Research in Engineering Education Symposium &
Australasian Association for Engineering Education Conference
5 – 8 December, 2021 - Perth, WA

Undergraduate Student's Perceptions of Factors that Enable and Inhibit their Professional Skill Development

Keith Willey [a], David Lowe [a], Emanuela Tilley [b], Kate Roach [b], and Tania Machet [c]
The University of Sydney [a], University College London [b], University of Technology Sydney [c]
keith.willey@sydney.edu.au

ABSTRACT

CONTEXT

The need for Engineering graduates who can balance strong technical competencies with broader professional and transversal capabilities is well recognised. In response to calls from industry and recognition by universities of underdeveloped professional skills in their students, there has been a move towards a more integrated approach to preparing undergraduate students for professional practice. This often involves the integration of professional skills development within the more traditional engineering science curricula.

PURPOSE OR GOAL

Engineering students tend to have diverse reactions to the teaching of these broader professional competencies with many students reacting negatively. This study explored the nature of these reactions and in particular aims to move past the common assumption that students' attitudes relate to students feeling like professional elements are not "real engineering". Understanding students' views on these competencies will enable universities to adapt their curriculum to maximise the quality of demonstrated learning related to professional skill development learning outcomes.

APPROACH OR METHODOLOGY/METHODS

As part of a broader survey on student reactions to the development of professional skills (with N ≈ 500), we asked an open-ended question seeking the respondents' comments that "might be helpful to us in understanding your views and experiences?". After undertaking a survey that required students to reflect on and think about their views in regard to their professional learning and development, this question captured those aspects that students thought were the most important additional information. We identified the dominant themes that emerged from these comments using a thematic analysis.

OUTCOMES

A number of dominant and often interconnected themes were observed. These ranged from a perception that professional skills cannot be taught at university and must be learned through workplace practice, to the view that university-based professional skills development is not authentic or valued, is poorly focused and structured and often being taught by academics who have not worked in industry themselves.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The student responses suggest that to successfully develop students' professional skills within university curricula, it is not sufficient to have an integrated, targeted and embedded program, but the intentions and outcomes of such programs, need to be well scaffolded and articulated to both students and staff and to be valued and seen as an integral part of a university's culture and beliefs.

KEYWORDS

student perceptions; professional skills; integrated engineering.

Background

The need for Engineering graduates who can balance strong technical competencies with broader professional and transversal capabilities has been well recognised for at least 20 years (National Academy of Engineering, 2004, King, 2008, Royal Academy of Engineering, 2007, Confederation of British Industry 2009). More recently, there have been critical analyses of the specific competencies that are desirable (e.g. Passow & Passow, 2017) and the approaches that are suited to the development of these skills (e.g. Winberg et al, 2016).

In response to calls from industry and recognition by universities of underdeveloped professional skills in their students, there has been a move towards a more integrated approach to preparing undergraduate students for professional practice. This move to a more integrated approach often involves the integration of professional skills training and development within the more traditional engineering science curricula. This move has also been reflected in the strengthening of professional skills development criteria within various engineering accreditation frameworks (ABET, 2011; Engineers Australia, 2018).

In part to address the need for a better balance between technical and professional compatencies various institutions have introduced integrative curricula (Lowe and Goldfinch, 2021). Two of these institutions, the University of Sydney, Australia and the University College London, have both introduced integrated engineering programs that are embedded through all years of students' engineering degree programs. At the University of Sydney integrated engineering consists of four multidisciplinary units typically undertaken in consecutive years as students progress through their degree. The units use online instruction and a series of workshops to support students in undertaking multidisciplinary engineering projects to address authentic, real world projects and workplace challenges and practices that require the integration, application and demonstration of students' technical and professional skills. Brookfield states that student resistance is often induced by learning that: challenges and stretches students; asks them to think critically; or use their judgement to deal with uncertainty and complexity (Brookfield 2017).

Similarly, engineering students tend to have diverse reactions to the teaching of broader professional competencies, with many students reacting negatively to the elements of their degree that focus on their broader professional development.

