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Work integrated learning competencies: Industrial supervisors' perspectives

Abstract

Research on student-learning outcomes indicates that university graduates do not possess relevant skills required by the industry such as leadership, emotional intelligence, problem solving, communication, decision-making skills and the ability to function in a multicultural environment. Currently, engineering graduates are expected to perform within a diverse working environment, hence the need to possess appropriate professional competencies and attributes. This paper seeks to identify strengths and potential shortfalls of work integrated learning (WIL) for students placed in the engineering sector. It presents findings from a study of workplace supervisors of chemical engineering students at one university of technology on the coastal seaboard. Supervisors from a variety of chemical industries completed a WIL students' competency assessment, which measures 23 work-related competencies using a 4-point Likert scale. The competencies were organised under two broad themes of cognitive and behavioural skills. The two themes were further broken down into five sub-themes, namely ability, performance, judgement, attitude and suitability. This defines the common characteristics of superior performers within the workplace. The results show that most students meet the standard expectation on the cognitive or 'hard' skills but seem to lack the behavioural or 'soft' skills. There were statistically significant differences between cognitive and behavioural skills. The findings from this study suggest that cooperative education programmes need to do more in developing the students' soft skills before they go out for WIL placement to ensure effectiveness and broad-based technical competence.

***Keywords**: competency; industrial supervisor; workplace; work integrated learning; chemical engineering; higher education; cooperative education; vocational education*

1. Introduction

Across the world, higher education has been moving towards outcome-based approach where universities are required to identify the knowledge, skills and attributes that they expect their graduate to have achieved (Grant & Dickson, 2006). Engineering education in South Africa is emerging and continually changing. Course structures, teaching methods and learning environments are developing. A number of universities of technology (UoT's) in the country will be replacing the three-year national diploma, which includes a 12 months WIL programme with a two-year certificate, which excludes a WIL programme. Some UoTs are replacing the three-year national diploma with a three-year engineering degree, which does not have a WIL component either. Problem-based learning, teamwork and peer assessment are set to become increasingly popular in the engineering discipline. As a requirement for all engineering programme accreditation, it is anticipated that non-technical competencies, including ethics and teamwork will be part of the engineering curricula. This study is motivated by the view that workplace supervisors' perceptions of the recent graduates should be considered when all of the curriculum changes in engineering education are made. The study seeks to find out whether the current engineering curriculum is consistent with the industry expectations with regard to the students' competencies and to identify competency deficiencies.

Competency deficiencies in graduates have also been referred to as "skills gaps", referring to the difference between the level of competence required for employment and the level of competence of graduates (Male, Bush & Chapman, 2010). A report by Bodmer *et al.* (2002) for a study in Europe where 1372 engineers with bachelor, master or diploma degree rated engineering competencies on graduate performance, indicated that the large gaps were in communication, leadership and social skills. It is important to note that the skills that were identified in this study are 'soft skills' or behavioural skills. Spinks, Silburn and Birchall (2006) conducted a similar study among 256 employers of engineering graduates in the UK. The study found that there was small, yet statistically significant, dissatisfaction with practical application and business skills and to a lesser extent, technical breadth.

In an international survey of chemical engineers from 63 countries, participants ranked competencies and abilities with respect to the quality of their education and relevance to their work (WCEC, 2004). On average across all 1091 engineers with diplomas and bachelor degrees, the competence rated as having the highest deficit was the business approach. The report further showed ratings for quality management methods, project management methods, effective communication and leadership as a high deficit. As demonstrated by the various research results from other countries, rather than assuming that these findings are applicable to South African students, it may be important to obtain local data as well.

Communication is the competency that features most frequently as a deficiency in education surveys (Male, Bush & Chapman, 2010). For instance, in a study by Bons and McLay (2003), the graduates' responses indicated the largest gaps for accountability, teamwork, communication, interpersonal skills and skills to advocate influence. Furthermore, in a survey by Ashman *et al.* (2008), 40 undergraduate chemical engineering students and six engineering managers rated graduate attributes on importance and competence. Manager's and undergraduate students' ratings indicated deficiency in communication and manager's ratings indicated a slight deficiency in graduates' business skills. Nair, Patil and Mertova (2009) investigated gaps between education and workplace needs of engineers among 109 engineering related employers. The largest identified competency gaps were in the areas of communication, problem-solving, time-management, teamwork, application of knowledge in the workplace, ability to cope with work related stress and the capacity to learn.

