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Engineering Students' Perceptions of their Development of Professional Skills

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Cover Page Footnote

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INTRODUCTION

Engineers play a central role in addressing the challenges which face society. These challenges evolve over time due to the impacts of globalisation and disruptive technologies, leading to changes in how engineers are required to work. Society will therefore continue to expect Higher Education Institutions (HEIs) to create engineering programmes which will better prepare engineering graduates for the future and several authors suggest that transformational change is required (Clarke, 2012; Miller, 2015; Seely, 2005; Trevelyan, 2019; Vest, 2006). As a result, the literature suggests that that there is a need for a greater focus on a wider range of professional skills (ASEE Corporate Member Council, 2020; Craps et al., 2017; Passow, 2012; Ramadi, Ramadi, & Nasr, 2016; Winberg et al., 2020).

Professional Skills Development

A large number of studies have been published in the area of professional skills development in engineering students and across other disciplines (Chan, Zhao, & Luk, 2017; Colman & Willmot, 2016; Farr & Brazil, 2012; García-Aracil, Monteiro, & Almeida, 2021; Ghosh & Padgett, 2010; Kövesi & Csizmadia, 2016; Nair, Patil, & Mertova, 2009; Nikolaenko, Bondar, Bulgakova, & Dukulis, 2020). The types of skills required by employers is evolving, and universities are no longer required to focus solely on technical skills, but are now expected to produce a more rounded graduate with IT skills, communication skills, leadership skills and the ability to develop more sustainable solutions for the communities they live and work in (Farr & Brazil, 2012; Nelson, 2003; Rusinaru, Popescu, & Nistorescu, 2010; Siller, Rosales, Haines, & Benally, 2009).

It is clear that it is not an easy task to define a concise list of required graduate professional skills (U Beagon, Carthy, & Bowe, 2019; Chan et al., 2017; Green, Hammer, & Star, 2009) . Extensive lists of graduate skills have been developed (Chan et al., 2017; Passow, 2012). Chan presented a list of 12 broad generic skills which was extended to 38 skill items once sub categories were considered, whilst Passow focused on the 12 ABET (Accreditation Board for Engineering and Technology) competencies. However there is conflicting opinion on the importance and interpretation of skills (Barrie, 2006; U Beagon et al., 2019; Green et al., 2009), which can lead to difficulty in defining required skills for any graduate group.

Due to the lack of consistency in skills definitions in the literature, as outlined above, for this study we have developed our own set of seven broad professional skills based on programme accreditation and industry and employer requirements summarised in the next section and described in full in (Byrne et al., 2021).

Student Perceptions

Students' awareness in how they are developing and how prepared they feel they are to enter the workplace can be directly related back to how confident they feel in skills they have developed (García-Aracil et al., 2021; Lizzio, Wilson, & Simons, 2002). This in turn improves their chances when applying for a job or for further study. Therefore, their perceptions in how they are progressing is an important factor in forging their future careers (Burke, Jones, & Doherty, 2005; García-Aracil et al., 2021; Lizzio et al., 2002; Qenani, MacDougall, & Sexton, 2014).

Additionally, researchers have found that engaged students are more likely to be better performers whilst at university (Bakker, Sanz Vergel, & Kuntze, 2015; Salanova, Schaufeli, Martínez, & Bresó, 2010) and also in the workplace (Bakker, Demerouti, & Ten Brummelhuis, 2012; Christian, Garza, & Slaughter, 2011; Zepke & Leach, 2010). It then becomes a cyclical relationship, that those students who perform well, are more engaged, leading to higher confidence and better performance (Salanova, Llorens, & Schaufeli, 2011).

However, it can be difficult to accurately capture student perceptions as described by a number of researchers (Chan et al., 2017; Green et al., 2009). In addition, the Dunning-Kruger effect explored in the field of Psychology suggests that individuals may not accurately evaluate their own abilities (Chan et al., 2017; Dunning, Johnson, Ehrlinger, & Kruger, 2003; Kruger & Dunning, 1999). Although various tools have been developed for students to self-assess (Drew, 1998; García-Aracil et al., 2021), Chan suggests that the validity of these may be unreliable due to methodologies employed. With these challenges in mind, in this study we aim to develop a list of professional skills as described in Section 1.1, and assess our students' confidence levels in them, aided by the tool of self-reflection in an e-portfolio. By inviting our students to reflect on their confidence levels in the skills we have defined, we can help them to identify what skills they have developed and how, and also identify any gaps that may exist.

