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Engineering Graduate Attributes

Skills Gained During a Service-Learning Module

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Engineering Graduate Attributes: Skills Gained during a Service-Learning Module

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Abstract: This article reports on the types of soft skills acquired by engineering students during a compulsory service-learning module. Certain engineering exit-level outcomes demand mastery of both "hard" (technical) skills and "soft" (nontechnical) skills, as do most employers from students entering the job market. Two independent cross-sectional datasets were collected in 2015 and 2016 of 347 and 294 respondents respectively, participants being second-year engineering students. A further two datasets were collected from alumni of the university who had completed the service-learning module as part of their studies. Results indicated that the module allowed engineering graduates to develop soft skills such as group work, time management, communication, and leadership skills. This research confirms that, although the service-learning module entails physical community work, soft skills were the most important skills acquired during the learning experience. Service-learning modules have proved to be the ideal vehicles for soft skills development in undergraduate students, particularly for engineering students who are not involved in service-related courses.

Keywords: Engineering, Engineering Education, Engineering Curriculum, Engineering Students, Graduate Attributes, Problem-based Learning, Service Learning, Skills, Soft Skills

Introduction

Engineers play a critical role in the infrastructure, power, and information technology sectors of a country. To shoulder such a responsibility, an engineer should be sufficiently trained in the technical aspects of engineering, understand the impact of engineering solutions in society, and subscribe to high ethical and moral standards. If any one of these building blocks is lacking, the engineer cannot adequately serve society. However, modern aspects of society, such as global commerce and constantly evolving technology, are creating an increasing demand for graduate engineers who are versed not only in technical or "hard" skills, but increasingly in people skills or "soft" skills.

Soft skills are mainly formed during pre-university life by the individual's schooling and home setting (Blom and Saeki 2012). Honing soft skills such as communication and interpersonal skills during students' undergraduate years is demanding in terms of time and effort. Time limits notwithstanding, various institutions worldwide have developed courses where engineers can practise soft skills while acquiring technical expertise (Alves et al. 2018; Ali and Mahmod 2018; Li, Loomis, and Caves 2018). Many of these courses are in the form of project-based learning modules.

By incorporating service learning in the curriculum, the abovementioned outcomes can be reached. Students have the opportunity to receive credits for their community outreach projects (Osman and Attwood 2007), which requires them to take part in a specific organised service activity. The aim of this outreach should be to address a specific need within the targeted community. During the execution of the project, students have to reflect on their service experience in order to gain a better understanding of the link between the curriculum and the dynamics of the communities. In so doing, students grow personally and realise their social responsibility (Bringle and Hatcher 1996).

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This article describes how an undergraduate service-learning module allows students to practise and attain essential soft skills for the workplace. The article is structured as follows: Firstly, extant literature is reviewed to ascertain the current state of soft skills training in engineering curricula worldwide. This is followed by a description of an existing service-learning module and the theory behind it. The research method is then described, followed by the findings and a discussion of the findings. The article ends with a practical conclusion.

Literature Review

The workplace has changed, and engineering professionals now work globally (Patil 2005) or at least within culturally diverse teams, which demands good communication skills, conflict resolution abilities, and leadership traits. The rapid rate of change in technology and the explosion of knowledge make an engineer's job much more demanding. In this modern world, a successful engineer adapts to new conditions and technologies. Factors such as the service economy and increasingly large work teams put the focus on people skills. In addition, the increasing pace of business creates a need for agile, adaptable workers who are creative problem solvers.

Penzenstadler et al. (2009, 1) define soft skills as "communicative abilities for interacting with other people." Lorenz (2009, 1) believes that it refers to "a cluster of personal qualities, habits, attitudes and social graces that make someone a good employee and compatible to work with." Alves et al. (2018, 2) define soft skills as social skills that are "the ability to communicate, persuade and interact with other members of society, without undue conflict or disharmony" or otherwise "the skills that are necessary in order to communicate and interact with others." For the purpose of this article, we define soft skills as professional ethics skills that students will need in the workplace.

