European Journal of Engineering Education
Vol. 30, No. 2, May 2005, 167–180

Engineering graduates' perceptions of how well they were prepared for work in industry

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(Received 26 April 2004)

This study investigated how well chemical engineering graduates perceive they were prepared for work in industry. To this end, sixteen interviews were carried out with a purposive sample of recent University of Cape Town chemical engineering graduates. Qualitative analysis of the interview data showed that graduates felt that overall, they were well prepared for work in industry. They perceived their strengths to be their technical background, problem solving skills, formal communication skills and life-long learning abilities. The following areas of weakness were also identified: work in multi-disciplinary teams, leadership, practical preparation and management skills.

The use of interviews for data collection is a significant departure from the methods used in other studies in this area. The rich and contextual data gathered from the interviews justified this choice and contributed to the identification of issues not previously mentioned in the literature. For example, an unexpected finding of the study was that there was a clear link between the technical and non-technical attributes of engineering graduates, a result which has clear implications for the design of undergraduate engineering programmes.

Keywords: Outcomes based degree; Graduate attributes; Competency gaps; Skills; Technical competence; Communication; Teamwork

1. Introduction

Since the mid-1990's there has been a global trend towards outcomes-based accreditation of undergraduate engineering programmes (Shaeiwitz 1999). This means that degree programmes are accredited on the skills and knowledge a graduate has when leaving the university rather than on how many hours of teaching time is dedicated to each particular subject. For the Chemical Engineering Department of the University of Cape Town (UCT), the move towards outcomes-based education began as early as 1992 when, in response to its changing student body and changes in South Africa, the Chemical Engineering Department began a process of curriculum review (Fraser 1994) after consultation with chemical engineers in industry (Fraser and Harrison 1997). In 2001 the Engineering Council of South Africa (ECSA) accredited the chemical engineering degree at UCT as an outcomes-based degree. This degree is a four-year full-time programme in which the fundamentals of science and the

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European Journal of Engineering Education
ISSN 0304-3797 print/ISSN 1469-5898 online
http://www.tandf.co.uk/journals
DOI: 10.1080/03043790500087571

principles of process engineering are integrated to provide graduates for the chemical and mineral processing industries.

Given that this outcomes-based curriculum development is frequently driven by a desire to produce graduates that better meet the needs of industry, it is necessary to consider whether the actual outcomes of such revised engineering programmes indeed match the needs of industry. The aim of this study was therefore to investigate this question by focusing on how UCT Chemical Engineering graduates feel prepared for their careers in industry. It was therefore necessary to investigate graduate attributes and to identify any competency gaps. In this context, a competency gap means that there is a difference between the level of performance expected from a graduate engineer by their employers and what the engineer actually delivers (Meier *et al.* 2000).

Although this study focused specifically on UCT chemical engineering graduates, the global nature of the engineering profession and close alignment of the UCT degree with degrees in other parts of the world (as recognized in the Washington Accord), suggest that the findings of this study could well be applicable to other contexts.

2. Studies of graduate competencies

Several researchers (Evans *et al.* 1993, Keenan 1993, Fraser 1994, Lang *et al.* 1999, Meier *et al.* 2000, Scott and Yates 2002) have attempted to identify the desirable attributes of an engineering graduate in terms of key technical and non-technical competencies. We have chosen to divide the technical competencies into two distinct areas – the *science* of engineering and the *practice* of engineering. The *science* of engineering is the set of mathematical and scientific tools used to solve engineering problems, while the *practice* of engineering is the recognition and formulation of a problem and its solution (even if the problem is not specifically an engineering one). The studies of Meier *et al.* (2000) and Sageev and Romanowski (2001) identified technical knowledge and skills, or the *science* of engineering, as the area of greatest strength in engineering curricula in the USA. This is expected since demonstrated ability in the technical aspects of the degree has always been the focus for determining whether or not a student is competent as an engineer.

Although open-ended design problems can be used to improve a student's ability in the *practice* of engineering, these skills require practice and experience and improve over time. It is therefore possible that graduate engineers leave university with a lack of problem recognition and solution skills, as highlighted by Evans *et al.* (1993) and Scott and Yates (2002).