This study explored the nature of these student reactions, aiming to move past the common assumption that students' attitudes relate to their perception that professional elements are not "real engineering". In particular, this study considered the question of what students' view as most important in terms of what enables or inhibits their development of professional competencies. Understanding this will enable universities to adapt their curriculum to maximise the quality of demonstrated learning outcomes related to professional skill development.

Approach and Methods

As part of a broader survey on student reactions to the development of professional skills (with $N \approx 568$), we asked an open-ended question at the end of the survey, seeking the respondents' comments: are there "…any other comments …. that you think might be helpful to us in understanding your views and experiences?". There were 118 of the students who provided a response to this question, averaging 48 words per response.

The survey required students to reflect on and think about their views on learning of professional competencies. Given the optional and open-ended nature of this final question, we believe that it was most likely to capture those aspects that students thought were most significant and/or were most important to convey to us.

We identified the dominant themes that emerged from these comments using a thematic analysis (Guest, MacQueen, & Namey, 2012).

Because of the different timing of semester sessions between Sydney University and UCL the survey was released at different times at both universities. At the time of writing the vast majority of responses (more than 90%) were from Sydney University undergraduate and graduate students. To reduce the potential for institutional or national differences to be a confounding factor it was decided in this paper to only consider the data from the University of Sydney respondents. A subsequent analysis will consider the UCL data and will explore the extent to which different themes emerge in different institutional (or national) contexts.

All the coding for the research reported in this paper was conducted by a single person (one of the authors who was experienced in conducting thematic analysis). All student responses were read first and a number of central codes (themes) were identified. NVivo was then used to code all of the student responses. During the coding process a number of additional codes (nodes) were identified and added. After a period of two weeks the coding was reviewed and refined.

Findings

The thematic analysis revealed a number of themes, however two themes were easily the most dominant. These two themes relate to what we have categorised as authenticity and value. In discussing the nature of these two themes, we will provide (anonymous) extracts from the student comments used in the thematic analysis.

Authenticity

Authenticity relates to students' perceptions regarding the extent to which their learning associated with developing their professional skills is representative of what they believe occurs in industry (or the "real world"). It is interesting that even many first year undergraduate students, despite lacking any significant industry experience, still have strong beliefs and perceptions as to what working as an engineer in industry is like, what type of work they will be doing and what skills are important and how they should be learnt. In a future study we intend to interview first-year students to investigate the origins of these strong perceptions.

A common perception of students is that professional skills cannot be successfully taught and developed in the University context and are best developed in the workplace.

> *The best place to learn such skills is in the workplace. There is no way to consistently equip students with such a toolkit from drilling theory into their heads. Squeezing your way into the workplace and learning from there experience is the best way to gather such knowledge in my opinion.* ***(Participant 1, male, under 20, international student, middle year undergraduate, spent 1 to 3 months in any work and less than 1 month working in a professional job)***

> *The way some competencies such as "team work" are taught at university are inherently flawed by the fact that there is always a deadline to the group assignment/project and that no one is getting paid to do good work like they are in the workplace. This means the kinds of pressures on teams that are "randomly put together so that students can learn to work with a wide array of people" are *significantly different* to a professional work context. Group members are always forced to pick up for people who slack off, forced to spell/grammar check entire sections from other students to avoid getting deductions, or forced to rewrite entire sections when other group members blatantly plagiarise to finish their section of the work* ***(Participant 2, female, 21-25 years old, international student, middle year undergraduate, 1 to 3 years in work, three to 12 months in a professional job)***

> *Personally, I feel as though professional conduct is something that is better taught through first-hand experience than something that is taught theoretically i.e. from a textbook. Despite being professional in a workplace requires some inherent skills which can be summarised, the amount you learn from say a professionalism subject or component is minimal compared to hands on*

experience - if you are looking for a job and realise that your actions don't really fit in professionally or culturally, you're going to realise pretty quickly what you should or should not have done. ***(Participant 3, Male, Under 20, domestic student, first year undergraduate, three + years in work, less than one month in a professional job)***

Other students commented that the way universities taught and expect students to develop professional competencies did not relate to (their understanding of) the real world. That is, the University environment does not authentically simulate the work environment and/or does not teach and develop the skills in an authentic or meaningful context.