According to Lorenz (2009), the ten most common soft skills are a strong work ethic, a positive attitude, excellent communication skills, time management abilities, problem-solving skills, the ability to be a team player, self-confidence, the ability to accept and learn from criticism, adaptability, and working well under pressure. Alves et al. (2018) call these skills the 4Cs: critical thinking, communication, collaboration, and creativity, while Ali and Mahmod (2018) categorise soft skills into communication skills, learning and information management skills, problem-solving skills, professional ethics skills, and leadership skills.

Engineering companies that hire graduate students seek not only technical proficiency but also reliable, open-minded engineering graduates who have integrity, work well in teams, and are willing to learn. Entry-level engineers also need to show leadership competencies such as initiative, communication, and good interpersonal relations (Hartmann and Jahren 2015). Recruitment agencies strongly believe that individual career success depends on interpersonal or soft skills. Indeed, certain soft skills are specified as exit-level outcomes by various accreditation organisations. The Accreditation Board for Engineering and Technology (ABET) has recently developed the professional engineering skills assessment (EPSA), which measures students' knowledge and application of professional skills (Danaher, Schoepp, and Kranov 2016). In its Exit Level Outcome 8, the Engineering Council of South Africa (ECSA) requires students to "demonstrate competence to work effectively as an individual, in teams and in multidisciplinary environments" (Engineering Council of South Africa 2014, 6).

However, in terms of soft skills, engineering graduates fall short. Pressure on students to attain technical expertise means the concomitant neglect of developing nontechnical or "soft" skills. A four-year engineering degree is demanding in terms of its cognitive load and credit hours. The number of available credit hours is under pressure due to efforts to reduce the students' financial burden and increase the production of trained engineers, while the course load increases due to the profession's diversification into areas of specialisation, such as civil, electrical, mechanical, mining, and metallurgical engineering (Galloway 2007).

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Many studies report that employers are satisfied with graduates' technical skills but not with their core employability skills and communication skills (Blom and Saeki 2011; Mori 2009; Schulz 2008; Sumanasiri, Yajid, and Khatibi 2015; Rae and Melton 2017). Galloway (2007) believes that engineers fail to grasp the importance of aspects such as effective communication skills, cultural sensitivity, and the ability to consolidate several different viewpoints. Indeed, professional negligence claims attest to the fact that engineers may fail to identify and satisfy clients' requirements (Johnston and McGregor 2005).

To address this shortcoming, Galloway (2007, 46) calls for the engineering curriculum to change and that "the subjects of globalisation, diversity, world cultures and languages, communication, leadership and ethics must constitute a core component of the overall engineering education, just as Physical Sciences and Mathematics do." Grasso and Burkings (2010) similarly call for engineers to grasp not only the technical aspects of their field, but also understand the human condition, which requires integrated and holistic thinking. This approach is followed by an engineering-based medical school as described in Amos and Dupont (2018), where engineers are trained in medicine and exposed to multidisciplinary teamwork with the aim of making them better innovators.

The call for supplementing technical skills education with people skills education has been a major theme in global engineering education literature for the last two decades. Engineering educators and professional organisations in countries all over the world are working diligently to identify the necessary competencies (Idrus, Dahan, and Abdullah 2012; Nair, Patil, and Mertova 2009) and create avenues for developing them. Various academic engineering education programmes have been developed to address soft skills development (Oladiran et al. 2011; Gnanapragasam 2008; Hillmer et al. 2007; Lohmann, Rollins, and Hoey 2006; Patil, Sid Nair, and Codner 2008; Idrus, Dahan, and Abdullah 2014). Others propose that soft skills training should be incorporated into the teaching of hard skills. In such cases there is the bonus that lessons become more attractive and therefore increase the success rate of learners. Various authors suggest that training should be adjusted to include more project work in teams, and grades should be earned as a team (Schulz 2008; Haldenwang, Slatter, and Pearce 2006; Nayak 2014; Idrus, Dahan, and Abdullah 2014; Blom and Saeki 2011).

Various role players took these suggestions to heart. Table 1 summarises the past five years' published research on interventions designed to teach soft skills as part of an undergraduate engineering curriculum.