Key non-technical competencies include communication, teamwork and life-long learning. The development of a professional and ethical attitude is also sometimes included under non-technical competencies. Although some of these skills could be considered to be related at least partly to a student's personality, it can be seen when examining the stated outcomes of several engineering degrees, that tertiary education institutions have, in recent times, assumed the responsibility of adequately developing their student's non-technical skills for use in the workplace. Furthermore, these outcomes are now explicitly required by bodies accrediting engineering degrees.

Surveys (conducted mainly in the USA and Australia) of industry perceptions of engineering graduates (for example, Evans *et al.* 1993, Katz 1993, Lang *et al.* 1999, Meier *et al.* 2000, Sageev and Romanowski 2001, Scott and Yates 2002, Holcombe 2003) have consistently identified communication and teamwork as important attributes where "competency gaps" are frequently found. The importance of these non-technical skills in promotion and career success is discussed by Sageev and Romanowski (2001), Bhavnani and Aldridge (2000) and

Scott and Yates (2003) and is summed up in the following quote from Sageev and Romanowski (2001:690):

> 'Technical abilities are a given, communication and leadership differentiate'

Given the prevalence of teamwork in industry, an area of concern is work in multi-disciplinary teams, since the nature of industry work frequently results in teams made of individuals with different areas of expertise. Understandably, given the segregated nature of different engineering programmes, most students are given very little exposure to this type of teamwork while at university. This can lead to a competency gap in this area, when graduates enter the workplace (Bhavnani and Aldridge 2000). Nonetheless, the ability to work in a multidisciplinary team is widely recognized as an important skill for graduates to develop (Rompelman 2000) and there are a number of examples of curriculum projects which have attempted to address this issue (for example, Skates 2003).

Meier *et al.* (2000) and Lang *et al.* (1999) both point out that good interpersonal skills play an important role in effective teamwork and high performance in the workplace. Interpersonal skills include listening skills, sharing information and cooperating with co-workers and the ability to cope with office dynamics. The communication of technical information to diverse audiences is another critical skill. Life-long learning is a critical skill expected of graduate engineers (Lang *et al.* 1999, Meier *et al.* 2000). This implies the ability to adapt to changing work environments, to learn new skills and to assess one's own abilities. A further issue raised by Keenan (1993), Black (1994) and Holcombe (2003) is the difficulty some engineering graduates have in understanding the importance of the business and economic aspects of industry.

3. Method for data collection and analysis

A semi-structured interview format was chosen as the method of data collection for this study. This is a departure from the majority of literature reviewed above, where questionnaires were generally used to collect data, and analysed quantitatively. Interviews allowed for interaction with graduates and a more in-depth exploration of their answers to the questions asked. Qualitative analysis of these data allowed us to explore links between different contexts and categories. Although such qualitative methodologies are less familiar to most engineering educators, in the social sciences their popularity has grown in recent decades and it has been argued that they are in many cases more appropriate for conducting research with human subjects (Lincoln and Guba 1985).

This study also involves a shift in the research outcome, from aiming for generalisability and prediction which are common in the natural sciences, to a focus on understanding human experience (Crotty 1998). Qualitative methodologies are well suited to this 'interpretivist' paradigm. Because of the different focus, such research does not involve the selection of a large and statistically representative sample, but rather a smaller sample selected to yield maximum diversity in responses (termed a purposive sample, Lincoln and Guba 1985). Even a few interviews with a well chosen sample can generate an enormous amount of useful data, and larger sample sizes usually do not add significantly to the research findings (this is termed theoretical saturation, Glaser and Strauss 1967).

Sixteen graduates were therefore selected in order to provide a purposive sample that was diverse with respect to race, gender, type of industry (petrochemical, minerals processing, biotechnology, business and textiles) and year of graduation (1995 to 2002). With regard to academic performance, the interviewees represented a typical spread of abilities.

