Expectations Versus Reality in the Education and Training of Engineers

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Abstract *— The stakeholders in an engineering degree programme, which include governments, university administrations, industry, academic staff, parents, students and the accreditation authorities, have varied, and often conflicting expectations and perceived entitlements. When managing a degree programme it is not possible to meet all the various expectations and therefore it is important to understand, prioritise and balance these expectations with the realities of the infrastructure, human resources, accreditation requirements and the skills of the intake. Some of the procedures and processes implemented by the School of Electrical and Information Engineering, described in this paper, include the selection process, strategies to change the students' habits and expectations, curriculum monitoring and implementing processes to ensure that the students are adequately prepared for their next year of study.*

Index Terms *— Curriculum development, Engineering education, Management.*

INTRODUCTION

The stakeholders in an engineering degree programme, at a public university, have varied and conflicting expectations and perceived entitlements. The stakeholders include the government, university administration, industry, academic staff, parents, students and the accreditation authorities. It is not possible when managing and designing a degree programme to meet all the various expectations and therefore it is important to understand, prioritise and balance these expectations with the realities of the infrastructure, human resources, accreditation requirements and the skills of the students coming from the secondary school system.

In this paper the problems and compromises in developing procedures and processes that have been implemented by the School of Electrical and Information Engineering to moderate and balance the multitude of expectations and the reality of an engineering programme are discussed. These procedures and processes include the selection process for the first year, analysing the first year students and implementing strategies to change the students' habits and expectations, curriculum monitoring for all courses in the degree programme and implementing processes to ensure the students are adequately prepared for their next year of study.

THE STAKEHOLDERS

There are many stakeholders in an engineering degree programme, ranging from the national government to the students. All the stakeholders have expectations and very often feel entitled to have all their expectations met. Unfortunately most of the expectations are based on a philosophy of greed, most output for the least input. The major stakeholders are:

- **Governments:** The expectations of governments are based on what they envisaged when planning their education policies; these are often based on political requirements and not necessarily best education practice. They also put in large financial support and therefore feel their expectations should be met and can even adjust the financial model to make sure their policies are implemented.
- **University Administrations:** University administrations are in a very difficult position as they have to balance the requirements of the first, second and third stream income sources (government, donors and student fees) and that of an excellent education system. Unfortunately, more often than not, the financial consideration usually wins as administrations are judged by their financial success.
- **Industry:** Industry expects and feels entitled to receive "work ready" graduates who are able to run the most complex projects without any further experience or training. The concept of the "engineer-in-training" has almost completely disappeared even though the accreditation authorities still require experience and training for registration as a professional engineer [1]. Training is a costly exercise and there is an attitude in industry that, as they are paying tax, it is the government's duty to supply them with engineers trained to their specific requirements.
- **Students:** The students expect to get a top class degree with as little work and the most fun as possible. The academics are expected to provide this environment for the students as, after all, they are paying their fees. Students also bring with them both expectations and perceived entitlements from the secondary school system where they

were totally dependent on their teachers who solved all their problems and they expect the same consideration at university.

- **Parents:** The parents' involvement is a relatively new phenomenon at our university. This is also a trait coming from the secondary school system. A visit by a parent to the teacher or principal would solve the student's problems. This expectation results in students believing that a visit, or even just a phone call, from a parent will change a fail to a pass, for instance.
- **Accreditation Bodies:** The other stakeholders' expectations are counter balanced by the accreditation bodies' requirements that the engineering graduates have to show that they meet the prerequisite outcomes and have defined knowledge and skills. One way to overcome this conflict is to offer a non-accredited degree programme where the expectations of the other stakeholders can overshadow society's need for minimum requirements for engineers, as defined by the accreditation bodies. This option has not been considered by the School as the country can ill afford to invest in the training of engineers who will never be able to follow an engineering career. Instead, these students should be actively encouraged to do a degree programme more suited to their talents.
- **Academic Staff:** With the pressures of research and the "publish or perish" syndrome, academic staff want perfect students, passionately interested in their engineering studies to an extent that they require almost no input or support from the academics, as this may interfere with their research outputs. University administrations often send mixed messages demanding increased undergraduate throughput (Academic Administration) and, simultaneously, increased research output (Research Administration). In the end, promotion is heavily weighted to the "paper count" in a particular focus area. Academic staff are, also, well aware of the necessity to maintain standards not only to meet the requirements of the accreditation bodies but to provide society with the best engineering graduates possible.