I don't believe that the university places enough emphasis on the professional skills that employers of undergraduates and graduates are looking for. Although the university is very aware that employers at these stages are interested in the professional skills that we have, the approaches to developing those skills in students seem misguided and disingenuous. ***(Participant 4, male, 21-25 years old, domestic student, middle year undergraduate, 1 to 3 years in work, no work in a professional job)***

I think it is important to consider that most of the current structure involves students and academics interacting with engineering principles and practice within a vacuum of sorts - there is very little real-world applicability of projects and learning within the university environment at the moment, which limits the job-readiness of professional engineering graduates. ***(Participant 5, male, 21-25 years old, domestic student, final year undergraduate, 1 to 3 years in work, 3 to 12 months in a professional job)***

I know this may be a radical idea, but I think university should replace any in-curricular engineering units focused on "professional development" that simulate "project management" and have students work in teams with a mandatory participation in an organic project, such as Formula SAE or the rocketry club. This will ensure every student has skills and personal experience that every employer will value, as they developed within an organic, extracurricular "real" environment. Some, if not most, employers disregard in-curricular coursework as evidence of competencies, therefore, university should make engineering extracurricular activities mandatory or at least schedule a unit in which students have the opportunity to focus on such activities. ***(Participant 6, male, 21-25 years old, international student, middle year undergraduate, less than one month in work, no work in a professional job)***

There were also concerns expressed by students that having a separate set of units to develop professional skills was not their preferred option and that it would be better to integrate their professional development within their technical subjects. Interestingly, the Integrated Engineering and professional practice programs at the University of Sydney were explicitly introduced to address this exact issue. However, at least for some students, it appears that the naming and identification of these programs means they are seen as somewhat separate, rather than embedded with their technical knowledge development and hence not grounded in what they regard as real engineering.

professional skills seem to be developed in tandem with technical skills, such that they should seen as holistic and their development should be approached in a way that can develop both at the same time (sic). ***(Participant 3, Male, Under 20, domestic student, first year undergraduate, three + years in work, less than one month in a professional job)***

These views from an undergraduate student were supported by a recent graduate who had more than three years work as a professional (though it is worth noting that this student would not have been exposed to the Integrated Engineering program).

It would have been even more beneficial to be mentored in the professional skills while studying the technical subjects. This is where you write reports, work with others, interact with staff/seniors and have to listen to the problem set (customer), ask questions, develop appropriate solutions and then "sell" them. ***(Participant 7, female, over 30 years old, was domestic student, employed***

professional, 3+ years in work, 3+ years in professional job) (note: completed undergraduate degree before the introduction of Integrated Engineering and PEP)

Other students expressed doubt as to whether academics were in a position to teach them or model professional skills relevant to industry, as many of them were seen as having limited or no prior industry experience.

I think it's difficult for some of the lecturers and researchers to discuss some of the professional competencies required for industry, particularly if they themselves are not privy to the industry. …. generally, the lecturers are not at the university to be teachers, but to be researchers, and that I think is a fundamental flaw in tertiary education: the educators don't have teaching as their focus. ***(Participant 8, male, 21-25 years old, domestic student, final year undergraduate, 1 to 3 years in work, 3 to 12 months in a professional job)***

Value

Students also expressed a range of concerns reflecting that they felt that the University did not value developing their professional skills.

Typically, students undertake four, six credit point units a semester. The Integrated Engineering program at the University of Sydney consists of four units. The first-year unit is a six-credit point unit while the second, third and fourth year units are only two credit point each and are taken in addition to the normal 24 credit point semester load (that is, students typically undertake a 26 credit point semester when studying Integrated Engineering 2, 3 or 4).