The findings from the literature review and the results of two pilot interviews were used to develop the final interview structure. After some introductory questions, the following issues were explored:

- Technical – Participants were asked to describe a normal day at work and what kind of technical challenges they faced. They were asked how prepared they felt for such challenges.
- Communication – Participants were asked to describe the different ways they are expected to communicate, how much time they spend doing this, the areas they feel the weakest and the effect of university communication courses.
- Teamwork – The major areas covered were working in multi-disciplinary teams and working as both a leader and as a team member.
- Management and business skills – Although this issue was not raised spontaneously in the pilot interviews, we included a question asking how participants felt they were prepared for this aspect of work.
- Life-long learning – Questions were asked about perceptions of their ability to learn new skills and assess their own work.

Each participant was asked how they perceived themselves compared with graduates from other tertiary institutions and also if they could describe some of the feedback they had received from their supervisors. A challenge for the interviewers was to draw out descriptions of specific experiences, which brought out richer and more contextual data. This was attempted by framing questions in the format of ‘Tell us about a time when . . .’ or ‘Tell us more about that . . .’.

Each interview was recorded and then transcribed in order to facilitate data analysis. Two of the interview analysis techniques described by Kvale (1996) were used in parallel in analysing the transcripts. These were meaning condensation (in which data is summarised and reduced) and meaning categorization (in which categories are generated comprising data falling under a particular theme).

4. Research findings

In the following sections the main themes which emerged from the interviews are presented, followed by some discussion of the context and implications of these findings.

4.1 *Technical abilities*

4.1.1 Technical competence. The majority of respondents said that they felt they were well prepared for the technical challenges of the workplace. In reading the context of these replies it appears that most respondents understood technical preparation to be a combination of the science and practice of engineering. Respondents mentioned fundamentals of chemical engineering and mathematical tools, as well as problem solving and analytical skills when describing how they approached problems in the workplace. They seemed to regard specific knowledge of a process or industry as a separate issue from their technical preparation.

Most respondents placed a high value on their ability to solve problems and think through a problem in a clear and analytical way. All respondents, except one, specifically mentioned one or more of problem solving ability, analytical skills and application of theory when describing how they solved problems in the workplace. Most attributed the development of these skills to the experience of completing a chemical engineering degree. This is illustrated in the following quotes:

> How to look at a problem on the plant and figure out a test work programme to solve it, that's stuff I was really well equipped with.
>
> Basic analytical skills... That's something that engineers are better at than anyone else.

An area that was a problem for several graduates was not having enough knowledge about the specific field in which they were working and they often described themselves as having been 'thrown in the deep end'. Those working in the minerals processing industry mentioned this problem more often than those in other industries. Some respondents also felt lacking in the technical knowledge needed to work with engineers from other disciplines.

It is important and encouraging to note that none of the interviewees seemed to feel that they were under-prepared for the technical challenges that they face in industry. Some participants had encountered certain challenges along the way (for example, learning field specific knowledge) but this did not seem to hinder their overall performance in the workplace. The chemical engineering degree at UCT is a very broad degree and, while there are optional courses in specific areas such as minerals processing, graduating engineers are not expected to have field specific knowledge of all industries. They are expected to apply themselves in industry and this attribute has clearly come through in the interviews. Both Sageev and Romanowski (2001) and Meier *et al.* (2000) mentioned that technical attributes are the greatest strengths in engineers and, for this reason, it was expected that UCT graduates would be adequately prepared for the technical challenges of industry.

An unexpected outcome from this section was the fact that the majority of the participants felt that they were competent in their problem solving abilities. This contradicted the literature reviewed which mentioned problem solving abilities as possible competency gaps (Evans *et al.* 1993, Scott and Yates 2002). It is possible that the perceptions that graduates have of their own abilities may not necessarily tie up with the perceptions of their employers. However, it is important to note that when participants were asked if they had received feedback from their supervisors on possible areas of weakness, none of them mentioned problem solving abilities as a problem in their development.

4.1.2 Practical aspects of work on a plant. Lack of preparation for the practical aspects of work on a plant was a problem mentioned by about half of the respondents. Problems ranged from minor issues like not really having an understanding of how big a $60\,m^3$ tank actually is, to more major issues like one respondent walking past an autoclave and not knowing what it was. One participant described one of the difficulties she faced in a minerals processing environment:

> We learn exactly how a particle attaches to a bubble in flotation but you learn absolutely nothing about these huge machines in which it takes place. And then you go onto the plant and you don't care about the bubble attaching to the particle, you've got to work with this massive piece of equipment.