1 PROJECT BACKGROUND

With these challenges in mind, a pilot project to assist students to develop their professional skills in a structural engineering programme with the use of an e-portfolio was completed in our school during the 2020-2021 academic year. The primary aim of the project was to design our structural engineering programme so that students can develop skills that will enable them to become exemplary structural engineers with a focus on the future of our planet and its people.

The main work packages completed in our project are shown in Fig. 1.

The work package structure shown in Fig.1, enables us to perform a review of our programme from both educators' and students' perspectives, identifying areas where staff feel there are gaps, as well as where students feel less confident. We can then target those for future development.

As part of this wider project, the primary aim of this particular study, shown as item 3 in Fig. 1, is to determine how third year students in our Structural Engineering undergraduate degree

programme perceive their skills development through the recording of their reflections in an e-portfolio.

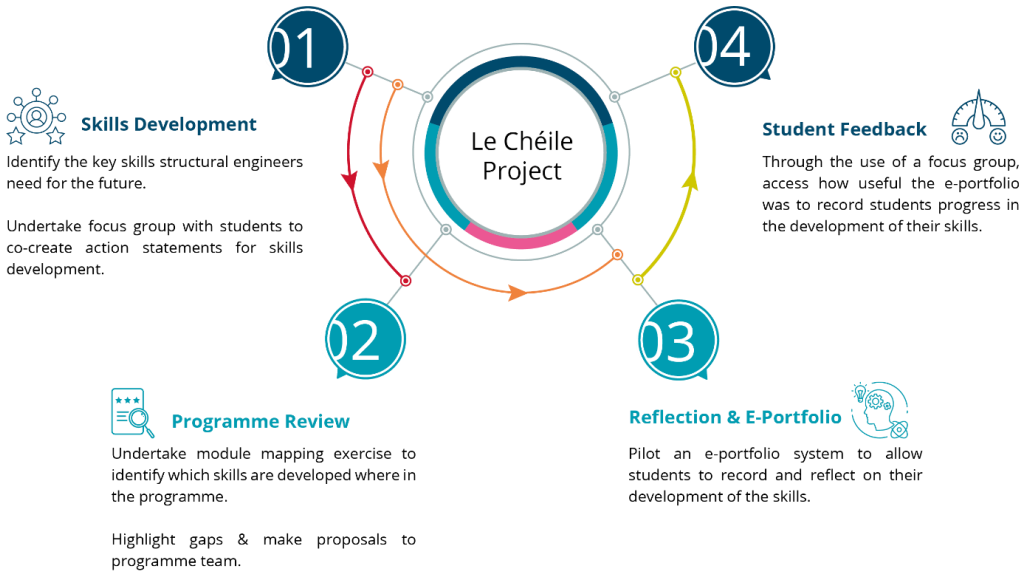

Figure 1 Results of students' perceptions to their skills (Lynch et al., 2021)

1.1 Skills Identification

The first step in this study was to identify what skills our students should be competent in upon graduating. The skills identification was a three-pronged approach as follows and is described in detail in (Byrne et al., 2021):

- A review of skills required by professional bodies
- A review of skills required by industry
- Input from students into how they perceive these skills including a feedback session with 3rd year Structural Engineering students to get a grasp of their understanding of the skills identified.

A review of the most recent relevant literature alongside chartership requirements of the Institution of Structural Engineers (The Institution of Structural Engineers, 2019) and Engineers Ireland (Engineers Ireland, 2021), as well as consideration of three seminal consultation and analysis reports on the future skills in the sector (Engineers Ireland, 2020; KPMG, FAC, & Dublin, 2020; National Skills Council, 2020), led to the identification of 7 skill clusters. These are the traditional, though evolving skills related to communication, technical ability, management and engineering practice, as well as emerging skills related to sustainability, technology and digitisation and society. It is accepted however that there may be different conceptions of each term, therefore, the presented research describes the co-creation of definitions for each of these skills with undergraduate structural engineering students (Byrne et al., 2021). Focus groups were used to engage students in a conversation around the meaning and importance of each skill resulting in specific action orientated definitions for each skill. These definitions were then used in the next phases of the project which engage the same students in a reflective e-portfolio exercise and structural engineering educators in a review of the programme outcomes in relation to such skills.

