Improving Student Success and Graduate Quality

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Abstract

This paper addresses what has been done in the Faculty of Engineering at the University of Cape Town over the past twenty years to improve students success and hence the quality of our graduates. The paper notes the uneven school education received by incoming students in South Africa and the pressure to produce increasing numbers of quality engineering graduates. Three key initiatives undertaken in the past are discussed: improving teaching, curriculum reform, and research into student learning. The range of initiatives currently being undertaken in the Phumelela Project is described. The paper presents the Centre for Research in Engineering Education argument that success is shown by entering into the discourse of engineering and taking on the identity of engineering communities.

Keywords: student learning; improving teaching; engineering discourse; identity, community

1. Introduction

The UCT Faculty of Engineering has grown significantly over the past three decades. This growth has been accompanied by massive changes in student demographics, with black African students only being permitted to enter UCT after 1980. These demographic changes have posed great challenges to us, given the educational disadvantage suffered by most black African students because of the previous apartheid education system in South Africa.

Ten years ago the faculty was enlarged to become the Faculty of Engineering and the Built Environment (EBE), by incorporating the School of Architecture and the Department of Construction Economics and Management.

Over the past two years the South African government has acknowledged the pressing need in our country for engineering and built environment graduates. This has led to a number of initiatives to improve the output of such graduates, including large grants to our university and three others for this purpose.

1.1. Academic Support Programme (ASPECT)

The first major response to the increasing diversity in our student body, and the poor success of students from disadvantaged educational backgrounds in our programmes, was the initiation in 1988 of a faculty academic support programme, ASPECT (Academic Support Programme in Engineering at Cape Town).

ASPECT is not a bridging programme, but an extended curriculum, which spreads the curriculum for the first two years over three years. It provides both additional input on key skills as well as special teaching and support in critical first year courses such as mathematics and physics. It provides access to the Faculty for students who do not meet the normal entrance criteria (although in chemical engineering virtually all ASPECT students have met the normal criteria). ASPECT has proved to be a most successful programme which has been used as a model for academic support and development in other disciplines at UCT as well as in other institutions in South Africa [1]. It has also been a laboratory for educational innovation in the faculty.

1.2. The faculty curriculum development project

The next major response, both to the changing student situation and the changing needs of the workplace, was the curriculum development project undertaken by the Faculty of Engineering between 1992 and 1998 [2]. The task of re-designing the curriculum was assigned to the Teaching Working Group in the faculty, which was a group of mainly younger staff that I headed, and including the Faculty Education Development Officer, Jeff Jawitz, who was also an ASPECT staff member. This group made use of worldwide trends in engineering education in developing a set of principles to guide the development process.

A major innovation that this project produced was introducing a hands-on course in engineering in each discipline in the first year of study.

One of the reasons why this project was so successful was the involvement of mainstream academic staff, and especially the leadership provided by senior staff (compared to other faculties at UCT where this was largely driven by relatively junior academic development staff).

1.3. *The Centre for Research in Engineering Education (CREE)*

In 1996 Jeff Jawitz and I established CREE so that we could make engineering education a recognised and sustainable research field at UCT. Since then CREE has played a major role in linking those of us doing engineering education research and encouraging us in our research. The quality and quantity of research done by CREE members has also increased significantly over the years.

In this paper I will first examine what has happened with regard to improving student success in the department I belong to (Chemical Engineering), then look at the faculty-wide project for increasing throughput and success that I am now leading, and finally discuss a more conceptual approach to student success that is being developed by CREE under Jenni Case's leadership. I will end by reflecting on the impact of these initiatives.

2. Case Study: UCT Chemical Engineering Department

The UCT Chemical Engineering Department has grown even more than all the engineering programmes together over the past three decades, both in terms of undergraduate students and also in terms of research activity (see Fig. 1, which shows the change in intake over 39 years– note that the ASPECT students are almost all black African).

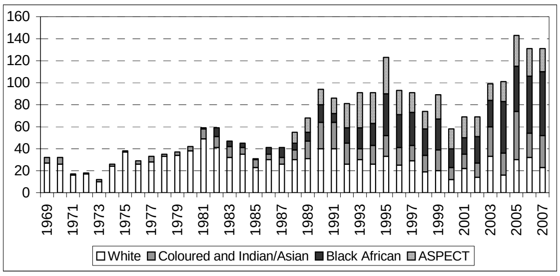

Fig. 1. Chemical Engineering Department student intake numbers & demographics.