Some respondents highlighted the benefit of vacation work in giving some practical preparation. One participant suggested that more plant visits during the undergraduate programme would be helpful and another believed that some compulsory vacation work every year would be beneficial. The lack of practical preparation experienced by many participants was a problem that was not mentioned in the literature that was surveyed.

4.2 *Communication*

4.2.1 Communication in the workplace. The respondents in this study clearly showed that communication is a vital part of work in industry as illustrated below:

> Unless you can make somebody else understand what you are doing, it's kind of pointless, because as soon as you leave nobody else can understand.

This confirms the importance of communication in the workplace, as emphasized by the literature, which mentions this as one of the key factors of success in the engineering workplace (Sageev and Romanowski 2000).

Some respondents also mentioned communication as a tool for building relationships. One participant described how the open plan nature of the office in which he works encourages colleagues to talk to each other and build relationships and how this makes asking for help and information that much easier. Another participant described how she used communication to build relationships on the plant when she first started working:

> I went on shift, just trying to understand, not only the plant itself but the way people work and the best way to try and communicate things and get it out of them. So you just sit there basically and observe, that's what I did when I first got there, and you build relationships.

The above examples both show the importance of informal communication in the workplace. Informal communication was mentioned indirectly in several other contexts, again highlighting its importance. These contexts include informal meetings, working in teams, working with operators and technicians, gathering necessary information from various sources in a plant and negotiating with colleagues, customers and operators.

4.2.2 Development of communication skills at UCT. When asked about communication, respondents frequently mentioned the role of the Professional Communication courses offered at UCT. The majority of people said that these courses had been helpful in preparing them for formal report writing and oral presentations. It was expected that respondents would have found these courses helpful in preparing them for communication in the workplace because they require students to devote an entire academic year to improving their communication skills.

The respondents felt that they had good general communication skills and it was interesting to note that two respondents attributed the development of these skills to the extra-mural activities that they participated in during their undergraduate studies.

The importance of extra-curricular activities during tertiary education was not mentioned in the literature review, and this is not unexpected as the literature does mention that engineering curricula are often overloaded and therefore do not allow much time for such activities (Sparkes 1991). Many application forms that graduating engineers are required to fill in when applying for jobs in South Africa place a significant emphasis on these extra-mural activities. It therefore seems that companies requiring such information recognise that important non-technical skills (for example teamwork and leadership skills) can be developed in these activities.

4.2.3 Interpersonal skills. The importance of good interpersonal skills in the workplace was identified by several respondents and is illustrated below:

> You get a lot of things done . . . simply in the manner that you deal with people.
>
> Friends of mine who were much better in chem. eng., I think they did not go as far as I have gone to date because of the interpersonal skills. I'm honest about this because there are guys that are just not cutting it in terms of coming across and moving up the echelons of the company because of the way you relate to people.

On a chemical plant one of the areas where interpersonal skills are very important is in dealing with plant operators and several respondents reported problems in this area. Participants discussed how important good relationships with operators are in aiding a process engineer to do their job, which often involves disrupting normal production in order to run trials and tests. Difficulties that graduate engineers experienced in dealing with operators could be in some part attributed to poor communication between engineers and operators and a misunderstanding on the part of the operators of the role of the engineer. One participant, a young black female, described how she felt that some operators on her plant didn't understand her role and saw her as trying to make their lives difficult and potentially take away their jobs. Two other participants' experiences both show that spending time on shift and getting to know the operators can significantly improve relationships and aid work on the plant.

Many of these difficulties were not unexpected considering the context of the South African workplace. As Case and Jawitz (2004) describe, female and black engineers could experience resentment in the workplace as industry slowly changes from a white male dominated place to one more representative of the South African population. The emphasis respondents placed on good interpersonal skills is not unexpected since both Meier *et al.* (2000) and Lang *et al.* (1999) highlight the importance of these skills in the workplace.

