year extended degree program (54%) was similar to that for students in the mainstream 4-year program (57%), not much more than half of the entering engineering students obtained degrees within seven years. For black students the figures were worse. Only 35% of black students on the 5-year program graduated within seven years of first registration. Although this is nearly twice the graduation rate for black students on the 4-year program, the attrition rate is too high to meet South Africa's need for equity and for engineers.

These figures are not too different from the national graduation rates for the 2000 cohort of engineering students of 64% for white students and 32% of black students after 5 years of study (Scott et al, 2007). Nonetheless, given that engineering students represent some of the best performing school leavers in the country the graduation rate, even for white students, is alarmingly low. The huge disparity in graduation rates between black and white students is unacceptable.

2009

In 2009 a new problem arose. Between 2006 and 2008 a new high school curriculum was introduced at the Further Education and Training, or FET, level (Grades 10 to 12). In 2008 the first school-leaving examinations based on the new curriculum were written. While the new curricula in mathematics and physical science were designed to focus more on conceptual understanding, problem-solving and critical thinking than the old curricula, the marks obtained in the first semester among science and engineering students who entered South African universities in 2009 were lower than in the past. Anecdotal evidence suggests that high school teachers did not feel adequately prepared to cope with the new emphasis and the new topics. As a result, it seems as if many teachers concentrated on drilling students on how to answer examination questions, rather than how to understand the concepts and think for themselves about how to approach the questions. Discussions with individual students during the year indicated that many students felt that their teachers had "spoonfed" them.

In July 2009, after the first semester results were available, a letter was sent out to all 1100 first year Engineering students at the University of Pretoria. Students who failed three or more courses were encouraged to transfer from Engineering to the extended degree programme in Natural Sciences. If they performed well enough, they were told, they could re-apply for Engineering in 2010. Those who made the switch would have the benefit of attending classes of 40, instead of lecture groups of 500, and taking courses that covered less material but in more depth and with more support than they had had in engineering. One hundred and ten students chose to transfer. Questionnaires returned by 60 of those students provide useful information about why the students did so poorly in the first semester and what can be done to help them.

Table 1 shows the answers to selected questions in the questionnaire. For each aspect of their studies, students were asked two separate questions, one about their expectations and one about what they could cope with. The results show that most students found that in the first semester the volume of work was too high, the speed was too great, the level of difficulty was too hard, the amount of support was too little and the students' time management was too poor. In some aspects of their studies there was a difference between what students expected and what they said they could cope with. For example, more than a third of students indicated they were able to cope with the amount of work, even though the load was more than they expected. On the other hand, most students neither expected nor could cope with the level of the difficulty of the work.

Table 1: Responses to a questionnaire about first year engineering students' experiences in the first semester (N=60)

The amount of work I had to do was	18 Much more than I expected	37 More than I expected	5 About what I expected	Less than I expected	Much less than I expected
The amount of work I had to do was	13 Much more than I could cope with	23 More than I could cope with	22 About what I am able to cope with	1 Less than I am able to cope with	Much less than I am able to cope with
The speed at which the work was covered was	22 Much faster than I expected	27 Faster than I expected	10 About what I expected	Slower than I expected	Much slower than I expected
The speed at which the work was covered was	16 Much faster than I am comfortable with	29 Faster than I am comfortable with	14 About what I am comfortable with	1 Slower than I can cope with	Much slower than I can cope with
The level of difficulty of the work was	14 Much harder than I expected	34 Harder than I expected	12 About what I expected	Easier than I expected	Much easier than I expected
The level of	8	32	19		

difficulty of the work was	Much harder than I am comfortable with	Harder than I am comfortable with	About what I am comfortable with	Easier than I am able to cope with	Much easier than I am able to cope with
The amount of support I got from lecturers was	Much more than I expected	5 More than I expected	16 About what I expected	31 Less than I expected	7 Much less than I expected
The amount of support I got from lecturers was	1 Much more than I needed	3 More than I needed	13 About what I needed	29 Less than I needed	14 Much less than I needed
The way I organized my time was	1 Excellent	2 Good	13 Satisfactory	32 Poor	12 Very poor

Students were also asked to summarise their experience as a first year engineering student. The responses below indicate several of the most common sentiments:

- Well I socialised too much in the first semester and that was the reason for my poor marks.
- When coming to the university I thought I was gifted academically and could handle all the work. But within two months my positive attitude turned into a negative one. No matter how much effort I put in, nothing seemed to work.
- I wasted my own time because I didn't study.
- I enjoy it very much, the subjects and classes, but I was new to student life and didn't study hard. Work is hard work and is done very fast. Self study is very important.
- I was relatively enthusiastic at first but, this feeling waned as I was confronted with the downward spiral of failure

Conceptual framework

In 2009 a new programme was designed, the Engineering Augmented Degree Programme (ENGAGE), according to the following design principles:

1. Students should be supported in making the transition from high school to university.
2. Student workload (time students spend working) should be high throughout.
3. The volume of work (amount of content covered) should be low initially and increase over time.
4. Support should be high initially and decrease over time.
5. Students should encounter familiar subjects early in the program, less familiar subjects later on.

The conceptual framework is represented in Figure 2.

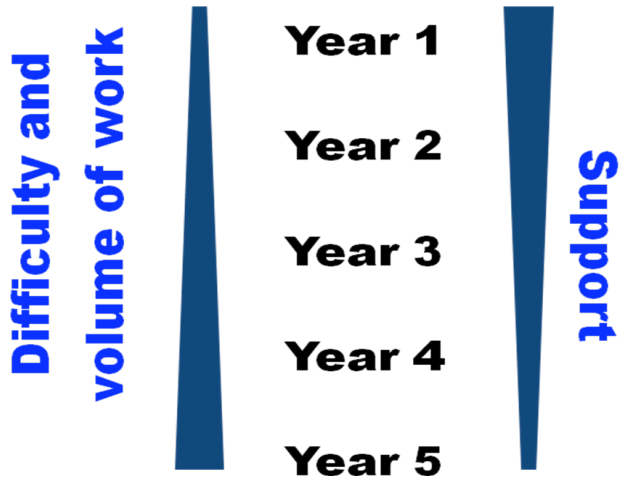

Figure 2: Representation of the conceptual framework of the ENGAGE programme

In coming up with these design principles, I was guided by my experience in running the Science Foundation Programme in the 1990s at the then University of Natal. Six factors were identified then as affecting student performance that are still relevant today. These are: background knowledge, attitudes, behaviours, cognitive skills, practical skills and metacognitive skills (Grayson 1996).

Description of the ENGAGE programme

The ENGAGE programme consists of both mainstream and developmental modules. At the end of the degree ENGAGE students will have taken 72 credits more than the four-year programme students. The developmental modules comprise two one-semester foundation modules called "Professional Orientation", offered in the first year, and augmented modules, called additional modules, offered in the first two years of the programme. The level 100 and 200 mainstream modules are spread out over three years. In the fourth year ENGAGE students join the mainstream. The decrease in support and increase in volume of work over the first three years are accomplished as follows:

In Year 1 students take a reduced credit load comprising level 100 basic science mainstream modules and additional modules, plus Professional Orientation.

In Year 2 students take level 100 engineering modules and additional modules. They take more credits than in Year 1 but fewer than 4-year programme students. They also take half of the required level 200 mathematics modules, with no additional support.

In Year 3 students take level 200 engineering modules and the other half of level 200 mathematics modules. There are no additional modules, but the number of credits is slightly lower than for 4-year programme students.

Table 2 shows how the volume of work and level of difficulty, indicated by the number of credits and level of the modules, of the ENGAGE programmes compare with the 4-year programme. The unfamiliarity of the level 100 engineering modules adds another dimension to the level of difficulty for ENGAGE students in Year 2.

Table 2: Comparison of the structure of the ENGAGE programme and the 4-year BEng programme

ENGAGE		**4-Year Programme**	
YEAR 1			
	CR		CR
Mainstream Science (level 100)	64	Mainstream Science and Eng (level 100)	144
Developmental	48		
YEAR 2			
Mainstream (level 100 + one 200)	96	Mainstream (level 200)	144
Developmental	32		
YEAR 3			
Mainstream (level 200)	128	Mainstream (level 300)	144
YEAR 4			
Mainstream (level 300)	144	Mainstream (level 400)	152/ 160
YEAR 5			
Mainstream (level 400)	152/ 160		

Professional Orientation uses a project-based approach to develop communication, technology, academic, information technology and life skills in an integrated way within an engineering context. For example, students receive copies of Engineering News every week, which are used as the context for developing reading and comprehension skills, as well as being a resource for some of the content required in the projects.