The Integrated engineering subjects are a good concept on paper but the execution and weighting causes students to lose motivation. The fact that Engg1111/Engg2111/Engg3111 are each only 2cp makes them feel useless and not a thing that the university considers important. As a result, the students don't see it as important either and hence don't make any commitment to work with their group members effectively and learn communication skills. ***(Participant 9, female, 21-25 years old, domestic student, middle year undergraduate, 3+ years in work, no work in a professional job)***

Last but not least, the workload and difficulty level of all of these subjects need to be adjusted accordingly so that students would treat them seriously. Integrated Engg units for 2CP whereas Engineering units for 6 CP, I think that would disincentivise people (as any economics lecturer would say to you) and promote apathy for these softer subjects, and continue to produce engineers who have the brains but not the heart to design their products / services for, not to mention a worse manager/executive/leader in the workplace as they progress in their careers. ***(Participant 10, male, 21 to 25 years old, was international student, employed professional, 3 to 12 months in work, 3 to 12 months in professional job) (note: completed undergraduate degree after the introduction of integrated engineering but before the introduction of PEP).***

*I think particularly with professional competencies, the skills introduced at university are considered more of an add-on than genuine learning necessities in comparison to mathematical fundamentals and technical skills. This is quickly reversed once in a work setting, where I found it was far less likely for employees to want me to work on their assignments unless I had proven a capability to communicate effectively. (****Participant 11, male, 21-25 years old, domestic student, middle year undergraduate, 3 to 12 months in work, 3 to 12 months in a professional job)***

Many students have an expectation that their University engineering studies should focus on technical skills as this is what they believe to be both valuable and most important to employers and will enable them to successfully get a graduate engineering job.

Throughout my survey, I have noted that I personally believe I experienced greater development of professional skills in more "technical" subjects (eg fluid, soil, structural mechanics), whereas

*subjects such as "Integrated 1,2,3 (4? haven't done it)" and "PEP" are in place to force this interaction between students, not so much for the student's development, but as a checkbox for the uni to say to employers "yes we put our students in positions to develop professional skills", hence my feelings that these approaches feel disingenuous. Whether or not this is the case, an underlying reason may be that the university does not understand the students' motivations for learning. In an environment filled with academia, where the pursuit of knowledge is its own reward, is the polar opposite of the beliefs expressed by many undergraduates (possibly enforced by a society where our self worth is dictated by what we bring to the table and thus we find the easiest way to do so), where we want our degree and a job as fast as possible and as easy as possible, so subjects like PEP and ENGGX111 do not feel valuable, as we expect to be taught technical skills in a higher education setting. (**Participant 4, male, 21-25 years old, domestic student, middle year undergraduate, 1 to 3 years in work, no work in a professional job)***

*In my experience, most of the professional competencies are either inherent or just have to be learnt on the job. Technical competencies are best taught at university so that students can feel prepared for a job's requirements and feel adequately suitable for engineering roles when they go to apply for them. (Eg. just about anyone will apply for a job if it says "good team work" in the job description, but not everyone will feel comfortable applying for a job that mentions "experienced with C++ and Java".) **(Participant 2, female, 21-25 years old, international student, middle year undergraduate, three + years in work, three to 12 months in a professional job)***

When students are transferring from other universities or receiving advanced credit for other studies they have undertaken, undergraduate program directors often chosen to exempt them from Integrated Engineering 1 (the first year six credit point unit). This is interpreted by some students as an indication that the unit is not important or not value by the University.

*In terms of improvements, I do admire the university's attempt to try to force students to develop professional skills on their own, however, its implementation requires some reworking. As an example, ENGG_111 (Will exempt ENGG1111 as it is a first-year subject) does not feel like a valuable subject (**Participant 4, male, 21-25 years old, domestic student, middle year undergraduate, 1 to 3 years in work, no work in a professional job)***

The following comment from a graduate student seem to suggest a view that professional skills should not be taught by engineering, calling for a more multidisciplinary approach to developing professional skills. The graduate student comments that even calling these core units Integrated Engineering, is sending the wrong message that they are about engineering and technical competencies are not professional skills. This is a particularly interesting perception as the units aim to integrate learning and development of professional skills with the application of the technical knowledge.