4.2.4 Factors affecting communication skills. Some respondents elaborated on the idea of preparation for communication and discussed factors that may affect their ability to communicate effectively. These factors include practice, confidence, technical knowledge and personality.

Some respondents said that although UCT had laid a good foundation for communication in the workplace, nothing but practice would encourage improvement. Practice leads to increased confidence, a factor identified by some graduates as very important in effective communication. Respondents also said that confidence in one's communication skills was not sufficient: a depth of technical knowledge and familiarity with the technical content of the report or presentation enhanced the effectiveness of the communication. This is how two respondents described this phenomenon:

> However, if you do have uncertainties, or if you are not feeling as comfortable with the work, especially if it's relatively new stuff, you feel insecure, so the better the background, or the more intensive your area of study, the better your presentation level will be.

> You need to go in there and hold, stand your ground and be firm, and you can only do that if you know you are technically sound and if you have got the confidence to do it.

From the above data, there is a clear link between effective communication and technical ability. This is in contrast to the literature, which made a distinction between technical and non-technical attributes. It seems that the reason for this was that questionnaires were used for data collection in the majority of the cases reviewed. Since questions were asked in a manner that segregated technical and non-technical skills, it is expected that the answers obtained would provide segregated results.

4.3 *Teamwork*

4.3.1 Teamwork in the workplace. Participants were asked to describe how much time they typically spent in teams. Half of the participants described teamwork as a major part of their jobs, with time spent in teamwork ranging from 60 to 80% of the working day. Many participants emphasised that engineers never work alone in industry with one person even going on to say:

> If you are not a team player you can't survive in industry.

Overall, the importance of teamwork highlighted in the literature (Evans *et al.* 1993, Katz 1993, Lang *et al.* 1999, Meier *et al.* 2000, Sageev and Romanowski 2001, Scott and Yates 2002, Holcombe 2003) was re-emphasised by the responses of the participants in this study.

Some respondents discussed factors that can affect work in teams. A feature of the current South African workplace is that teams will often be made up of people from diverse cultural and racial backgrounds. Two white respondents said that being exposed to the diverse nature of the UCT student body had been good preparation for working in diverse teams in industry:

> I'd say this is one of the areas where, in terms of the exposure we got as undergraduates . . . it was very good. You are in a diverse group of people. You don't see diversity or ethnic difference as being a challenge as much as a potential opportunity.

Associated with the issue of cultural and racial diversity in a team environment was the role of different personalities in a team, as described in the quote below.

> Probably the biggest difficulty is you've got people with different outlooks on life, some people are ambitious, some people are not, some people are really proud of what they do, some people see it as an eight to five job and they've got a life outside the job.

Difficulties working in teams can also stem from other factors. The two respondents who mentioned this as a problem both attributed difficulties to a situation where there are too many intelligent people in one room, resulting in difficulties in reaching consensus and making decisions. One of these respondents also said that working with much more experienced people can be a problem because it can be difficult to challenge their point of view.

4.3.2 Preparation for teamwork at UCT. Respondents were divided on whether or not UCT preparation for teamwork was adequate. Some people simply said their preparation for teamwork was 'good', while others felt that more team-based assignments, with assessment of team participation would have been beneficial.

Some respondents said that being forced to work with a randomly selected group in the final year design project was good preparation for the workplace and for working with your peers. However, one participant highlighted that the pressure of the design course may detract from the experience of working in a team.

> The only team that I really worked very hard in for 9 weeks was my design project team, and the pressure that goes through that time just sometimes forced you to work together and sometimes not to work together.

The divided responses to the question of preparation for teamwork were not unexpected. This was because although teamwork is part of the UCT curriculum, it is not a major focus of the degree nor of assessment. This could lead to the amount of exposure in the degree being sufficient for some but not for others. The literature also indicates that difficulties with teamwork could be expected. For example, Katz (1993:172) says, 'given that students have spent at least sixteen years of their lives working primarily as individuals, it is not surprising that the shift to teamwork is problematic.'

4.3.3 Leadership roles in teams. Most respondents said that they are expected to take on leadership roles in teams. No respondents reported that they felt prepared for taking on a leadership role and some respondents, like the example below, highlighted their feeling of being under-prepared.