There have been three major sets of initiatives we have undertaken to address the challenges of increasing student diversity, which I will deal with in turn:

- Changing the teaching and learning process (largely improvements within particular courses);
- Changing the structure of what is taught (curriculum revision, both across the whole programme, and within individual courses); and
- Research in engineering education (which has focused on student understanding and student learning, and which informs the first two).

This was not a linear process, but involved iteration between these three areas. As we started to see diminishing returns from improved teaching and learning we realised the need for structural curriculum changes. This was reinforced by my own technical research in process synthesis, where we have learned that unless the structure is right improvements possible within the structure are limited. Diminishing returns from curriculum reform in turn led us to look more fundamentally at student learning, and then at affective factors.

2.1. *Improvements to teaching and learning*

In 1991 I introduced collaborative study groups into our major second year course, in an attempt to improve the success of black African students in the course [3]. This had a significant effect on the success of the black students in the course, and also led to an improvement in the success of the white students as well (as one would hope it would).

This system was reviewed by Jenni Case in 1996, leading to a better way of handling collaborative groups in tutorials, particularly by reducing the size of the groups [4]. Since then we have been putting more effort into training our tutors so they could function more effectively in the tutorial sessions.

I was also responsible for organising a number of teaching workshops at UCT which were attended by some of our staff, together with other academics from the faculty, and from UCT and other regional institutions. The following workshops were run:

- Collaborative Learning (Karl Smith, 1995);
- Effective Teaching (Richard Felder and Rebecca Brent, 1996 & 1999);
- Creative Problem Solving (Scott Fogler, 1997);
- Enhancing Student Success Through Student Development in the Early Years (Ray Landis, 2006);
- Enhancing Student Learning through Participatory Pedagogical Approaches (Jeff Froyd, 2006).

Karl Smith is a respected engineering educator from the USA, well-known for his work on collaborative learning. Richard Felder and Scott Fogler are also noted engineering educators from the USA, running excellent workshops. Ray Landis has done much to help students study engineering, and Jeff Froyd was one of the leaders of the Foundation Coalition that developed the approaches he covered in his workshop. Staff, particularly the younger ones, reported that these workshops changed their whole approach to teaching. Since then we have run a number of in-house teaching workshops, and also special tutoring workshops for both lecturers and tutors.

In the first year engineering course, we put a lot of emphasis on student personal development, helping them make the transition from school to university. We also take a lot of trouble to get to know the students personally, and to help them to get to know one another. This is started at the beginning of the academic year, so that they can develop good working relationships with their peers. Some research we did on the effects of this indicated that the relationships developed in this course in first year carry over both into other courses in first year, and into subsequent years [5].

2.2. *Curriculum revision*

A range of curriculum revision initiatives has been undertaken, at a university-wide level, a faculty level, and a departmental level. These include the establishment of an Academic Support Programme in the university (of which the ASPECT Programme has been a significant part), the Engineering Faculty Curriculum Development Project (both described above), and departmental initiatives. Full details of these developments are covered elsewhere [6]. It is important to recognise that our department does not exist in a vacuum, and both benefits from wider initiatives in the faculty and university, and also contributes to them.

As noted above, the Curriculum Development Project involved the introduction of engineering courses in the first year of study. In chemical engineering this led to the development of some novel experiments to introduce students to the fundamental concepts of the discipline [7].

The curriculum development process in the Chemical Engineering Department is covered in detail by Fraser and Harrison [8]. This also extended beyond the Faculty Curriculum Development Project, addressing issues such as overload through a series of staff workshops [9].

From 1999 to 2001 we undertook a further process, which was to change our curriculum to an outcomes basis [10]. This was because it was to be required for accreditation of our degree in future, but we saw it as a chance to take the education development we had already begun to a new level.