Additional modules are offered in both the basic sciences and engineering modules at level 100. Students take the additional modules in parallel with the mainstream modules. For each one semester, 16-credit, level 100 module students take an 8-credit additional module. Three of the four periods a week allocated to each additional module are "discussion classes", in which the focus is on developing conceptual understanding and cognitive, metacognitive and problem-solving skills. Additional modules are taught in groups of 50 students, in contrast to the mainstream modules, in which lecture class size may exceed 500 students. In each discussion

class session, two staff are present, the lecturer and a student tutor. In order to help students make the transition from high school to university, students are assisted in developing behaviours that characterise successful students. Attendance is compulsory in all developmental modules. Time management and metacognitive skills are enhanced through weekly assignments in each developmental module that are submitted and marked.

Discussion

In 2010 the first cohort of 304 students enrolled for the ENGAGE programme. When the change was made from the old Senior Certificate to the new National Senior Certificate, it was unclear how to set the admission criteria into various university programmes. The School of Engineering at the University of Pretoria chose to make the minimum marks required for entry into the 4-year BEng programme 70% for Mathematics and 60% for Physical Sciences. The minimum marks for entry into the ENGAGE programme were thus set 10% lower, i.e. 60% for Mathematics and 50% for Physical Sciences. About one quarter of the students in ENGAGE opted to register for ENGAGE although they met the entry requirements for the 4-year BEng programme. Figure 3 shows the marks obtained in Grade 12 Physical Sciences and Mathematics for the 2010 ENGAGE students. This figure shows that the majority (67%) of the ENGAGE students met the mathematics entry requirement for the 4-year programme.

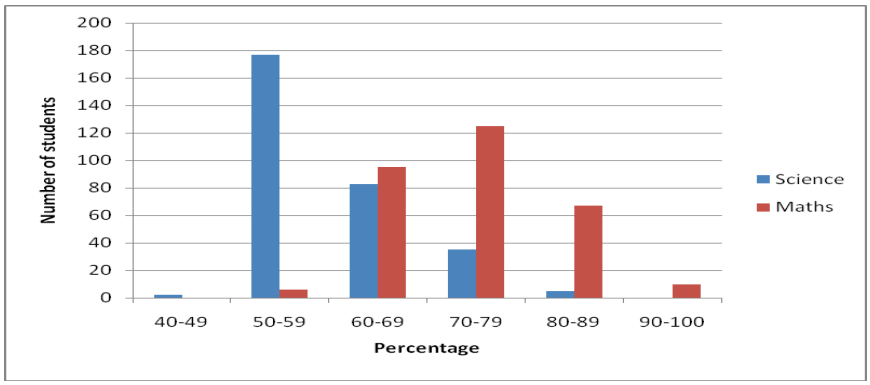

Figure 3: Grade 12 Physical Sciences and Mathematics marks for 2010 ENGAGE students

At the end of the first semester, the pass rate for the two mainstream modules, Calculus and Chemistry, were 55% and 42%, respectively. For these mainstream modules the overall pass rates were 81% (after supplementary examinations and a winter school) and 59%, respectively. Figure 4 shows how ENGAGE students performed in terms of credits passed (out of 56), where each of the two mainstream modules is worth 16 credits and each of the three developmental modules is worth 8 credits, and number of modules failed (out of 5). Only about one third (112/305) of students passed both of the mainstream modules in the first semester. However, the Chemistry module is offered in both semesters at the University Pretoria, so a number of the students are repeating Chemistry this semester.