> Chemical engineers in general are expected to assume leadership positions, be it technical leadership or project managers or people managers, so that they are expected to provide a leadership role which is something we are very under-prepared for.

The importance of leadership was not mentioned specifically in the literature reviewed but it was often implied when issues like management were raised as possible competency gaps (Keenan 1993). However, the sense of a lack of preparation for leadership in industry was not unexpected. Although the stated outcomes of the UCT chemical engineering degree include being able to work in a team in a leadership role, this skill is not specifically developed in the current curriculum.

4.3.4 Multi-disciplinary teams. The majority of graduates interviewed said that they work in multi-disciplinary teams. The types of multi-disciplinary teams discussed fall roughly into two categories. Firstly there are teams made up of chemical, electrical and mechanical engineers and other technical people, which can truly be referred to as *multi-disciplinary* teams. Secondly there are teams made of people on several different levels within the company. These teams are really *multi-level* teams and include operators, technical officers, engineers and managers. Difficulties in multi-level teams are often related to the communication and interpersonal issues mentioned previously.

Those graduates who work in multi-disciplinary teams said that they battled to communicate effectively with electrical and mechanical engineers when they did not know enough about the work done by these other disciplines, as highlighted below.

> What I have found lacking from university is being able to converse adequately with electrical and mechanical engineers because they actually form a big part of the process.

Another participant had a very different experience. He worked exclusively in multi-disciplinary teams but he was given introductory courses in other fields when he started work and this helped him to function effectively alongside people from other disciplines.

This feeling of being under-prepared for working in multi-disciplinary teams was expected. Firstly, the literature highlighted this as a possible competency gap (Bhavnani and Aldridge 2000), and secondly, UCT graduates are not given any exposure to this type of team environment in their undergraduate degree.

4.4 *Other issues*

4.4.1 Preparation for management. More than half of the respondents said that they were expected to take on some form of people management role. Although the respondents said their employers gave them management tasks, none of them said, or implied, that their employers expected them to have any explicit training in management skills.

About half of the respondents were explicitly asked if they had felt prepared for taking on a management position and all said no. The need for management skills was mentioned in the literature (Keenan 1993), however there was not a great emphasis placed on these skills and they were often grouped together with business skills. The number of times that management was mentioned by the respondents was therefore unexpected. However, since management skills are not taught in any formal way in the UCT curriculum, it is not surprising that graduates felt they were not prepared for this.

4.4.2 Life-long learning. Life-long learning was a skill that was mentioned by the majority of respondents. In some cases respondents were specifically asked how they felt they could cope with learning new skills or tackling a problem they hadn't seen before, but often life-long learning was raised spontaneously when respondents discussed their approach to problem solving, although it was not labelled as such. Below are some quotes, which illustrate how several respondents demonstrated a sense of life-long learning.

> I think that's where university comes in. It teaches you to be confident that you can learn. And I think that's the biggest thing for me that I realised a couple of years into working. It's not that they wanted to make me the best engineer ever; they wanted to teach me to become the best engineer ever in my lifetime as an engineer.
>
> There was nothing that was so difficult or not do-able for me at the time, I knew I could do it. I knew that as soon as we were clear on what needs to be delivered, I'll do it and I did it, and I've seen many other UCT chem. eng students do it.
>
> . . . for being able to take on more, to learn more, to build on your knowledge base, we are very well prepared for that.

The frequency with which life-long learning was discussed highlights the importance of this skill to an engineer in the workplace. This ties up with the literature that describes life-long learning as an important skill expected in all engineers (Lang *et al.* 1999, Meier *et al.* 2000). The above comments lead us to believe that UCT graduates are well equipped with life-long learning skills.

4.4.3 Financial and business skills. Responses to questions about financial and business skills were mixed. Contrary to the literature reviewed (Keenan 1993, Holcombe 2003), the participants did not seem to place a great emphasis on these skills despite varying levels of preparedness. The respondents did not imply that these were unimportant skills but rather that they had been sufficiently prepared in these areas to cope with the challenges they faced.