According to Masoka and Selesho (2014), not much has been done in South Africa in terms of developing employability skills. This may be viewed as a concern, considering that employability skills are important since jobs today require graduates who can undertake different tasks. Today's jobs are not as narrowly prescribed and defined as in the past and generally they are more service-oriented, including on information and social skills (Kruss, 2007). In addition, the positions which employers are offering today require graduates to have a broader range of competencies than before, competencies which are job-specific but which include organisational and social skills (Miller, Biggart & Newtown, 2013).

In agreement with other researchers, there is an increasing demand from employers that graduates should have a range of competencies (behavioural and cognitive) in addition to their subject-specific knowledge. If chemical engineering is to continue to prosper as a discipline then our graduates may need to demonstrate behavioural skills at a level comparable to graduates in general and preferably to a higher level. This matter is likely to become just as important to chemical engineering education as the matter around course content. This study attempts to provide a South African perspective on competency deficiencies of engineering students.

This paper, therefore presents the background of the study that consists of a competency definition adopted for this study and the qualification programme. The paper then presents the literature review; in which it highlights the need for skills and competencies and the graduate employability trends internationally and in South Africa. In the same section, the workplace supervisors' responses from previous studies are explicitly stated. The study focused on students who undertook and completed a WIL practical component in various companies around the country.

1.1 Background

Cooperative education programmes aim to prepare students for the workplace by developing generic and specific competencies useful to the student career development and to the employer. The Engineering Council of South Africa (ECSA) defines competence as the possession of the knowledge, skills and attitudes necessary to perform the activities within the professional category to the standards expected in independent employment and practice (ECSA, 2012 : 2). ECSA (2012) further prescribes the knowledge component of competency as consisting of knowledge from the engineering education process and knowledge subsequently acquired, which is likely to be specialised and related to the engineering work context.

The purpose of work integrated learning (WIL) in the chemical engineering diploma is to ensure that the student can function as an active and competent member of an engineering team in the workplace. The diploma is a 3-year qualification, the first 2 years of which constitute the theoretical component offered at the University of Technology (UoT). The WIL practice 1 and 2 is the third and final year of this qualification. The time spent by the student in the workplace should ideally be two blocks but cannot be less than 22 weeks for each block. WIL seeks to promote the integration of theoretical concepts learned in the academic space with the industrial practices. It also allows students to develop other skills, which might not be fully developed in the academic setting. The emphasis during the WIL period is therefore placed on the application of knowledge, the development of skills and the formation of a professional attitude towards work.

The roles of the technicians which are a product of a UoT are changing and a shift in the paradigm of engineering is becoming more appropriate in today's environment (Nair, Patil & Mertova, 2009). In the past, engineering technicians were mainly concerned with the technical aspects of engineering, which is known as hard engineering. Even though the shift involves movement towards soft engineering, the technical aspect of engineering remains the core function of the engineering discipline. However, Duggins (1998) emphasises that it is only the dimension of the core that has changed. Assuming that every university endeavours to produce graduates with the skills that the industry values, it may be useful to know the industry's response to our students.

2. Literature review

WIL researchers contend that the context of the work-integrated learning situation has not been given adequate consideration in terms of the learning environment affordances (Billet, 2009), potential of graduate skill transfer (Jackson, 2013), multiple stakeholders' perceptions of placement quality and in particular concerning the impact of the direct work supervisor and the quality of work supervision (Henschke & Poppins, 2009). Smith and Smith (2010) emphasise the need to understand industry stakeholders as important co-contributors to a work-as-learning culture. Work integrated learning placement can be considered as learning endeavours that have important outcomes for three stakeholders – the student, the university and the employer (Bilsland & Nagy, 2015).