1.2 Recording Student Reflections in an e-portfolio

Portfolios are generally used as a way to record a learner's development, i.e. their knowledge, skills and competences. Portfolios also serve as a stimulus to encourage students to reflect

on their performance to enable them to self-assess, both key aspects of developing into life-long learners (Meeus, Petegem, & Looy, 2006). The current growth in availability of technologies for learning provides an opportunity for students to easily record evidence and artefacts which reflect their learning in an accessible manner. Thus e-portfolios serve as both a tool to encourage reflection and self-assessment in addition to a repository of evidence on development of competences and skills.

A number of e-portfolio options were considered in this project. As this was a pilot study, it was decided to use the e-portfolio available in Brightspace which is the Virtual Learning Environment (VLE) we currently use in TU Dublin City Campus. Students are already familiar with this VLE and we felt it would be a good way for the students to save their reflections so that they could review them ahead of future self-assessments. The e-portfolio can link to the students' modules, and may be shared with staff whilst not publicly available.

The usefulness of the e-portfolio was explored in a focus group which was conducted as part of Work Package 4 of this project and is described in detail in Beagon et al. (Una Beagon et al., 2021).

2 METHODOLOGY

2.1 Participant Selection

The sample of students for the study was drawn from current third year structural engineering students at TU Dublin. This is a four year programme which is accredited by Engineers Ireland as meeting the educational standard (with further learning) for chartership. The rationale for selecting these students is that they have a better range of educational experiences when compared with first or second year students and so they are best equipped to understand and reflect upon the skills that are presented to them. We also hope to assist them in developing their portfolio of skills development in this year and also in final year.

2.2 Ethical Approval

As the research work involved human participants, ethical approval was required for the survey and the analysis of reflections. All participants received written information about the objectives of the study, confidentiality of data collected and the possibility of withdrawal. They provided written consent before the survey data was included in the analysis and approval was granted by the TU Dublin Research Ethics and Integrity Committee.

2.3 Student Participation

A request for research participants was emailed to the third year structural engineering class group and all volunteers who had signed the ethical approval form were accepted. Using the skills identified by the work done earlier in this project, and outlined in Section 2.1, students were provided with the skills definitions and asked to rate their confidence as Completely Confident, Fairly Confident, Somewhat Confident or Not Confident at all. Providing just four options eliminates any "sitting on the fence" or "Neither Yes nor No" responses. Students then reflected on why they selected that particular rating for each skill. Their ratings and reflections were then compiled and assessed by the authors.

2.4 Data Analysis

The quantitative results of their perceptions of their ability in specific skills was calculated simply by recording the number of students who indicated each option. The data was analysed using a General Inductive Approach (GIA) (Thomas, 2006) which although similar to Grounded Theory (Glaser & Strauss, 1967) produces outcomes which are descriptions of the most

important themes uncovered, in contrast to hypotheses or theories to explain relationships. The data was analysed independently by two researchers on the team. They then met to discuss and debate their findings until they reached agreement providing validity to the study findings.

The results are presented in two sections. The first being the primary themes, i.e. their reflections on each of the clusters of skills identified. Secondly, cross cutting themes which emerged regardless of the skill set were also identified in the transcripts and these are also presented individually.

3 FINDINGS

Overall, students showed higher confidence in their technical skills and skills such as communication and management, however, showed little confidence with more global skills associated with societal and sustainability (see *Fig. 2*). They demonstrated some understanding of these skills, however, weren't clear on how these related to their future careers.