Upon examining the studies in Table 1, it becomes clear that programmes such as work-based learning, service-learning, and project-based learning are proving effective and efficient in developing undergraduate engineering soft skills. At the same time, all the studies reported in Table 1 emphasise that the development of people skills and technical skills need to go hand in hand in engineering curricula to create holistic engineers. Various authors call for schools and universities to exchange information on their successful practices, as they believe that diversity of practices and professional environments will enrich engineering curricula worldwide and improve engineering graduate work readiness (Sumanasiri, Yajid, and Khatibi 2015; Rae and Melton 2017; Colaux et al. 2018). This article forms an answer to this call by describing a service-learning module that allows its participants to acquire various self-reported soft skills.

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Table 1: Soft Skills Development Initiatives

Author, country	*Type of soft skill development in undergraduate engineering curricula*
Ali and Mahmod 2018, Malaysia	Work-based learning programmes can improve how students work in a team, communicate, solve problems, the management of learning and information, their leadership skills, as well as their professional ethics skills
Alves et al. 2018, Portugal	Project-based learning programmes deliver a rich context where social skills can be practised and enhanced. These skills include effective teamwork, how conflict is managed, oral and written communication, the ability to adapt to different work environments, assuming responsibilities, caring about the others' learning, evaluating own work and that of others, and being prepared to participate in student and professional associations.
Amos and Dupont 2018, USA	Discuss creating a curriculum for an engineering-based medical school to create innovators who are able to address the growing healthcare needs of an ageing population. Students are required to show that they can function in interdisciplinary teams, understand professional and ethical duties, communicate effectively, and understand the impact of medical engineering solutions in different contexts.
Colaux et al. 2018, France	Describe the design of a competency framework to teach technical skills and soft skills to young engineering students, including the identification of the learning activities that support it. Students benefitted in various ways, including better marks and the cultivation of soft skills.
Grange and Miller 2018, USA	Outline how a partnership between a community-engaged course and a digital storytelling initiative can be facilitated.
Hoosain and Sinha 2018, South Africa	Develop graduate attributes by integrating engineering community projects into engineering curricula.
Li, Loomis, and Caves 2018, UK	Describe a service-learning module where hard and soft skills were successfully acquired in an enjoyable, sustainable, and mutually beneficial community outreach.
Blicblau, Nelson, and Dini 2016, Australia	Students who spent time on work-integrated learning or industry-based learning in the second last year of their engineering course obtained better grades than those who did not.
Proctor 2016, USA	This study examines the use of games and simulations as viable teaching tools for practising interviewing soft skills.
Rae and Melton 2017, USA	Explain how the Kern Entrepreneurial Engineering Network (KEEN) enables entrepreneurial graduate engineers to create societal, personal, and economic value.
De los Rios-Carmenado, Lopez and Garcia 2015, Spain	Describe a project-based learning initiative that has secured its place as the most suitable educational tool for developing skills and linking learning activities to the professional environment of academic programmes.
D'Souza and Rodrigues 2015, India	Proposes "extreme pedagogy," a student-centred conceptual framework to improve the quality of engineering education involving students and lecturers and their response to change.
Sumanasiri, Ab Yajid and Khatibi 2015, Malaysia	This is a literature review on the employability of university graduates and reveals that employability not only depends on the attributes of the individual graduates, for instance, the knowledge of a specific subject, but it also includes the faculty, curriculum and pedagogy in the university systems, and the expectations of the employers who hire the graduates.
Hartmann and Jahren 2015, USA	The researchers identified that companies strongly favour engineering graduate applicants with communication, teamwork, and interpersonal collaboration skills, as well as those who display creativity, confidence, and engagement in extracurricular and volunteer activities.
Gibb 2014, Scotland, UK	This is a critical review on soft skill assessments that could help shape future investments in systems to develop improved soft skills, ensuring lifelong learning.
Gibson and Sodeman 2014, USA	Reciprocal mentoring is suggested as a solution to use within organisations to develop soft skills.
Idrus, Dahan, and Abdullah 2014, Malaysia	Describe the extent to which cooperative learning and problem-based learning approaches are being used in order to integrate the teaching of soft skills in an engineering course.
Nayak 2014, India	An experimental study that has found evidence of the positive effect of soft skills training (such as teamsmanship, leadership skills, and emotional intelligence) on the performance of engineering students in group work.

Source: Data Adapted from Listed Studies; Mennega 2018

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Background to the Research

In 2005, the Faculty of Engineering, Built Environment and Information Technology (EBIT) at the University of Pretoria introduced a compulsory undergraduate community service-learning module. This was the first time that service-learning had been incorporated into the Faculty's curricula. Instead of adding a service-learning strand to the Faculty's existing modules, it was decided to develop a separate module, called the Community-based Project (JCP) module.