Barrie (2006) argues that the connection between education and economic growth has resulted in a worldwide growth of higher education. As a result of this connection, the institutions of higher education are increasingly feeling the pressure to develop programmes that meet new requirements that are characterised beyond up-to-date factual knowledge and technology-driven skills (Zehrer & Mossenlechner, 2009). The fulfilment of the new requirements is expected to be featured in the curriculum design where industry practitioners from the engineering field participate for development purposes. One way of featuring the industry view regarding the university's students is by understanding their views on student competence.

It is generally accepted that engineering graduates need to be prepared for the increasing use of advanced and appropriate technology in their prospective workplaces (Patil, 2005). A report prepared by the Institute of Science and Technology at the University of Manchester highlighted the fact that the careers of most engineering graduates include managerial tasks, despite the fact that many remained in predominantly technological jobs. According to Dudman and Wearne (2003), most engineering careers demand a variety of managerial skills and expertise, particularly in the leadership and management of projects. Nair, Patil and Mertova (2009) emphasise the point that the workplace performances of engineering graduates have been a constant subject of criticism. For example, a report published in 2009 by the Business Council of Australia (BCA) cautioned universities about falling behind in the ability to meet the industry needs. The report identified simulation techniques as one of the essential engineering skills that was lacking in graduates (Maiden & Kerr, 2006).

2.1 Skills and competencies

Most employers look for a more flexible, adaptable workforce as they themselves strive to transform their companies into being flexible and are more adaptable in responding to ever-changing market demands (Clarke, 1997; Berrie, 2006). Some researchers have looked at the employability of graduates and job requirements in the engineering field and different qualifications – technical knowledge and skills, attitude, proficiency in language/communicative skills, decision-making abilities, planning abilities and standards of engineering practice – have been identified (Pudlowski & Darvall, 1996; Nguyen, Pudlowski & Kerr, 1997).

Knight and Yorke (2003) highlight that there has been many attempts to 'pin down' employability skills and competencies of engineering graduates and the discussion has also been shaped by the limitations these functional lists might have since they always gravitate to the element of choice. Employers seem to approach the issue of employability from yet another perspective, which can be explained through the variety of business fields and focuses

(Zehrer & Mossenlechner, 2009). Many examples of such employers lists can be found in literature (Knight & Yorke, 2003), varying in their degree of differentiations, sometimes over-generalising or idealising skills.

Hence, the problem of variation and notation seems to emanate from distinct interpretations of particular skills and competencies and the extent to which they are rated is important as well as to which they should be developed (Drummond, Nixon & Wilthsire, 1998). Most taxonomies on competencies can be broken down into knowledge, abilities and skills which suggests that a set of skills or abilities can be part of an overall competency (Zehrer & Mossenlechner, 2009).

2.2 Graduate employability

Students commence their studies with the expectation that a higher education qualification will improve their chances of finding a job (Brauns, 2012). This is a reasonable expectation given that labour demands are shifting to higher skilled workers and professionals. It is therefore important to highlight that the ultimate goal of higher education is to ensure that they produce graduates that are employable after receiving qualifications.

Bridgstock (2009) gives a narrow definition of employability, emphasising skills and dispositions that might make an individual attractive to potential employers, often (not necessarily) focusing on short-term employment outcomes. Employability can also be defined as a graduate's achievements and his/her potential to obtain a 'graduate job', which should not be confused with the actual acquisition of a 'graduate job'. Employability derives from complex learning and is a concept of wider range than those of 'core' and 'key' skills (Yorke, 1998).

Futage, Kinicki and Ashforth (2004) refer to employability as one's ability to identify and realise job opportunities while (Hillage & Pollard, 1998: 85) maintain that employability is "the ability to gain initial employment, maintain employment and obtain employment if required". Interestingly, (Brown, Hesketh & Williams, 2003) challenge the definition of (Hillage & Pollard, 1998). They maintain that it is ideologically loaded because it ignores the fact that employability is predominantly determined by the labour market rather than the capabilities of the individuals suggesting that their definition of employability signifies a classic example of blaming the victim.