5. The interaction of graduate attributes in the workplace

Our findings have allowed us to develop the following conceptual picture of how the various graduate attributes fit together in the engineering workplace to build towards success. This picture is shown in figure 1 below. As this picture shows, technical knowledge (the science of engineering) and technical skills (the practice of engineering) are the fundamental building blocks of success in industry. The absence of either one of these attributes will cause the whole structure to collapse. The other attributes necessary for success in industry (interpersonal skills, communication, teamwork and management) are built on this foundation. Specifically, communication depends on interpersonal skills, and teamwork and management depend on communication. It should be noted that merely having the technical knowledge and skills is not sufficient for success. The picture also shows that life-long learning skills are the attributes

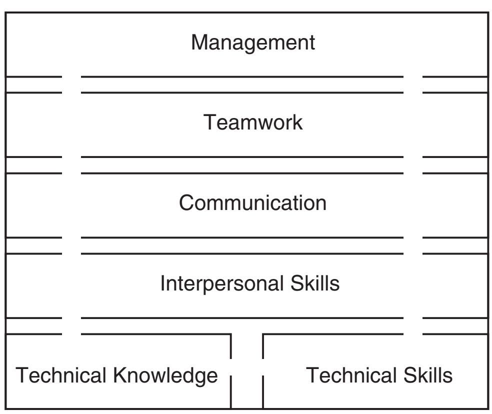

Figure 1. A conceptual picture of graduate attributes and their interactions.

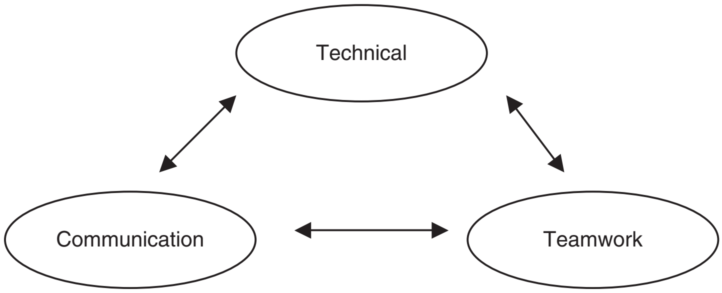

Figure 2. A diagrammatic representation of the interaction of graduate attributes.

that hold the whole structure together and the gaps between the blocks indicates that all of these attributes interact with each other in the workplace.

Our results have shown that many of these graduate attributes are also integrally linked. We have identified three major links: technical competency and communication, technical competency and teamwork and finally teamwork and communication. Figure 2 is a diagrammatic representation of these links. We have described a link to be when competency in a certain area relies on a combination of skills, often technical and non-technical attributes interacting together. For example, one respondent illustrates the link between technical competency and communication when he says that he does better presentations when he is familiar with and confident about the technical content of the presentation. Multi-disciplinary teamwork is a particular example of the link between technical competencies and teamwork. This is because knowledge of other fields is required to work effectively in multi-disciplinary teams.

The link between teamwork and communication has been identified in the literature (Bhavnani and Aldridge 2000) and confirmed by our interview data. The links between the other graduate attributes were not identified in the literature reviewed. As has been discussed previously, there is a good reason for this. Most of the studies discussed in the literature review used questionnaires for data collection. These questionnaires segregated questions about technical and non-technical skills and therefore it is not surprising that they did not identify links between these skills. This type of finding shows that our study has not merely confirmed the findings of other researchers, but rather broadened the body of knowledge around graduate attributes.

Our results suggest that the vital link between communication and teamwork in the workplace is interpersonal skills. The importance of these skills in the workplace was highlighted in the literature review and by several respondents. Two people in our study who displayed good interpersonal skills both attributed the development of these skills to the extra-curricular activities they participated in while at university. Scott and Yates (2002) have also identified that interpersonal skills can best be developed through peer interaction and involvement in the whole university experience. They recognize that these skills may not be possible to teach in a formal manner but recommend that the development of these skills in engineers be encouraged by lecturers actively stressing the importance of extra-curricular activities throughout the engineering degree.