The main reason for developing a separate module was the perceived challenge of adding a service-learning strand to each of the different curricula of every EBIT department, particularly due to the large number of students enrolling in the faculty annually. Moreover, students in some study fields within the faculty are not permitted to work in their fields of study before they have qualified (Jordaan 2014).

The JCP module was launched as a pilot project in 2005 and became compulsory for all undergraduate students in the faculty in 2008 (Jordaan 2014). The ratio of the average class size in the module is extremely high (1,700 students to one permanent lecturer and one administrative assistant). Students execute their projects during the academic year, which may be any time from February until the end of October.

The module's main objective is to enable students to learn to solve problems in real-life learning situations (Jordaan 2012). It is also important that students reflect formally and informally on their experiences before, during, and after their involvement in the community (Bender and Jordaan 2007). A student is assessed on what he or she has learnt and to what extent the identified learning outcomes have been achieved. The assessment includes the following activities:

- Completing assignments after attending a compulsory orientation session
- Evaluating and approving the project plan
- Being assessed by a supervisor from the community
- Reflecting on the project on the institution's e-learning management system
- Producing a final report, which is uploaded onto the e-learning management system
- Making a YouTube video
- Presenting the project to the lecturer after completing the fieldwork (Jordaan 2012).

Students are encouraged to choose a project, identified by the lecturer, which will address the needs of their community partner, and about which they are passionate. Alternatively, students can identify a possible new community partner, provided they can indicate the workability of the proposed partnership as well as propose feasible projects at this partner's site (Jordaan 2014).

Typical student projects for the JCP module are repairing and renovating school buildings and animal shelters, teaching Mathematics and Physical Sciences at previously disadvantaged schools, repairing old computers to be donated to schools and nonprofit organisations, teaching basic computer skills to community members, and developing websites for nonprofit organisations or public schools (Jordaan 2014).

Education Theory Underlying the Module

Teaching and learning strategies have been designed to ensure that students become more aware of the demands of future employers and develop better communication, presentation, problem-solving, organisational, teamwork, and leadership skills (Humphreys et al. 2001). Problem-based service learning has become an important part of the undergraduate engineering curriculum (Ropers-Huilman, Carwile, and Lima 2005; Dukhan and Schumack 2010; Coyle, Jamieson, and Oakes 2006; Froyd, Wankat, and Smith 2012). The module's educational approach is aligned with the University of Pretoria's teaching and learning strategy. This strategy incorporates the

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theory of Kolb (1984), which entails experiential learning that includes project-, problem- and enquiry-based learning.

Kahn and O'Rourke (2005) identified enquiry-based learning as a learning approach. This approach includes problem-based learning, fieldwork, and small case study investigations (Kahn and Rourke 2005). It can be described as a total educational strategy (Barrett, Mac Labhrainn, and Fallon 2005). This approach is perfectly suited to teamwork. The starting point of an enquiry is crucial, as it must provide the basis from which the students are required to develop knowledge and understanding for a learning opportunity. The enquiry's beginning must be accentuated, as it needs to be sufficiently open to provide the basis for the enquiry, which could be an interesting case study or a "real-life" project (Kahn and O'Rourke 2005).

The outcomes of the JCP module can be closely linked to the characteristics of enquiry-based learning. For instance, students are required through enquiry-based learning to engage with a real-life project. This allows them to find one unique solution or a variety of possible solutions to a problem. Students use their existing knowledge to determine a solution to the problem. Students furthermore take responsibility for their learning and appropriately present evidence thereof.

Students are empowered through problem-based learning, which is an instructional student-centred approach incorporating theory and practice. Through problem-based learning students apply their acquired knowledge and skills to develop a new solution to an identified problem (Savery and Duffy 1995). For problem-based learning, the purpose of the learning activity must be clear to the students, and they must take ownership of the problem-solving process. Students should also feel that they have ownership of the problem itself (Wilson, Stelzer, and Bergman 1995).