In summary, these definitions assume a connection between employment and employability, implying that if one has the right combination of skills, attitude and behaviours, then one is supposedly employable. This is what every university seeks to achieve. They aim to identify the right combination of skills that will ultimately increase the likelihood of success in the employment of its graduates. It makes sense for employers to employ graduates with desirable skills and competencies relevant to the job market. Therefore, it becomes crucial to identify any competency deficiencies in students in order to try to bridge the gap through curriculum design, with an intention to increase students' employability.

Rainsbury *et al.* (2002) suggest that students and new graduates perceive hard skills as more important than soft skills. It seems likely that this may influence students' study habits and attempts at skills development. If this is the case, such a practice may lead to students focusing on one side of their expected skills (technical) or content related to their studies, rather than developing their soft skills such as their interpersonal skills and process-type competencies (Burchell, Hodges & Rainsbury, 1999). The key issue is whether the workplace supervisors are satisfied with the competencies that our students possess and whether it is cognitive or behavioural competencies. Identification of any differences would enable the engineering academics to identify the competencies requiring greater emphasis in the curriculum. Perhaps, the extent to which the cooperative education programmes might assist in the development of specific competencies should also be highlighted.

3. Research methodology

Participants in the study comprised 106 students that were placed for WIL practical 1 in 2015. The workplace supervisors were asked to complete an assessment feedback sheet, which is a summary of their views regarding the students' performance after completion of the first six months training. They are expected to rate the students' performance focusing on five main competencies. The students collected these assessment feedback sheets as they form part of their report at the end of the training period. Hence, the response rate was 100%. It is well understood that there might be supervisors who assess more than one student per period, however this is not a problem since the assessment is for each student placed. The permission to use this data was obtained from the head of department.

The competencies listed on the feedback sheet were adopted from Spencer and Spencer (1993) namely attitude, ability, judgement and teamwork. These competencies were deemed necessary in order to gain a more complete perspective concerning chemical engineering students/graduates from industry personnel. The competencies were listed under two themes (soft skills and hard skills) and the participants were given a space to write additional comments that they felt relevant after each assessment. Workplace supervisors were asked to rate each student's performance using a 4-point Likert scale, where 1 indicated that the student needs to improve in this particular performance area and 4 indicated that the student exceeded the minimum requirement in the particular performance area.

The ranking given to each competency by the workplace supervisor (based on comparisons of mean values) is provided in table 1. These means also ranked from highest to lowest performance. Two sets of ranking are provided, one each for hard and soft skills, along with an overall ranking. The competencies were categorised into hard and soft skills by the author. The mean importance for each category was determined by summing the mean ranking of the competency within that category and dividing this by the number of competencies for each category.

Table 1: A full list of students' attributes used in the feedback report

Item no.	Attribute
1	Development of technical skill
2	Adapt to changing work assignment
3	Cope with several assignments concurrently
4	Self-starter and shows initiative
5	Cooperate and work with other people
6	Listens and carries out instructions
7	Works efficiently without close supervision
8	Meets deadlines and keeps superiors informed
9	Produces quality work and displays professionalism
10	Produces an acceptable quantity of work
11	Makes sound decisions based on available information
12	Seeks the appropriate help and advice when needed
13	Shows ability to solve problems
14	Accepts responsibility
15	Exhibits an interest in the job
16	Maintains acceptable dress and grooming habits
17	Good attendance and time keeping
18	Adheres to company regulations and standards
19	Willingness to work beyond standard working time
20	Dependable and conscientious
21	Adapted to working environment
22	Adapted to the social environment
23	Appears suited to this career

3.1 Research findings

3.1.1 Response rate and participant profile

Of the 106 complete supervisor feedback reports, only two feedback reports were not completed properly. All of the supervisors' feedback reports were returned with each student's P1 report forming part of the appendix.