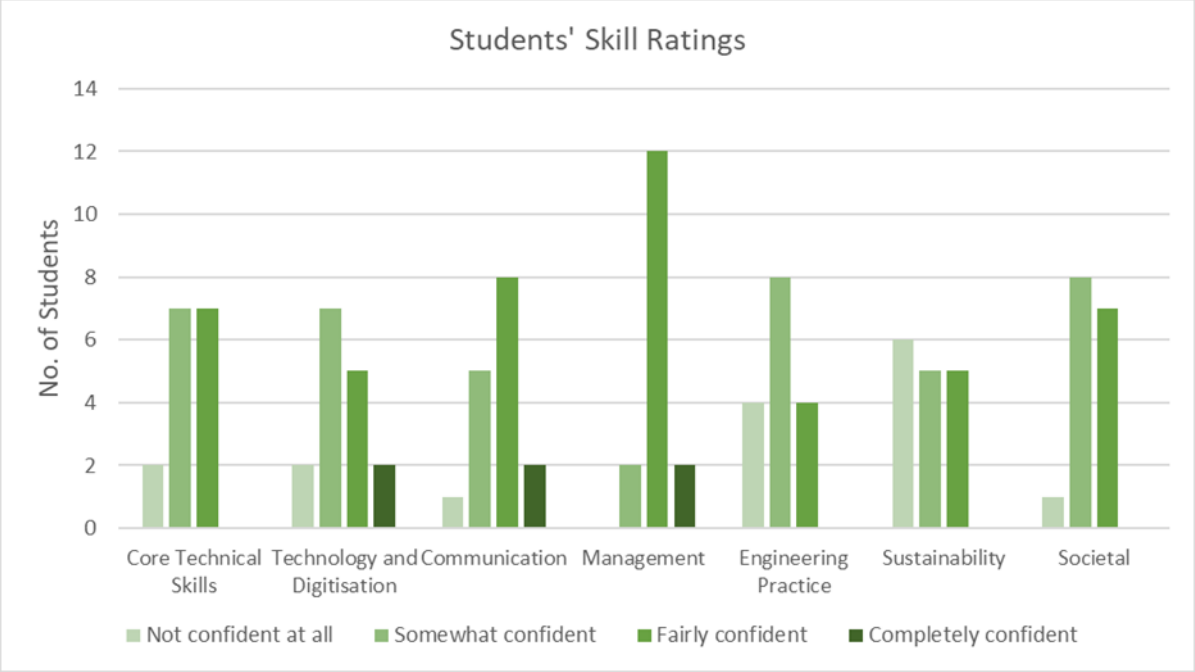

Figure 2 Results of students' perceptions to their skills

3.1 Primary Themes

3.1.1 Core Technical Skills

The primary theme which emerged from student responses in this skill set was in relation to the application of engineering principles. There was a mixed level of confidence within this theme with some students feeling fairly confident and others not so much. No student selected "Completely Confident".

Application of Engineering Principles: Students generally feel that they understand the mathematical processes but maybe not the engineering applications. *"I feel confident in my mathematics when it comes to my skills but I could improve with the science of it.", "The main way my core technical skills could be improved is within the area of terminology and definitions as although I can do calculations",*

3.1.2 Technology and Digitisation

There was a range of confidence levels demonstrated here with two students responding "Completely confident" and equally two students responded "Not confident at all". Most students' responses were in relation to software packages they had used for drawing, or other technical tasks in university, neglecting to think of other devices such as phones, tablets etc. and none mentioned using technology in a lab setting which was described in the skill definition.

Software: There is a diverse range of opinions here with some students being very confident and others not at all confident: *"never seemed to have trouble with it", "I feel very confident in using computers to help with calculations or modelling."* A general theme is that they would like more consistency in using software packages throughout their undergraduate programme; *"Don't think there are enough modules on this and often forget if I don't keep going back over"*.

3.1.3 Communication

Communication, along with Management, was one of the skills where students demonstrated the highest levels of confidence in their abilities. There were two themes which stood out in this skill; Presentations and oral communication with peers. Overall students felt they developed these skills well through group projects, however some noted difficulty with oral communication. Other forms of communication such as reports, emails and messaging were not mentioned.

Presentations: Students demonstrated quite a range of confidence levels here with some feeling very confident and others not at all. *"Not great in presentations and fully understanding questions the first time round", "There is lots of group projects and this is a good way of being better at this." "I feel I can communicate in a more casual setting such as while doing group work but struggle with more formal presentations"*.