Through the exploration of possible solutions, students are required to ask questions to develop a contextual and unique solution to real-life problems. To construct new knowledge students are required to work collaboratively. More questions or further investigation may be the outcome of this new knowledge. This new knowledge may be applied by students in their future careers. The learning process can be viewed as a cyclical, continuous, and ever-expanding process.

The main theoretical framework of the JCP module encompasses student-centred education and problem-based learning. Problem-based learning is a more student-focused approach. This learning approach involves introducing students to a problem and encouraging them to develop ideas, use prior knowledge, and discuss thoughts. Ideas on how to solve problems and the actions that must be taken to reach the solution are part of the process. Therefore, problem-based learning focuses on what students are learning rather than on what the lecturer is teaching.

In the case of the JCP module, the steps in problem-based learning are clearly defined. The students are presented with a problem, such as building a hoist feeder for a giraffe, after which they brainstorm ideas based on their prior knowledge. They also identify what they need to do to design and develop the project. Subsequently, the students present their solution to the problem by building the hoist feeder. Finally, they review what they have learnt from their project via their assignments for the module (Barrett et al. 2005).

Generally seen, when adding service-learning to the curriculum of a nonservice qualification, it is important that the following aspects are considered:

1. Students must understand the reason for the inclusion of such a module in their undergraduate curriculum, and the outcomes of the module must be correlated with their employability.
2. The skills the students acquire depend on the type of project they choose.
3. Students must be made aware of the skills they will be acquiring during the project's execution.
4. Students should have the opportunity to choose their projects within the set criteria so that they can develop the best possible skills set via the module.

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Methodology

Data for this survey was collected from students who had successfully completed the service-learning module described in "Background to the Research." Participants were second-year engineering students of the University of Pretoria who were doing their compulsory JCP service-learning module. Two independent cross-sectional datasets of 347 and 294 students respectively were collected during 2015 and 2016. Data collection was done each year during the month before the final exams, via the university's e-learning management system, and comprised a survey consisting of nine questions that included one open-ended question. The content for the questions on soft skills was gleaned from the literature. In addition to the two abovementioned datasets, two alumni datasets were also available. These datasets were collected (using the same survey questions) during two time periods: the first consisted of data collected from 2005 to 2010 and the second consisted of data collected from 2009 to 2014. Participants were alumni of the JCP service-learning module. The two sets of alumni data overlapped, as some of the students were still studying during the collection of the first set of data.

The completion of the survey was voluntary, and it was made clear to the students and alumni that their participation, or lack thereof, would have no bearing whatsoever on their grades. The survey could only be completed once the students gave their consent. Out of a total of 1,687 students in 2014, 347 participated in the online questionnaire, while 294 out of 1,660 students participated in the survey in 2015. This means that 20.57 percent and 17.71 percent of the enrolled students in 2014 and 2015, respectively, completed the survey. The first alumni survey for students who completed the module during the period 2005 to 2010, 518 alumni responded, and in the 2009 to 2014 alumni survey, 820 alumni responded. The first survey was completed by 7.8 percent of the alumni and the second survey was completed by 10.8 percent of the alumni.

The first question in the survey focused on the informed consent for the study. The students and alumni were required to indicate that they understood the nature and objective of the survey. They were also made aware that the results would be published. Questions two and three collected general information about the participants. Question four focused on the participants' reflection on the skills they had developed during the execution of their projects. Questions five to seven related to the perceived value of the module.

Most of the students who completed the survey were enrolled in BEng (Mechanical Engineering) (17.29% in 2014 and 23.47% in 2015). This correlates with the enrolments in the module where the highest percentage of students is enrolled for BEng (Mechanical Engineering) (15.74% in 2014 and 21.88% in 2015).

Findings

Even though the students worked in teams and were required to organise all the logistics of the projects, the students completing projects that entailed group interaction indicated better mastery of leadership skills. These projects included renovation projects (35.16% in 2014 and 26.85% in 2015), education-related projects (10.37 in 2014 and 15.02% in 2015), career guidance (13.26% in 2014 and 13.20% in 2015) and teaching Mathematics and Physical Sciences (10.95% in 2014 and 10.65% in 2015). Figure 1 lists the most popular types of projects in the JCP module.