2.3. *Research in engineering education*

Another significant development in our department has been research in engineering education (we have been a major driving force in CREE). This led to a number of the improvements outlined above. It also underpins our efforts at teaching and curriculum reform, and lends credence to what we propose. Our research in engineering education was greatly enhanced by a donation in 1992 from Caltex Oil (SA) (Pty) Ltd (now Chevron) which enabled us to establish an Education Development Officer post in the department. Much of what we have achieved since then is due to the contribution that Jenni Case has made to since her appointment to this post in 1996.

One focus of our research has been student understanding of fundamental concepts [11]. We have covered topics such as moles, energy, ratio and proportion and, vapour-liquid equilibrium, mainly through fourth year student research projects [12-15].

In 2001 Jenni Case completed her PhD on the influence of the learning environment on how students learn in our major second year course [16]. Following on the restructuring of our mass and energy balances course, Alison Lewis was able to implement an approach to teaching which focused on students' conceptual understanding of the subject and metacognitive (learning) development [9]. Jenni's research investigated students' perceptions of these actions, and also sought to explain instances where students' conceptual development was insufficient to ensure passing at the end of the course [17]. She identified an approach to learning which she called the procedural approach, which lies somewhere between the classical deep and surface approaches.

More recently, Jenni has shifted the focus of her work to affective issues, with particular emphasis on alienation and engagement [18].

Another research thrust concerns factors affecting student success. The first study in this area looked at how students in our third year recover from failure [19]. The second study was a master's project, in which Evelyn Dhliwayo examined the development of problem solving skills in chemical engineering students [20]. The study of student success has also picked up and furthered earlier work done on monitoring student success rates [21].

Student learning has also been studied from a different perspective, namely the framework of learning through variation. This has been applied in a study of student learning through computer simulation [22]. Further work has also been done on learning through computer simulations [23, 24]. All this work was done through final-year research projects.

Another student project went into the workplace to examine students' perceptions of the education they had received and how well it matched with workplace expectations [25].

3. The Phumelela Project

In 2006 the Faculty of Engineering and the Built Environment at UCT was given a grant of R16.3 million by the Department of Education for the years 2007 – 2009, for improving the throughput of EBE students and the output of EBE professionals. This was a South African government response to two of their own initiatives: ASGISA (Accelerated Strategy for Growth in South Africa) and JIPSA (Joint Initiative for Priority Skills Acquisition). It also recognised the high proportion of black engineers in South Africa produced by our faculty (we got the most of the four faculties given funds).

The faculty has largely used this money, together with money set aside out of accumulated reserves, to fund additional human resources to improve the success and throughput of our students. This initiative has been dubbed the Phumelela Project (the name means "succeed" in Xhosa).

In this section of this paper I will describe the considerations which led us to develop the particular objectives we set for this project, and then discuss the major objectives in some detail.

3.1. Considerations

The following were considerations that were taken into account in developing the major objectives for increasing student success in the faculty. They emerged from a small working group of a few key staff and a student representative.

- The importance of focusing on improving student success in general, and not only on improving overall throughput rates.
- The importance of undertaking both short-term measures that would improve success in a relatively short time-frame, as well as long-term measures that would not necessarily bear fruit immediately, but which would ensure sustainability of this undertaking into the future.
- The need for meaningful measures of student success and throughput, given the large degree of scatter in success and throughput data.
- The differentials in all our programmes between the success of white students and the success of black students, together with the danger of marginalising groups who are performing poorly.
- The variability of standards within the faculty with regard to feedback for students regarding their progress within a course.
- The additional challenges posed by the shorter academic calendar in 2006, and especially the new examination scheduling system.
- The importance of engaging with departments regarding their experience in this area, as well as their perceptions of the difficulties and possible ways of solving them, noting that each department has its own particular needs and difficulties.
- The key role played by academic staff in the learning of their students, and the impact of their attitudes on students, either for good or for bad.
- The increasing pressures on academic staff, both in terms of teaching and research, particularly in view of increasing numbers and the increasing academic needs of many undergraduate students.
- The tendency of many students not to attend classes, despite (or possibly because of) poor performance in courses.
- The financial difficulties faced by many students which negatively impact on their studies.
- The recognition that there are many non-academic factors which affect student success, most of which we have no control over, though there are interventions that would help students cope better with them.
- The present funding regime, both as far as government funding and UCT financial policy are concerned.
- The possibility of receiving teaching and development grants from the university.