Oral communication: Students overall are confident in their oral communication skills but appear to have difficulty in communicating with people they don't know. *"It is easy to talk to people that I have talked to before, but new people are still somewhat challenging." "I am new to this year so communication with people I don't know can be a bit difficult."*

3.1.4 Management

Two thematic areas emerged from the topic of Management; one was managing themselves and their own workloads, and the other was people management or group management in the form of leadership. Similarly to the Communication skill, 14 out of 16 students chose "Fairly Confident" or "Completely Confident" demonstrating a high level of confidence in this skill.

Leadership: Leadership was a very strong theme which emerged from the Management topic. Despite a lack of experience in leadership, the students mostly feel confident about their leadership skills with lots of positive reflections. *"I am fairly confident in my management skills especially with delegation within a group, leadership and planning which are strong skills I have." "I feel like I can manage and lead well" "I feel as though I'm a leader" "Group tasks and assignments have forced me into management roles which I now feel fairly confident in ".*

Workload Management: Our students also felt mostly confident in managing workload and being organised. *"I feel confident in managing my work/time and think that the group projects we do help me in this skill too." "I think I manage the course work load reasonably well as there sometimes be a lot of due in and around the same time."*

3.1.5 Engineering Practice

Two themes emerged from this topic also; one was experience with Engineering Codes and Standards, and the other was in relation to workplace experience. Overall, students felt that

they have some confidence in codes and standards, however most felt this could be better. There seemed to be a lack of clarity around this topic and none chose “Completely confident” for this skill.

Codes and Standards: There was a general lack of confidence concerning Engineering Codes and Standards. *"Becoming more familiar with standards and codes of practice”; “not confident at all in the codes and references and cost benefit analysis"*.

Workplace Experience: Students felt that they would benefit from experience in the workplace in order to improve their confidence in Engineering Practice. *"I still feel like I've stuff to learn when it comes to this practice." "I feel like I have very little experience in this area". "…Going to a site would be a good way of learning this.”*

3.1.6 Sustainability

Again, two main themes emerged from the topic of Sustainability; these were in relation to sustainable materials and design. There were lower levels of confidence within this theme than previous themes with just five students (31%) feeling “fairly confident” and no student “completely confident”. In their reflections, students primarily discussed materials and design, however didn’t refer to longevity of structures which was described in the skill definition. There was also a theme emerging of a requirement for the topic to be taught in class.

Materials: There were mixed levels of confidence in relation to the use of sustainable materials with most students not really understanding how they could incorporate it into their practice. *"I would not know what materials are more sustainable or where to locate local materials." “I am not confident in sustainability as it is not something that is discussed in class.”*

Design: Overall there is a lack of confidence when it comes to sustainable design with most students not really understanding how they could incorporate sustainability into their practice. *"I am normally focused on finding one answer that works rather than the most economical answer." “Don’t know a lot about this and how to put it into practice”*

3.1.7 Societal

Similar to sustainability, students say that they are normally more focused on finding the most efficient design rather than thinking about its impact on society. There appeared to be a range of levels of understanding of this theme with most students seemingly understanding the theme, yet no student selected “completely confident”.

Social/Community: Students showed a general interest in learning how to consider wider society and community in their work. *"I take a great interest in the effects of engineering projects to those in the area and how it will affect people." "No experience in dealing with local community for the betterment of structural engineering”.*

Environment: There were some responses in relation to the environment which provided mixed viewpoints. *"I am normally focused on finding one answer that works rather than the most environmentally friendly answer." "I think it is important to look after the environment"*.

Ethics: Two students also mentioned that they felt they understood ethics and how to behave ethically. *“I think I have the ability to be ethical…”* and *“…do understand the concept of impacting society and behaving in an ethical manner in daily engineering practice”.*

3.2 Secondary Themes

There were also number of cross-cutting themes which came across throughout the thematic areas as follows:

There was a strong **lack of proactivity** evident in the students’ feedback. Students didn’t appear to feel confident in an area unless they had been taught it and there was little recognition of experience or knowledge gained from outside the classroom, through

committees, clubs and societies, work placements, hobbies etc. *"I am not confident in sustainability as it is not something that is discussed in class." "I am not confident in sustainability as I believe it is not discussed enough"; "I am not confident in this skill as I am not really sure what it entails and it is not spoken about much during lectures".* In responses to topics such as Digitisation and Communication, the reflections focused mainly on university education without any recognition of skills gained outside of the university environment. We all experience Digitisation issues every day in the form of website "Cookies" or the use of apps such as Facebook, Snapchat, Google Drive, video editing software etc., and many of the students may have experienced issues in relation to GDPR, however this experience was generally not recognised by the students where they focused more on specific software packages. *"Still have a bit to learn when it comes to using new technology." "I feel very confident in using computers to help with calculations or modelling."*