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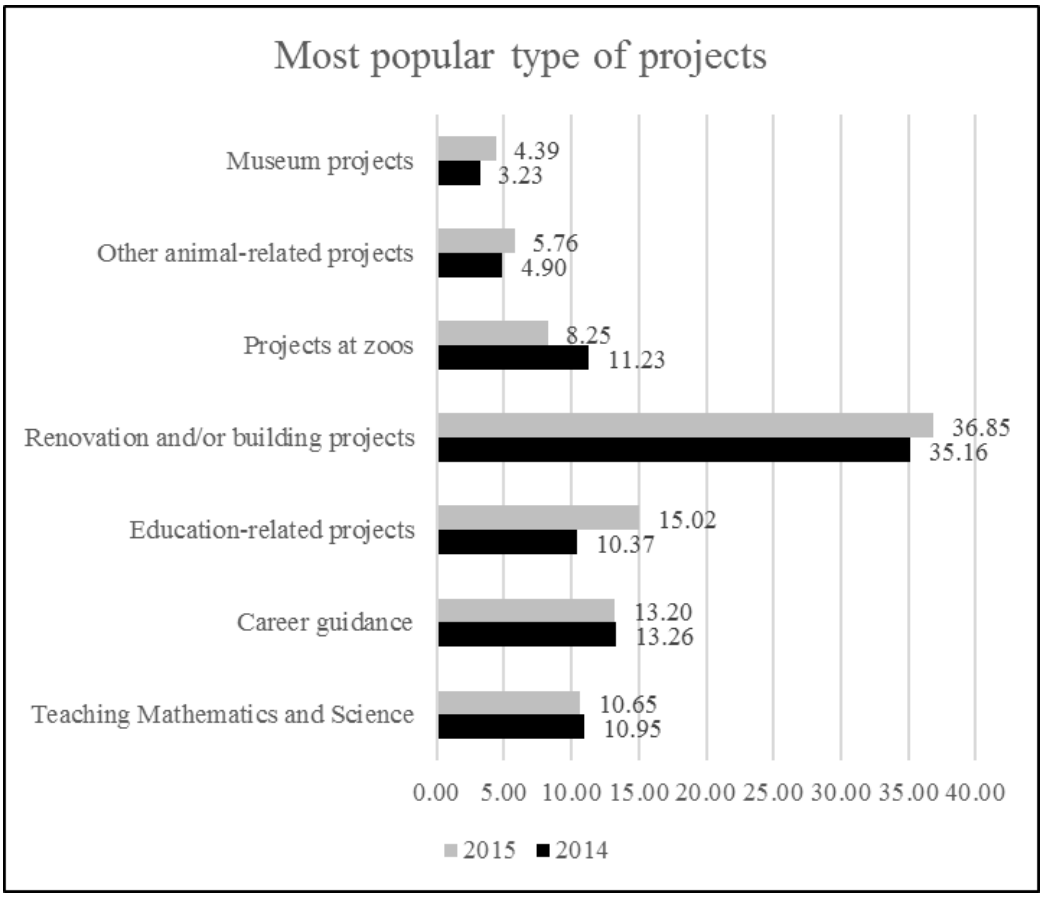

Figure 1: The Most Popular Types of Projects in the Module
Source: Jordaan

The type of skills the students acquired during the projects naturally depended on the types of projects that were undertaken. However, as seen in Figure 2, students in both years identified group work (73.8 % in 2014 and 67.3% in 2015), time management (70% in 2014 and 60.2% in 2015), and communication skills (65% in 2014 and 70% in 2015) as the most essential skills acquired. Leadership skills (53.9% in 2014 and 51% in 2015) and project management skills (53.3% in 2014 and 49% in 2015) followed close behind.