We still need to understand better what sorts of interventions will have the desired effect of improving student success. Experience has shown that education is such a multi-faceted process that it needs a multi-pronged approach – there is no single one-size-fits-all intervention which on its own will magically increase student success in each of our undergraduate programmes. The set of major objectives recognises this and thus includes a range of interventions that, together, are likely to have the greatest impact on student success in the faculty.

We also needed to take into account those things that are under our control (both within our faculty and within UCT), and those things that are beyond our control (such as what is happening in the school system and in students' personal lives). A special challenge we are facing is drastic changes to school curricula in mathematics and science, and to the school leaving examinations in 2008.

These considerations led to the development of the major objectives for the faculty, which will now be discussed one by one.

3.2. Appointment of Faculty Academic Development Lecturers

The major intervention that we have undertaken as a faculty to improve student success is the appointment of an Academic Development Lecturer in each department. These staffs are expected to do education research to help address factors affecting success, and also work with their departmental colleagues to help them improve the teaching and learning in their courses. They will also form a team whose skills will be used across the faculty.

3.3. Maintain quality of incoming students

We already attract a good proportion of the students from the South African school system who have good enough mathematics and physical science to study engineering. We are, however, in a very competitive environment and we need to ensure that we continue to get our fair share of these students. Our Faculty Public Relations Officer is working on this with help from others.

The only potential for increasing the number of well-qualified students coming into engineering is to attract such students who are currently going elsewhere, particularly female students and commerce students. This requires a national effort.

3.4. Improve the institutional climate for student learning

There are two key institutional factors that are currently having a negative impact on student performance in EBE.

The first is the new academic calendar that has been adopted, which has shortened the examination period at the end of each semester. This also led to a new examination scheduling system, which has resulted in much more congested examination timetables for students. This has a negative effect on their success, particularly in courses where the examination may count as much as 80% of the course mark. Here we need to address both the examination scheduling problem and the heavy examination weighting of a number of courses.

The second is the very poor climate for studying in many of the student residences. We are collaborating with our Residence Administration to help overcome this.

3.5. Improve the learning environment in the faculty

There are a number of areas that we are addressing in this regard.

We have a system for mentoring of first year students by senior students, but it does not work equally effectively in all departments. The Faculty Counseling Officer (see 3.9 below) has been helping to run this system in 2007 and is developing recommendations for how to improve it.

Tutoring is a key area we are addressing, through providing funds for additional tutors in courses, as well as providing training for the tutors so that they can be more effective in the tutorial sessions. The training has only been fully utilised by one department so far, so there is still much room for improvement here.

Some of the departments are undertaking particular curriculum revisions with the aim of improving coherence and reducing the overload on students.

We are also identifying courses which are particular sticking points in each programme. A proposal that has come from the students is that these courses should be offered again (with just intensive tutoring) in the summer or winter terms for students who have narrowly failed them. We are busy investigating this proposal with a view to implementing it in 2008.

3.6. Develop staff teaching skills

Here we are planning to run more workshops to help staff develop their teaching skills, particularly in respect of large, diverse classes.

Another key area for staff development is in the area of assessment, to ensure good feedback to students of their learning during courses, as well as the alignment of course objectives and assessment.

As indicated in Section 3.4 above, there are some courses which might not meet acceptable standards in terms of in-course feedback and weighting of the final examination relative to in-course assessment. We are aiming to develop a set of minimum standards for typical courses of different types. In conjunction with this we also plan to encourage good practice by disseminating examples of good teaching.

3.7. Encourage students to take responsibility for their own learning

This is a challenging area, which we feel is best addressed by increasing students' motivation. This will be addressed in Section 4 below, where we suggest that the participation perspective on learning should strongly impact student motivation.

3.8. Provide financial assistance to good students in need

Some funds have been made available to help students who are succeeding academically but who cannot continue their studies for financial reasons. We are working on this together with the UCT Financial Aid Office.

3.9. Help students deal with external issues affecting their studies

We feel strongly that this is an area that has not been adequately dealt with in the past – the university Student Health Service is overloaded, and students with personal problems have had to wait around two to three weeks for an appointment. So this year we appointed our own Faculty Counseling Officer, who has been seeing many students already, largely from first and third year. This is working so well it is already being adopted as a model for the rest of the university.