Experiential learning: Students do not feel they have the skills if they have not experienced them, usually in the form of practicing them. For example, they are aware of the concept of how engineering impacts society, but have no "experience". *"I find the topic [sustainability] interesting but I have no experience in carrying it out so I'm not confident in my ability."* The exception to this rule was the theme of "Leadership" where students felt confident they could lead without necessarily having any prior experience in leadership. *"I have not had much experience in managing but I feel confident that I could do it well.*"

Impact of the COVID-19 pandemic: There was some evidence of impact of the COVID-19 pandemic throughout the responses. Students felt that not being in the university will have impacted on their communication skills, and in particular presenting or public speaking. *"I would be very confident in myself when communicating to anyone, although being out of college for nearly a year probably has hampered my ability to speak publicly somewhat."* One student also felt that his/her performance this year in group projects was affected by the environment, believing they performed better in previous years in a physical setting. In relation to management, the student stated: *"When I am tuned in; I believe I am pretty good at this. I work better in a physical setting where I am part of a team rather than a virtual one, that's why I believe I performed better in second & first year in group projects than I have this year. No excuses though, I need to improve on that."* Students also felt that not being present in the university will have affected their skills in the use of technology in the laboratory *"…We haven't done a lab for nearly a year so using the equipment again would need some getting used to."*

4 DISCUSSION

Although limited by the number of students who partook in this study, this study has shown us that students perceive themselves as being very competent in skills such as Management and Communication, but have difficulty in relating their studies to broader skills such as Engineering Practice or Sustainability. Students tended not to consider experience gained outside of the university such as work experience or experience on club or society committees etc. and related their confidence levels only to what they have learnt directly in university. This was particularly true in the skill of Sustainability, where undoubtedly students have an awareness of Sustainability issues through the news and media etc. but perhaps do not link learnings in class to sustainability unless it has been explicitly stated by the lecturer.

Finally, a theme of experiential learning came through from the students, where they did not feel confident in a skill unless they have experienced it. However, an exception to this theme was the leadership skill where students felt confident they had the ability to perform well as

leaders even without experience. A possible reason for this might be that they feel they understand what leadership involves.

The benefit of using an e-portfolio to record their reflections was explored in Work Package 4 of this project (Una Beagon et al., 2021). Feedback gained through a focus group with the students showed that students found the exercise difficult and required additional support in aligning the skills developed with the modules where they were developed. Students also found it difficult to self-assess, as also found in (Burke et al., 2005; Dunning et al., 2003; Kruger & Dunning, 1999). They also suggested that although they found the reflection exercise useful, unless there was a requirement to undertake the e-portfolio exercise, they would be unlikely to continue to use it in the future (Una Beagon et al., 2021).

It is important to note that this pilot study was limited to one group of 16 students in our structural engineering programme and the skills identified were based on the professional skills requirements outlined in skills reports and chartership requirements in Ireland as outlined in Section 1.1.

5 CONCLUSIONS AND RECOMMENDATIONS

This pilot exercise demonstrated to us how important it is to be explicit in what we are teaching our students. Some confusion was evident in cases where teachings were not explicitly linked to a theme or skill. Future plans of the project team include opening up the collection of these reflections across the entire programme, encouraging students to reflect from their first to final years of study. Analysis of the student reflections in parallel with a full-programme review from the perspective of the educators would firstly enable us to compare students' vs educators' perspectives, but also to identify skill gaps which should be eliminated.

The feedback we received from students gave us valuable insights into how they perceived their skill levels to be. Deeper reflections using the DIEP or Gibbs models (Gibbs, 1988; RMIT Australia, 2021) would encourage students to perhaps consider how their skills have been developed to date and how they will continue to be developed. This would be particularly useful for more senior students in third or fourth year.

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