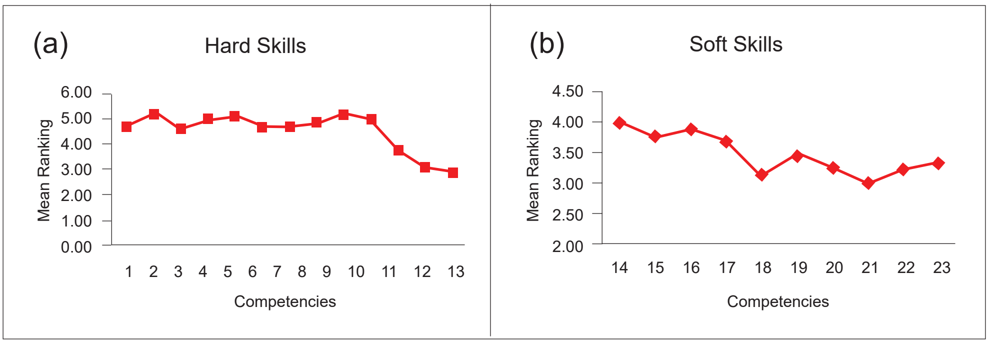

Figure 1: Ranking of students by workplace supervisor on (a) hard skills and (b) soft skills

Figure 1 shows the ranking based on a 4-point Likert scale as per the feedback report. Of the 23 attributes measured in the report, workplace supervisors rated five attributes as the least that all students possessed. These were independence, adapting to social working environment, teamwork and adhering to company standards and procedures. On the other hand, the workplace supervisors rated four attributes in which all students were acceptably satisfactory. These were meeting deadlines, ability to solve technical problems, decision making and producing an acceptable amount of work. It is noticeable that the least competencies that the students possessed are the soft skills and the strong competencies that they demonstrated in the workplace are hard skills.

4. Results

The (engineering) workplace supervisors' opinions collected and presented in this research provide insight for engineering educators. The conceptual themes were developed iteratively, to group units of data that indicated similar competency deficiencies. The themes evolved from repeated concepts in the collected data. However, the purpose of the study influenced the dimensions used to identify the themes and awareness of current and past changes in engineering education in South Africa provided insight. The purpose of identifying competency deficiencies is to assist continuous improvement of engineering education. Therefore, themes were selected to group competency deficiencies that might be addressed simultaneously by similar improvements in engineering education. The results were presented in two broad themes, the hard skills and soft skills.

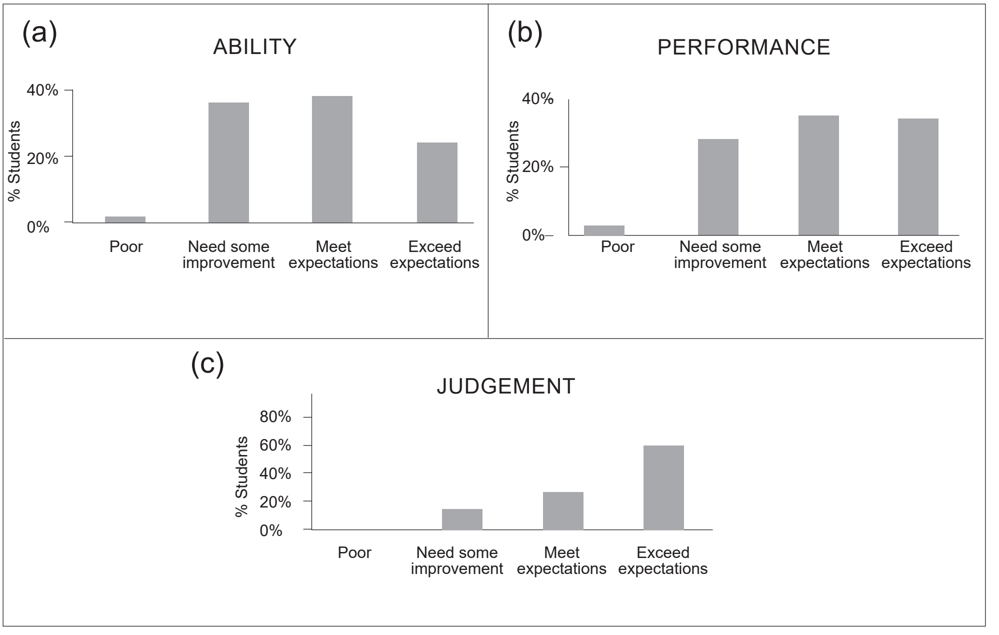

Figure 2: Assessment feedback on students' hard skills (a) ability to do work, (b) performance on the actual job and (c) judgement on technical matters