It is not possible for a degree programme to meet all the expectations of all the stakeholders but the procedures and processes implemented must be aimed at selecting the correct students, changing their habits and expectations, monitoring their progress and making sure they are prepared for the next year of study and future working life.

SELECTION PROCESS

There are expectations and the feeling of entitlement in the minds of both the applicants and their parents when applying for a place in an engineering degree programme. "An application automatically receives an acceptance" is the expectation. The reality is that there are in excess of fourteen thousand applications for only seven hundred and thirty places in the Faculty of Engineering and the Built Environment. The thought that there is competition for places at the university has not entered the applicants', and especially their parents', minds. The unreasonable expectation of a place in an engineering degree programme is highlighted by the fact that over twelve thousand of the fourteen thousand applications fall way below the university's published "Likely Acceptance Levels". This is probably based on the premise that "even if my child's marks are bad they have the potential to do anything, if given the chance". This attitude is also prevalent in those students who fail their first year of study and demand a "second chance" despite the fact that they are "stealing" someone else's first chance.

Selection procedures are currently dictated purely by the applicant's National Senior Certificate (NSC) marks. A good pass in English, Mathematics and Science is mandatory together with a good overall performance as defined by their "Admission Point Score" (APS). Analysis of the students' first year performance and their APS show a good correlation for the top 10% of the students admitted but no correlation for the other 90%. All that it shows is the good secondary school performers make good tertiary performers but for the other 90%, some reasonable secondary school performers perform dismally, and some poor secondary school performers excel.

A further problem is that the cohorts are not standardised from year to year. In 2008 the cohort had massively inflated Mathematics marks when compared to previous years and as a result inflated both the intake numbers with a resulting massive first year failure rate and drop out. Analysis of the 2009 intake indicated that about 60% should not have been accepted as they had no chance of passing [2]. Traditionally the mathematics mark correlated to the students' performance at tertiary level but with the advent of "Procedural Mathematics" [3]-[4], and inconsistent performance measurement, has ruled mathematics out as a predictor for success. In 2008 the science mark was a better predictor but there is no guarantee that this will be true in the future.

Bursary companies are also big offenders when they offer engineering bursaries to students from disadvantaged backgrounds, to meet their own social development targets. Students with no interest in engineering accept, as this is the only way they can get a tertiary education, and fail dismally trying to do very difficult courses that they have no interest in. These large companies should accept that providing bursaries for music, fine art, social sciences etc to clever students, with both aptitude and interest, in fields where they will succeed is beneficial to both the company and the country.

We must be careful in the selection process to distinguish between students who have the ability to get high marks in mathematics and science at school, and those with an aptitude towards and, especially, an interest in engineering.

From 2011 all applicants will be required to provide a biographical sketch (essay) and a motivation on why they should be allowed to enter into an engineering degree programme. This addition to the selection process has multiple goals as follows:

- Make the applicants, and their parents, aware that there is competition to get a place in an engineering degree programme.
- Reduce the number of spurious applications from students with marks below the "likely acceptance level" as more effort than just filling in an application form is required.
- Make the decision on "border-line" applicants easier as a simple scoring system will be used to assist in the selection of motivated and eager students.
- Assist with ensuring that we give preference to students whose first choice is to study engineering.

CHANGING THE HABITS AND EXPECTATIONS

Since 2004 changes have been implemented in the two first year courses presented by the School of Electrical and Information Engineering to modify the students' habits and change or nullify their expectations and perceived entitlements. The other first year courses are presented by the Science faculty making changes in those courses more difficult. The goals and the changes in terms of habits and expectations are:

1. To change the students' study habits from one of procedural learning to one of conceptual learning [2],[5].
    - Both the teaching style and the laboratory assignments were changed to develop conceptual and critical thinking.
    - Changing mark allocation for test and exam questions to emphasise conceptual thinking rather than mathematical procedures used as tools to solve the problems. No marks for the procedures if the concepts and basic knowledge is missing or incorrect [2].
2. Remove their dependence on their teachers, after twelve years of total dependence [6].
    - Introduction of self-evaluation tests in the first half of the year.
    - Individual and informal laboratory tasks to assess the students' ability to work on their own and complete tasks by the published deadlines
3. To make them responsible for their own success, not the "teachers" responsibility [7].
    - Emphasising at all interactions with the students that it is their responsibility to pass and not the university's responsibility to pass them. The response to a student's "I am disappointed with my mark" is "So are we, and what are you going to do about it".
    - Satisfactory performance as regards to participation and dead-lines, as communicated in the Course Brief and Outline [8], is strictly enforced. One warning letter and then deregistration from the course.