3.10. Research impact of interventions on student success

We are continually seeking to understand better the factors affecting student success, although this is quite challenging in such a complex system, especially with multiple simultaneous interventions. The educational research undertaken by the CREE is aimed at developing such understanding.

We have partnered with a consultant to develop a set of data analysis tools that will help us both track student performance and test predictors of performance, both from school level and within the university. These tools will also help us monitor the impact of the interventions we are undertaking, if only in an overall sense.

4. The CREE position paper

UCT prides itself in being a research-led institution. We feel strongly that this means that education research should inform the teaching and learning in our faculty, and are fortunate to have CREE in our midst doing research in engineering (and science) education. Over the past ten months CREE has been developing a position paper that aims to inform the process of improving student success in engineering and science in particular. This paper was recently presented to staff [26].

While this position paper is not yet ready for publication, we can already draw some important conclusions from it. I am summarising the major thrusts of this paper here, because of the fresh insights it brings to our consideration of student success and graduate quality.

4.1. Major points

The starting point for this study was the need for more engineering and science professionals, coupled with low throughputs and many dropping out from these professions after graduating.

The paper recognises the complex nature of education, and that such complex systems are characterised by many interacting variables and no guaranteed outcomes. Thus improved teaching methods alone are unlikely to adequately deal with the challenges we are facing. These considerations point to the need for a much deeper understanding of the education process if we want to increase the possibilities for students to learn in our classes.

Two major perspectives on learning are presented, as depicted in Fig. 2. The acquisition perspective sees learning as primarily acquiring knowledge, either through transmission from a teacher, or as a process of construction, either individually or in conjunction with other learners. The participation perspective sees learning as a process of participation in a community. While both perspectives are valid, we reduce the opportunity for learning if we only engage with the acquisition perspective in our approach to teaching.

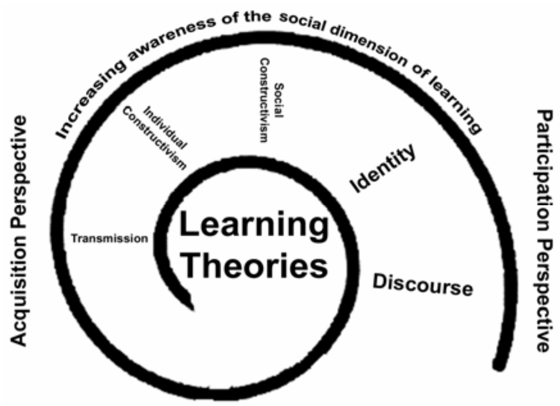

Fig. 2. Increasing awareness of the social dimensions of learning

The participation perspective also raises the issue of the difference between the classroom community and the workplace community. This gap can be bridged by engaging in authentic activities in the classroom.

The paper then focuses strongly on discourse and identity as critical aspects of the participation perspective. Discourse refers to particular ways of using language that define a community (which could be a particular discipline or field). For science and engineering this means using data, symbols, laws, equations, calculations, and models. Membership of a community is displayed by being able to use the discourse of that community. This is intimately bound up with your identity as a member of that community.

Here we also need to recognise that all of us, including our students, are members of multiple communities and thus hold multiple identities. Our students, like us, also have agency, which is the ability to choose to enter a particular community and take on its identity.

All this leads to the notion of discursive identity, which emphasises that students' identities are constituted through engaging in discourse. Failure to engage with the discourse and take on the identity will either lead to a student dropping out of a particular programme, or not following that particular career after graduation.

This view of learning means that we need to define success in engineering and science with reference to the identities presented to students in relation to identities in the workplace. One challenge for science and engineering is the limited portrayal of workplace identities in the popular media. Another challenge is how to meaningfully model authentic workplace identities in the classroom environment.

The paper also notes the wide range of incoming identities and aspirations brought by students, as well as the wide range of communities and identities in the workplace. In contrast to these, tertiary institutions often provide a very limited view of the role of engineering and science in society, which could (and seemingly does) alienate many students. Fig. 3 shows the constriction of students in tertiary education, compared to the breadth of the incoming and outgoing communities.