Figure 2(a) demonstrates the ability of the students in doing the actual job in the engineering discipline. This result indicates that the workplace supervisors rated 2% of the students poorly on their ability to perform the technical duties. The students that meet expectations of the supervisors and the students that need improvement in their ability were almost equal at 38% and 36% respectively. The rest of the students were rated as having exceeded expectations of their workplace supervisors. In relation to the ability of doing the job, is the performance standard of doing the job hence, figure 2(b) also shows similar results where 34% of the students demonstrated a higher strength in performance in their given technical projects and in delivering results. Approximately 3% of the students displayed poor performance in this area of competency.

Figure 2(c) shows that the students are stronger in decision-making where 64% of them met their supervisor's expectations and 6% of the students exceeded the expectations. It may be expected that the students who lack the technical skills that prevent them from performing in their jobs, will also be poor decision makers. Surprisingly, none of the students was rated as poor decision makers, which is in contrast with the results in figure 2(a) and (b).

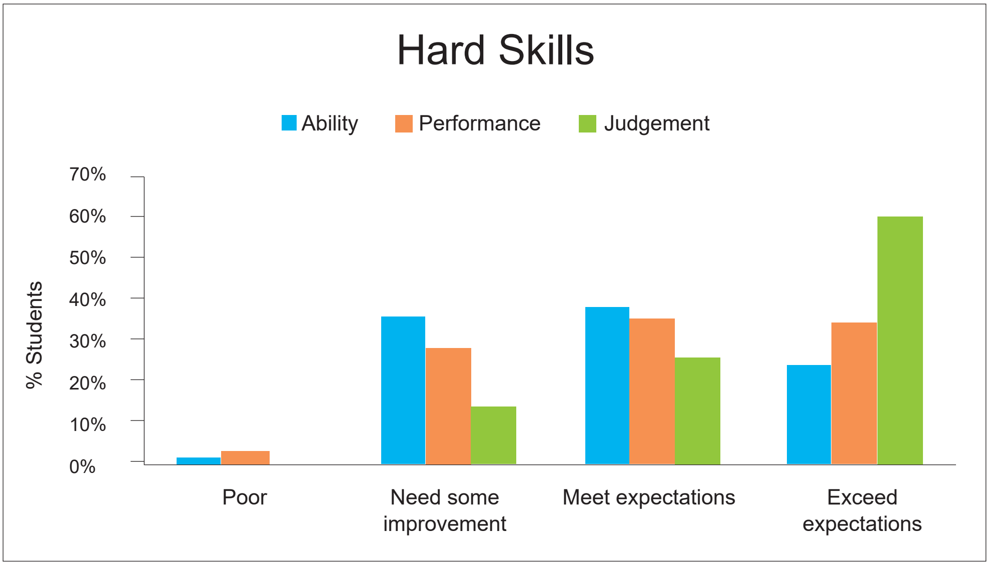

Figure 3: The overall view of students' hard skills combined

The statistical analysis was performed using Friedman's test to investigate the students' performance on hard skills. This is a non-parametric statistical test developed by Milton-Friedman and is used to detect differences in treatments across multiple test attempts (Friedman, 1937). This tool was used because the study has categorical and repeatable sample data. The statistical test showed that judgement, performance and ability were significantly different ($p < 0.05$). It is shown in figure 3 that judgement is the only competence where students did extremely well. This means that most of the students are able to make sound technical decisions based on available information and they seek appropriate help and advice when needed. The students' performance is the second strongest attribute that they possess, which is a great result as well. Over 70% of students met and exceeded the workplace supervisors' expectations because they are able to listen and carry out instructions. These students are able to work efficiently without close supervision and they produce an acceptable quantity of work.

It is important to note that not many students were rated high on ability to cope with several assignments concurrently. This result is unexpected since the students are exposed to such situations during the course of their theoretical study at the university. Most students need to improve in developing the necessary technical skills and knowledge needed in the industry.