The Integrated Engg units are a good step in the right direction, but you need to ask the Arts, Commerce and Law lecturers to teach these subjects because when you name it as such, people still think that these subjects are about Engineering and technical competencies, and not soft skills. They will think of it as peripheral to the educational experience and this is not what the intended outcome should be. In every semester, the student must take at least one of this subject to ensure that professional competencies are developed incrementally (as you cannot teach things overnight and certainly to teach that at postgraduate level is a bit too late). Good values are inculcated and indoctrinated over time and that has shaped my personality and my character as I have gone through the degree.

*In order to effectively teach professional competencies, interdisciplinary degrees that include arts, commerce and law subjects should be offered as these subjects are not maths based, are about people and require writing arguments from a multitude of perspectives and at times with no right and wrong answers. Unfortunately, the STEM way of thinking and the Arts/Commerce/Law way of thinking is almost always mutually conflicting, and some people might end up hating it, but it must be taught, as much as it is a pain in the neck to think in two different ways. **(Participant 10, male, 21 to 25 years old, was international student, employed professional, 3 to 12 months in work, 3 to 12 months in professional job) (note: completed undergraduate degree after the introduction of Integrated Engineering but before the introduction of PEP).***

A number of students also commented on the Covid 19 pandemic, noting that having to interact with students in their class and teams via Zoom was problematic. However, one first-year student saw the pandemic as providing them an opportunity to develop professional skills that will be necessary in the future because of anticipated changes to the way we work.

> *Developing professional skills online has been quite a learning curve. Learning to communicate with people, ensuring each person gets a chance to speak and is on the same page is really challenging. However, I think these skills will be useful heading into the future where it will become easier to collaborate on an international level* ***(Participant 12, female, under 20 years old, domestic student, first year undergraduate, 3 to 12 months in work, no work in a professional job)***

Outcomes

A number of dominant and often interconnected themes were observed. In this paper we have focused on examining the themes of authenticity and value.

Comments attributed to the authenticity theme ranged from perceptions that professional skills cannot be taught at university and must be learned through workplace practice, to the view that university-based professional skills development is not authentic and/or being taught by academics who have not worked in industry themselves.

It is interesting to note that most participants had definite ideas about how professional skills should be learnt and what skills are required in the workplace even when they had little or no experience in a professional position. Furthermore, there is a belief by many students that problems with lack of professionalism, teamwork, poorly performing team members, motivation and conflicting priorities do not occur in the workplace, and their existence in university student learning and projects contributes to their perception that these activities are not authentic and do not reflect professional practice.

It would obviously be nonsensical to acknowledge that working in professional practice with other professionals and undertaking the associated activities and consequences would not be meaningful. However, many students do not seem to appreciate the opportunity their university studies provide to develop and receive feedback on their professional skills in a low-risk environment. It is interesting that many students appreciate that the technical knowledge they learn at university is regarded as preparation for professional practice and they expect to learn much more from experienced professionals when they have to apply this technical knowledge in practice. Yet many students do not view that they can develop their professional skills in the same may.

Comments coded to the *value* theme range from perceptions that the University does not value the teaching of professional skills, often as a consequence of the limited credit points attributed to the Integrated Engineering units. Students also felt the value of the Integrated Engineering units was diminished as they are often given as exemptions to transferring students and hence the University does not value them as much as technical units for which they perceive it is harder to obtain credit.

Some students felt the University's commitment to teaching of professional skills was more of an add-on, being poorly focused and structured and hence was not valued by the University. A number of students expressed their concern that the University should focus on developing their technical skills as, in their view, this is what employers wanted and what would enable them to successfully achieve a graduate engineering position. While other students believe that professional competencies are inherent and are learnt through working and everyday life.

Interestingly it was a graduate student who, after three years working professionally, suggested that the program should be expanded and have a wider interdisciplinary focus

where arts, commerce and law lecturers should be used to teach important professional skills and competencies as they felt the STEM way of thinking is more technical.