6. The importance of life-long learning skills

There was a sense from the respondents that having completed their degree, and especially the final year design course, they felt confident to tackle new problems and formulate a solution. This is the central idea of life-long learning. As was seen in the literature and the results, life-long learning is an important skill for an engineer and one that is often called upon when solving problems. It is therefore essential that an undergraduate engineering programme develop life-long learning skills.

Respondents often attributed the development of their life-long learning skills to the experience of the final year design course, which is a structured eight-week open-ended design project. The course has clearly defined deliverables and a limited timeframe. Therefore, although students are not given any guidance as to how to solve the problem, they have clear understanding of what is expected of them. We postulate that the structured and defined nature of the course contribute to the development and improvement of a student's life-long learning abilities.

Several respondents used the metaphor of being "thrown in the deep end" when describing their transition into industry. One of the participants also used this metaphor when describing his experience of the final year design course. He viewed this as a positive experience that taught him a lot, especially in the application of theoretical principles (the practice of engineering).

There was a sense from many of the respondents that having completed their degree, and especially the design course, they felt confident to tackle new problems and formulate a solution. This is the central idea of life long learning. As was seen in the literature and the results, life long learning is an important skill for an engineer and one that is called upon often when solving problems. Since the design course especially, and the chemical engineering degree in general, involves an element of being thrown in the deep end, we postulate that "being thrown in the deep end" promotes the development of life long learning skills.

On the other hand, another participant described "being thrown in the deep end" in her early work context as a negative experience. She found herself in a situation where she had to "fend for herself", with little guidance of what was expected of her. She was overwhelmed by the unexpected aspects of her job, including practical aspects, the hierarchical structure on the plant and not being called upon to use her technical skills initially. We suggest that this experience is not one of being thrown in the deep end, but rather one of being of being thrown in the dark. This was clearly not a positive learning experience.

A comparison of these positive and negative "deep end experiences" shows that what differentiates them is not the problem itself, but rather the presence or absence of clearly defined expectations. If such experiences in the undergraduate curriculum (for example, the final year design course) are structured and provide the participant with clear expectations, then we can conclude that being "thrown in the deep end" can indeed be a good thing and crucial for the development of life-long learning skills.

7. Conclusions

It would appear that UCT chemical engineering alumni are adequately, if not well, prepared to face the challenges of work in industry, including key technical and non-technical areas of competencies. This study has also been able to highlight certain aspects of work in industry to which graduates have had little or no exposure, including multidisciplinary teamwork, management, and practical experience. Some of these strengths and weaknesses appear to relate very specifically to the UCT context, such as strengths in formal communication (relating to particular courses) and exposure to diversity (a function of the demographics of the student body), but on the whole we believe that these findings have broader applicability to other engineering disciplines and other contexts.

The study confirms the importance of technical skills as a basis of engineering practice, as well as the need for communication, team-work and interpersonal skills in the workplace. It also points to the complex interactions between these different skills, specifically that the non-technical skills area built on a technical basis, and therefore that a lack of confidence in the technical arena would hamper abilities in these other areas. The implications for curriculum development are that the non-technical skills can not be taught in isolation from the technical context in which they will be used, and that integrated projects are a crucial tool for achieving such ends.

In addition to the implications for engineering curricula, this study also has clear implications for researchers. Firstly, the decision to use interviews instead of questionnaires in our study was justified. Our study has shown the advantages of using interviews for data collection. As expected, interviews allowed us to probe interesting topics raised by respondents and to explore more fully the impact of context and the relationships between different graduate attributes.

Secondly, our findings can be used to design studies in this area, and could be used to develop better questionnaires. This is because the discovery of clear links between graduate attributes could be used to ask questions that will generate more useful results. We do, however, believe a quantitative study performed using questionnaires will be limited by the need for fixed questions and a small range of predetermined answer categories into which all responses must fit.

In conclusion then, this research has highlighted the importance of the traditional technical core of the engineering curriculum, has pointed to comparative success achieved in some of the newer outcomes like communication, and has highlighted potential areas of weakness. These findings have clear relevance for engineering educators, both at UCT and further afield.

Acknowledgements

This work is supported in part by a research grant from the National Research Foundation (NRF).

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