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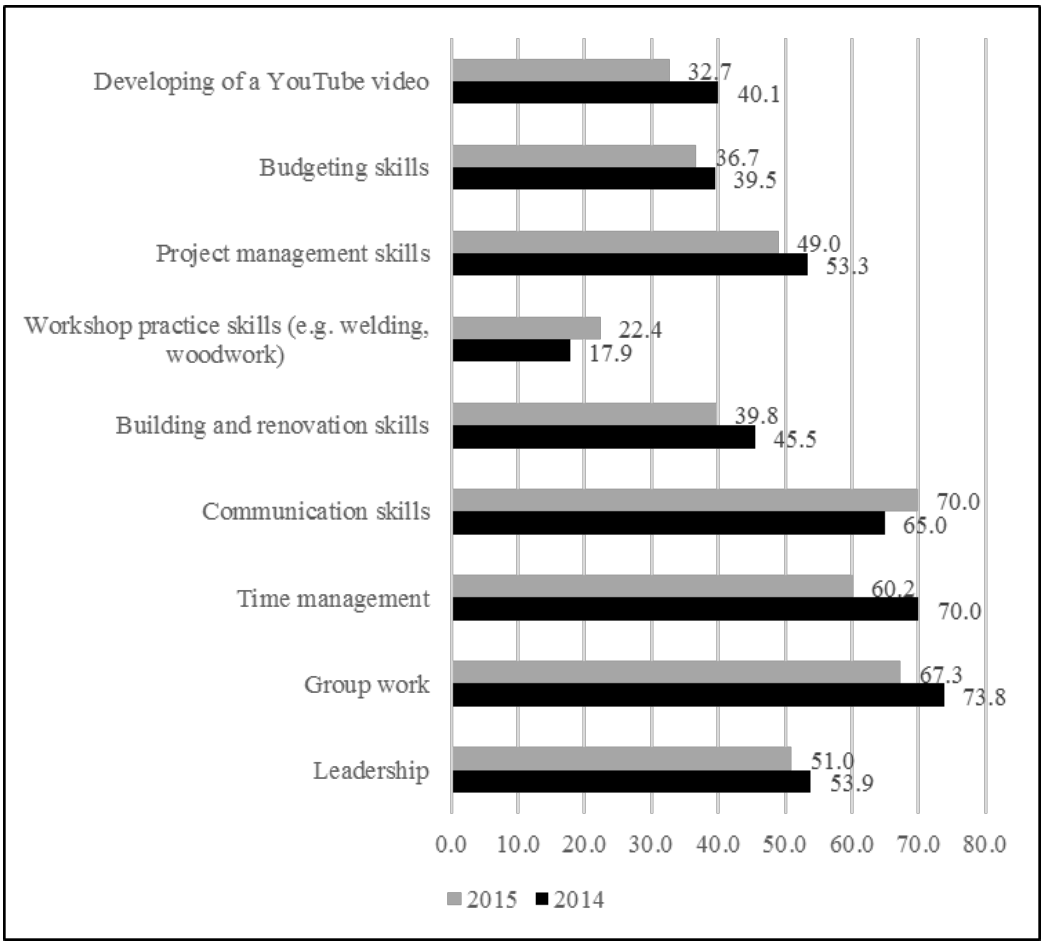

Figure 2: The Top Nine Skills Acquired during the Module
Source: Jordaan

Students involved in career guidance projects, teaching mathematics and physical sciences and projects at zoos, indicated group work as one of the most important skills they had learnt. Time management was the second-most important soft skill all students had acquired. There was, however, no significant difference in their identification of time management skills between the different projects. Leadership was the third-most imperative soft skill the students felt they had acquired.

To a lesser extent, students also indicated acquiring emotional intelligence skills and social ethics by working with people from different backgrounds. These skills neatly mesh with the skills required by employers (Nair et al. 2009; Hartmann and Jahren 2015). The top soft skill that students felt they had acquired was group work. Under the term "group work," the students understood that they had to work as a team in order to finish on time while completing the various aspects of the project.

This correlates with a questionnaire where alumni of the module were asked what they had learnt through the module (see Figure 3). Most alumni indicated that they had learnt group work, followed by working with people from different backgrounds, communication and interpersonal skills, project management skills, and time management skills.