It should be noted that when the Integrated Engineering program was initially introduced at the University of Sydney there was resistance from some staff and students. This resistance was often associated with value, including concerns about the reduction of credit points focused on more highly valued technical content, and a dislike, particularly by students, of the more open-ended, complex and broad problem-based learning the Integrated Engineering units introduced. This required students to use judgement, manage competing demands, uncertainty and complexity. Unlike much of their more technical studies where problems often have a unique correct answer and their learning is "associated with absolutes, moving from the 'knowable' to the 'known' using predetermined rules, facts and analysis to manage encountered uncertainty" (Willey & Machet 2018, 2019).

While five years into the program this resistance has largely dissipated and student satisfaction with the two credit point units has been steadily increasing, the fact remains that the two credit point Integrated Engineering units are still perceived as being a bolt on, requiring students taking a standard program, to undertake five units in a semester. In response to the concerns, many of which are discussed in this paper, the program has recently been redesigned to consist of three, six credit point units which are now embedded into a student's normal program. It is hoped that this will increase the perceived value and subsequent commitment to these units by both students and staff.

Recommendations

The student responses suggest that to successfully develop student's professional skills within university curricula, it is not sufficient to have an integrated, targeted, well designed and embedded program. It is clear for success that the intentions and outcomes of such programs, need to be valued, well scaffolded, articulated and demonstrated to both students and staff and to be seen as both authentic learning and an integral and supported part of a university's culture and beliefs.

References

ABET. (2011). *Criteria for Accrediting Engineering Programs*. http://www.abet.org/uploadedFiles/Accreditation/Accreditation_Process/Accreditation_Documents/Current/eac-criteria-2012-2013.pdf

Brookfield, S. (2017). Becoming a critically reflective teacher. San Francisco, CA: Jossey Bass.

Engineers Australia. (2018). *Accreditation Management System: Accreditation Criteria User Guide – Higher Education (AMS-MAN-10)*.

King, R, (2008), "Engineers for the Future," Sydney, Aust.,. Accessed April 28, 2021 [Online]. Available: https://www.engineersaustralia.org.au/sites/default/files/content-files/ACED/engineers_for_the_future.pdf .

Confederation of British Industry (2009), "Future Fit: Preparing Graduates for the World of Work," Confederation of British Industry (Great Britain) (CBI), London, UK.

Guest, G., MacQueen, K. M., & Namey, E. E. (2012). *Applied Thematic Analysis*. Sage Publications. https://books.google.co.uk/books?hl=en&lr=&id=Hr11DwAAQBAJ&oi=fnd&pg=PP1&dq=validity+of+automatic+coding+for+thematic+analysis&ots=Xi4zyKwIuH&sig=0aNyKVAlnU3b6dRmv5ZtZlvw42Y&redir_esc=y#v=onepage&q=validity of automatic coding for thematic analysis&f=fals

Lowe, D., & Goldfinch, T. (2021). Lessons from an Analysis of the Intended Learning Outcomes of Integrative Project Units within Engineering Programs. *IEEE Transaction on Education*. In Press

National Academy of Engineering, (2004), "The engineer of 2020: Visions of engineering in the new century", Washington, D.C.: National Academy of Engineering.

https://www.voced.edu.au/content/ngv:63792

Passow, H. J., & Passow, C. H. (2017). What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review. *Journal of Engineering Education*, *106*(3). https://doi.org/10.1002/jee.20171

Royal Academy of Engineering, (2007), "Educating Engineers for the 21st Century," London, UK. Accessed April 28, 2021 [Online]. Available: https://www.raeng.org.uk/publications/reports/educating-engineers-21st-century

Winberg, C., Winberg, S., Jacobs, C., Garraway, J., & Engel-Hills, P. (2016). 'I take engineering with me'': epistemological transitions across an engineering curriculum.' *Teaching in Higher Education*. https://doi.org/10.1080/13562517.2016.1160045

Willey, K., Machet, T. (2018). Complexity makes me feel incompetent and it's your fault, In Proceedings of 29th Australasian Association for Engineering Education Conference 2018 Hamilton New Zealand

Willey, K., Machet, T. (2019). Assisting tutors to develop their student's competence when working with complexity. *8th Research in Engineering Education Symposium (REES 2019)*, Cape Town: Research in Engineering Education Network.

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