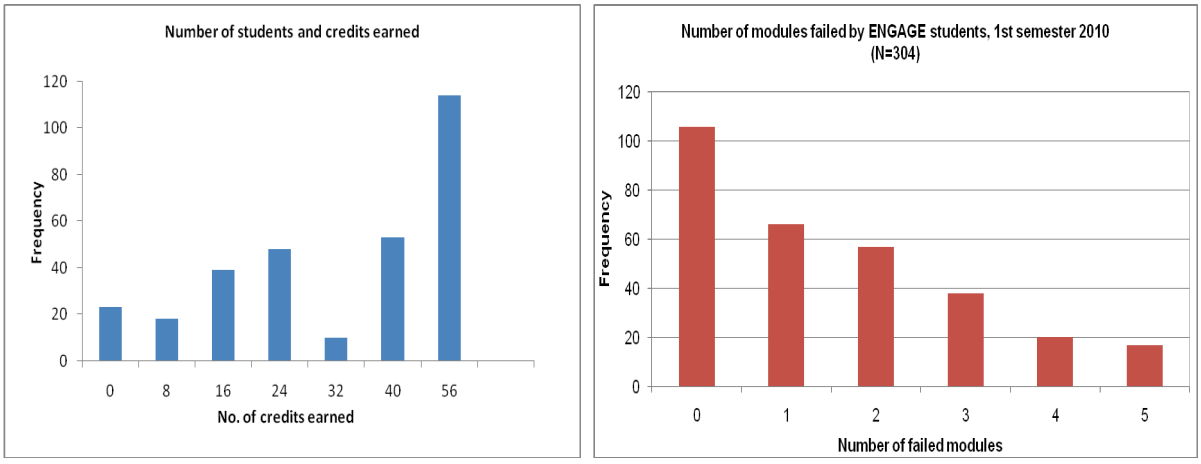

Figure 4: Performance of ENGAGE students in the first semester of 2010

Many questions arise from these results. One question is whether the criteria used to select and place students in the ENGAGE programme are appropriate. As mentioned above, the grade 12 mathematics and science marks

were used as two criteria. In addition, the students who did not meet the entrance criteria for the 4-year programme wrote the National Benchmark Tests (NBT). However, it is not yet known how the cut-off scores for the three categories of marks in the NBT (proficient, intermediate and basic) relate to the levels required for success in either ENGAGE or the 4-year BEng programme. In 2011 the School of Engineering will use a three-tiered admission system (Table 3).

Table 3: Admission criteria Engineering for 2011

	Points	**Min Maths**	**Min Phy Sc**
4-year	36	80%	70%
4-year or ENGAGE	30-35 +NBT	70%	60%
ENGAGE only	25-29 +NBT	60%	50%
Maybe 4-yr BSc	<30 + NBT	50%	50%

A second question is whether the ENGAGE model of a reduced load of mainstream modules running in parallel with additional modules provides extended degree students with enough support to make the transition from high school to university successfully. It is possible that the difference in approach and requirements between the large-lecture mainstream modules and high school is too big for the type of students in the ENGAGE programme, even with support in the additional modules. A third question is whether one semester is enough time for a student who is not ready to take the 4-year programme to adequately adjust to university. Are semester examinations inappropriate for extended degree students?

There were also logistical problems this year that could have negatively impacted on students' performance. These include late appointment of lecturers due to funding uncertainty, with the result that lecturers have had to develop new curricula and teach it "on the fly", late appointment of student tutors to assist in the discussion classes, uneven performance of these tutors and unequal group size in the discussion classes resulting in some groups that were much too large due to scheduling problems. All of these problems should be addressed in 2011.

At the end of the first semester we administered a questionnaire to ENGAGE students and received 209 responses. These responses show that most students perceive that ENGAGE is helping them adjust to the demands of university and to make the transition from high school to university (Table 4).

Table 4: Percentage (number) of ENGAGE students who agreed or strongly agreed with the statements in a questionnaire at the end of the first semester (N=209)

Being an ENGAGE student has helped me make the transition from school to university	84% (175)
I felt there was someone I could go to if I had academic problems during the semester	68 % (142)
I got the support I needed this semester	73% (153)
I kept up to date with my work this semester	71% (148)
I coped with the workload this semester	73% (153)
I learned useful life skills in ENGAGE this semester	84% (175)
After this semester I still want to be an engineer	95% (198)

The questionnaire responses also show that for most ENGAGE students the developmental modules are pitched at a level of difficulty and volume of work that the students think is manageable (Table 5).

Table 5: Percentage of students who agreed or strongly agreed with the statements about the ENGAGE developmental modules in the first semester of 2010

	Manageable amount of work	**Manageable level of difficulty**	**Got enough support**
Additional Mathematics	97	92	83
Additional Chemistry	96	88	79
Professional Orientation	93	96	87

It thus seems that from an affective perspective ENGAGE is proving to be successful for most of the students. It will take several years before we know whether throughout improves.

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