Furthermore, students also bring along different sorts of cultural capital, which refers to the familiarity with the discourse of higher education that tends to be fostered in middle and upper class homes. A challenge we face in South Africa is how to validate and harness the cultural capital that working class students bring with them.

The paper concludes that in order to achieve successful learning in tertiary engineering and science we need both to recognise the multiple identities held by our students and provide an authentic range of engineering or science identities with which they can engage. We also need to make more explicit key aspects of the discourse of engineering and science of which we are tacitly aware (challenging because it is taken for granted).

4.2. Some examples

Here are a couple of examples which we have tried in the Chemical Engineering Department at UCT which have been informed by the participation perspective (implicitly and explicitly).

In 2006 we started an exercise in which we take our whole second year class on an industrial field trip. The class of 93 students was divided into seven groups, each of which went to a different industrial site during the last week of the mid-year vacation. The sites were either petrochemical plants or mineral processing plants.

Each group was accompanied by an academic, and had to perform a range of tasks in smaller groups, from following lines and checking pump characteristics, to heat exchanger surveys and mass balances around particular sections of the plant.

Not only were the tasks authentic, but they were subject to errors, unlike textbook problems which always work out exactly. The students also learned about safety in a real plant environment.

Another important feature of this field trip was the way the students interacted with a range of plant personnel, from operators to engineers and managers. They particularly valued the way they worked with pant engineers. What an opportunity to participate in a real engineering community!

Another example along similar lines was the weekend camp for first year students that we ran for the first time in 2007. This was aimed at breaking down barriers between students and developing a student learning community. Students were in fixed groups for the whole time, and each group had a leader who was either a course tutor or a first year mentor.

Most students engaged well with this exercise, but some did not. We learned we needed to take more account of where they were all coming from, and also to have a more representative range of demographics in the group leaders.

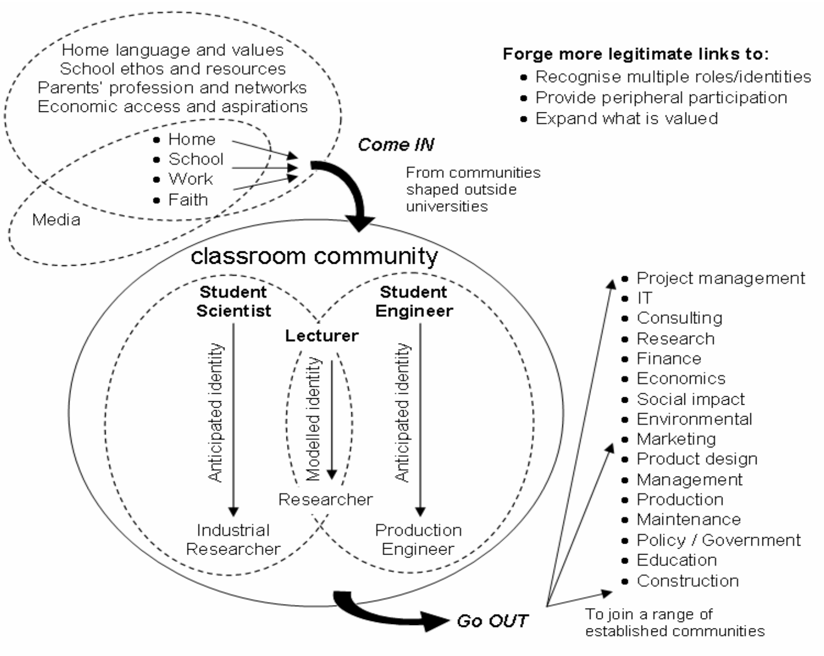

Fig. 2. Trajectory of science or engineering student identity

5. Closing remarks

This paper has described a range of initiatives to increase student success and graduate quality. Success may be readily measured if it is seen purely in terms of marks or pass rates. I contend that both success and quality are hard to measure, and can only really be judged by what happens after graduation in the workplace. This view is strongly supported by the view of education promoted by the CREE paper. So, while I am encouraged by the data we have obtained that shows improving success rates [27], I am much more interested in the feedback we get from industry that tells us how well our graduates are doing in the workplace.

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