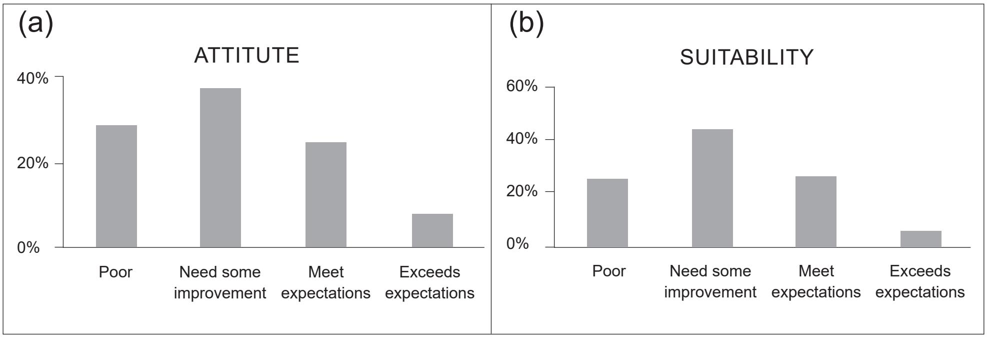

Figure 4: Assessment feedback on students' soft skills (a) attitude towards work in the industry and (b) suitability in the discipline

Figure 4(a) shows that almost 40% of the students need to improve their attitude at work. The students do not exhibit an interest in the job and they show less enthusiasm about the tasks that they are given. Only 5% of the students were rated as having an excellent attitude towards work; even so 25% of the students met their workplace supervisors' expectations on attitude. The main areas of concern are the adherence to company rules, time keeping and absenteeism, being dependable and willingness to work beyond the standard working hours. The soft skills results were dissimilar to the hard skills results where students exhibited high performance and high decision-making abilities. One could have expected that the students would have good soft skills for them to be rated high on performance. The result is not that far from what the study hypothesised, in that the students lack soft skills.

It is no surprise that figure 4(b) shows a similar trend as figure 4(a) because these competencies are intertwined in a manner that it is predictable that if a person has a bad attitude towards his/her work then a conclusion can be made that s/he is not suitable for it. There are only 5% of students that were found suitable for the engineering career. Above 40% of the students were found to have not adapted well to the working environment. It may be noted that 26% of the students met workplace supervisors' expectations on social adaptation in the workplace. Again, this result contradicts the rating that the students achieved on hard skills, it was expected that they would be more suitable in the career because their technical skills exceeded expectations. These results may be attributed to the low motivation and low self-confidence from some of the students. The workplace supervisors may view this as if the students are less suitable for the job.