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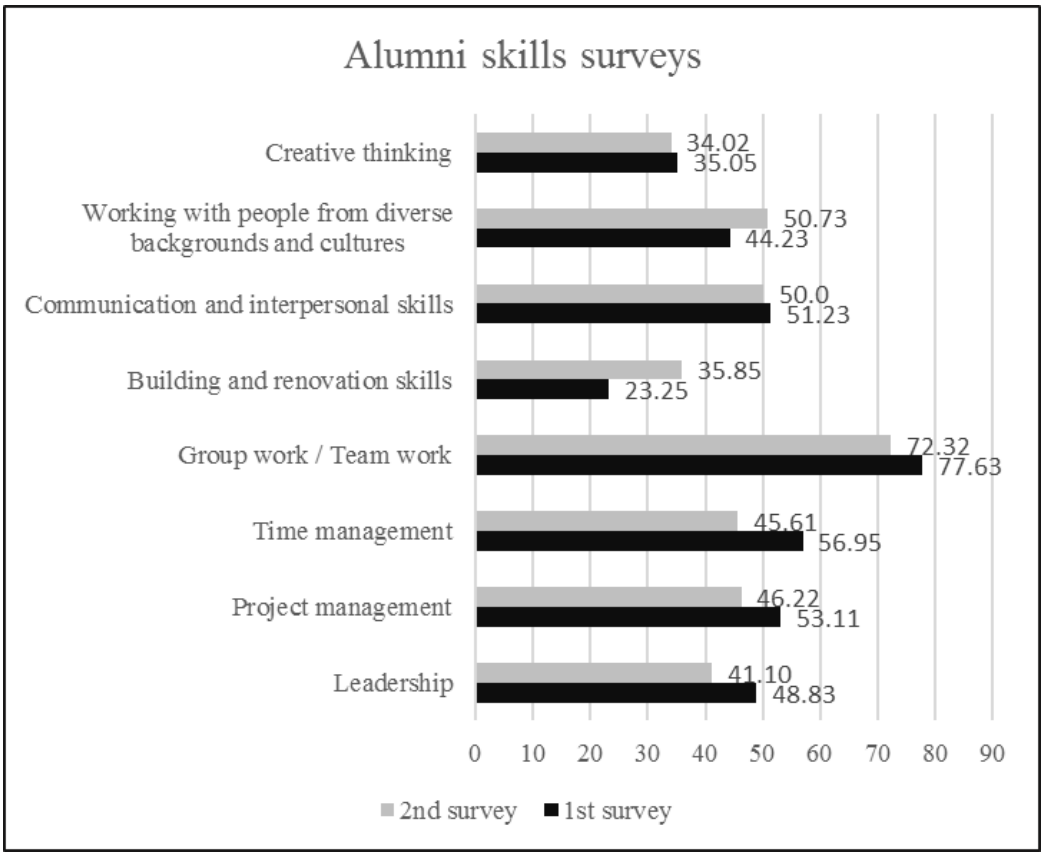

Figure 3: The skills Acquired as Indicated by Alumni
Source: Jordaan

Alumni in the first study indicated that they had developed skills in group work (77.63%), time management (56.95%), project management (53.11%), and leadership (48.83%) during their involvement in the module. The soft skills that the students attained count toward industry accreditation. The above-mentioned skills attained during the module satisfy one of ECSA's exit-level outcomes for engineering students, specifically Exit-level Outcome 8 that addresses individual, team, and multidisciplinary working (Engineering Council of South Africa 2014).

Discussion

The service-learning module described in this article stretches over one academic year. Every year, as the year progresses, the lecturer observes the same process occurring among all the students enrolled. Upon commencing the module, the students are reluctant to move out of their comfort zones. Being used to passive learning, it comes as a shock to them when they are confronted with a module where they have to behave autonomously and take ownership of their chosen projects. They struggle with the initial logistics and real-world working aspects. However, they report immediate gratification when the communities provide ongoing positive feedback on their work. Looking back, they found the projects challenging and interesting, and indicated a willingness to voluntarily continue with community service projects. The experience broadened their horizons at an early stage in their studies, providing them with a wider perspective through which to view their studies and the world they would enter as professionals.

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Limitations and Future Work

A limitation of this study is that it was performed at only one university. Future work could include administering the questionnaire to engineering students at other universities that offer similar service-learning modules.

Conclusion

Engineering curricula worldwide are being adjusted to include modules that allow students to supplement their technical skills with people skills. Service-learning modules have proved to be ideal vehicles for soft skills development in undergraduate students, particularly for engineering students who are not involved in service-related courses. This study shows that although most students chose construction and renovation projects for their service-learning module, they still reflected that the most important skills they had acquired during their service-learning experience were soft skills. The research conducted in this article confirms that a mandatory service-learning module in the engineering curriculum provides students with a glimpse of the world outside academia and allows them to practise skills that hugely improve their work readiness.

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