MAKING SURE THE STUDENTS ARE PREPARED FOR THE FUTURE

A major change was introduced to the Electric Circuits course in 2009 whereby the students were required not only to pass the course with a 50% pass mark but were also required to pass all four of the topics (knowledge areas) [2]. This was introduced as analysis showed that students were optimising their marks by concentrating on the procedural sections of the work and actually not covering in any way the conceptual parts. This compromised their success in second year as subjects such as Electronics and Electromagnetic Systems are impossible to pass without the basic concepts from the Electric Circuits course.

This concept of passing all topics to pass a course has now been introduced to the second year subjects and the third year mathematics course where the students' optimisation to pass the course was resulting in very low marks for the "Complex Variables and Integral Theorems" topic essential for the Signals and Systems and Control courses. In fact the marks and pass rate for these two courses relate almost exactly to the marks the students obtained for the "Complex Variables and Integral Theorems" topic and not the overall mathematics mark. The "pass all topics" requirement will be phased in to all subjects presented by the school from 2011.

MANAGING RESOURCES

Resource management is one of the more difficult tasks when deciding on the intake numbers for a degree programme. Stakeholders such as governments, university administrations and industry are often prepared to invest single "donations" to develop capital infrastructure, such as new lecture halls and laboratories to increase the production of engineering graduates. This is often rewarded with an opening function and a brass plaque acknowledging the donation. Donations for equipment to use in the new facilities are more difficult to obtain and companies do not want to donate funding for equipment into a laboratory with a competing company's name. On-going maintenance of the new facilities and equipment is not normally included in the "once-off" donation and when accepting such donations both the university and the schools must have the long term resources for maintenance and the upgrading of equipment.

Human resources are probably the most difficult to manage as none of the infrastructure and equipment donations consider the human requirements. Single donations are easy to plan and account for and usually come from a budgeted

item in a single financial year, where as increasing the staff compliment is a long term investment (100 years and more) requiring different budgeting techniques and commitment. It must be made quite clear to the stakeholders that just doubling the student numbers and doubling the infrastructure is doomed to failure if the staff compliment is not also doubled. This increased staff compliment would include academic staff, technical staff and administration staff. Schools need to make it quite clear that increasing student numbers can only happen if there is corresponding increase in human resources, not withstanding any improved infrastructure.

DISCUSSION

Other than offering a non-accredited degree programme it is possible to adjust the teaching methods to cater for the expertise of the student intake, i.e. make the programme predominantly procedural, and still obtain accreditation at the minimum level. This option has not been seriously considered by the academic staff in the School of Electrical and Information Engineering as this would reduce the competencies of our graduates and result in disaster for the development of South Africa.

The infrastructure (energy, water, sewage, roads, transport) in most of the developed countries in the world are reaching a point where much of it requires extensive maintenance and often complete replacement. In the emerging market countries, such as South Africa, the problem is even worse as we have to both maintain (replace) aging infrastructure and provide new infrastructure. In many cases the problem is getting away from us as there are not enough human resources, at all levels of the technology chain, to cater for all the demands.

It is imperative that we do not pander to the stakeholders and continue to produce conceptual and critical thinking graduates so that we, as a country, have a chance to meet all the expectations of the population in terms of maintaining and developing the infrastructure.

CONCLUSION

Managing the expectations and perceived entitlements of the multitude of stakeholders in an engineering degree programme is a difficult but essential task. As far as the students' expectations (and their parents) are concerned these can be managed by implementing selection procedures, course presentation styles and evaluation methods that will change the preconceived expectations and produce better graduates.

Managing the expectations of the other stakeholders such as governments, university administrations and industry is more difficult as this requires more political finesse to persuade these stakeholders to do the right thing and put their money where it will benefit to the school in its endeavours to provide quality engineering graduates to the country.

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