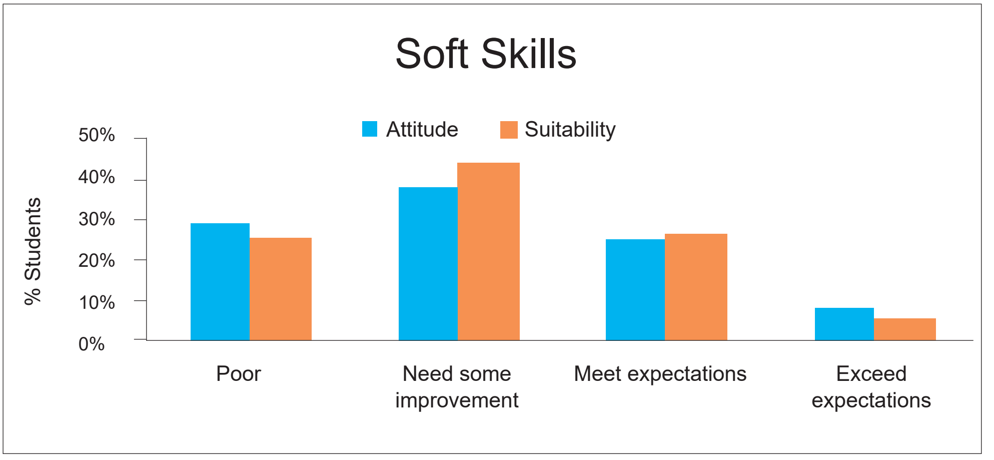

Figure 5: The overall view of students' soft skills

The statistical analysis was performed using Wilcoxon signed-rank test to investigate the students' soft skills. This is a nonparametric test procedure for the analysis of matched-pair data, based on differences or for a single sample (Woolson, 2008). The statistical test showed that the competency of students on attitude and suitability was not significant ($p > 0.05$). Figure 5 shows that approximately 30% of the students seem to be rather poor in attitude which is a challenge for the students. This result depends on the self-efficacy of each student, which will consequently determine his/her success in the industry. It is unfortunate that the students are struggling in this regard, which may jeopardise their chances of securing permanent employment in their respective places of work. More than 70% of the students were found unsuitable for the engineering career by their workplace supervisors.

5. Discussion

The introduction to this paper discussed the status of engineering education in South Africa, which is emerging. On the other hand, qualification offerings, course structure and the learning environment are changing. Are these changes aligned with competency deficiencies identified by the industry supervisors in this study?

The results of this study suggest that engineering education has some improvements to make in at least two areas of competency. Those areas are problem solving and communication. The results correlated with the findings of previous research indicating that engineering university students and graduates lacked skills required by the industry (Jones, 2007). The results showed consistencies in findings from previous research in that the shortfalls related primarily to communication, problem solving and social ethics skills (see figure 5). These results further imply that workplace supervisors require higher levels of knowledge and skills application from engineering students. Workplace supervisors found that there is a shortfall in soft skills, mainly in adherence to company rules, attitude towards work and social ethics. A possible reason for workplace supervisors to find this short fall could be that these attributes are not easily measureable and they are perceived as hard to be embedded in the course curricula in higher education. This finding is supported by the work of Coates (2007) and Shuman, Besterfied-Scare and McGourty (2005), which reported that there are very few examples of a successful tool for development of professional skills, such as students' ability to solve conflict, resolve ethical dilemmas and assessment of team skills development and project effectiveness.

This paper agrees with the findings by Nair, Patil and Mertova (2009) where it discusses that the aspect of global employment of graduates has created a requirement for a new attribute essential for engineering graduates. This is an ability to work in a multicultural work environment. Rojter (2005) reported that cultural awareness and diversity were attributes required for effective engineering practice. However, the results of this study showed that the students are actually lacking this attribute, which is a gap for the students at this point. Furthermore, the results of the workplace supervisors concerning the students were consistent with the study which showed that engineering graduates are lacking soft skills because they perceive these skills as unimportant when compared to hard skills.

The competency gap that was observed by Bons and McLay (2003) which highlighted accountability, teamwork, communication and interpersonal skills is similar to what this study established as well. Furthermore, the report from (WCEC, 2004) showed ratings for quality management methods, project management methods, effective communication and leadership as a high deficit. The same trend was observed in this study, which reaffirms the lack of soft skills in students. This study contributes a new dimension of competency deficiencies to engineering education in a South African context.

Nguyen (1998) posed a challenge to higher education by stating that in order for the engineering technicians to function effectively in a multi-disciplinary environment, engineering education must have the capacity to equip its graduates with skills and attributes from social science, computer/technology, mathematics and management. Some of these skills include communication skills, presentation skills and computer skills, programming skills, problem solving skills, leadership skills and team building skills. Most of these attributes were found to be below the expectations of the workplace supervisors, which leave engineering education with the challenge of correcting this in future graduates.

6. Conclusions

This study established that more than 70% of the students seem to be unsuitable for an engineering career, mainly because of their behavioural skills that include attitude, teamwork, social ethics and communication. The study is in accord with the international studies on graduate/students' attributes. This result may be related in that there is no formal education behind the development of soft skills, unlike the hard skills where you develop them over time in years of schooling. The argument that the soft skills should be embedded in the curriculum in order to ensure its development is a valid argument. The university needs to take responsibility of ensuring that its product is completely specified in terms of hard and soft skills. One approach could be utilising these findings to address the shortfall in soft skills (i.e. teamwork, communication skills, adherence to regulations and standards) in engineering by integrating annual project-based learning with more traditional instructions.

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