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Addressing graduate competencies: Understanding the contextual factors impacting the engineering discipline

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Abstract

The knowledge of contextual factors that impact the engineering discipline is one of sixteen competencies that must be demonstrated by engineering graduates upon completion of an accredited engineering degree in Australia. This research critically analyses learning outcomes, learning activities and assessment tasks associated with the knowledge of contextual factors for the Mechanical Engineering (Honours) degrees at two universities to determine how this competency is perceived and addressed within the curriculum. In the majority of cases, the learning outcomes do not address the competency and there are instances where this competency has been misunderstood and misrepresented. Various assessment tasks are used in the subjects that address this competency, including exams, tests, assignments, reports, presentations, tutorials, reflective journals and others. Universities and accreditation providers must review their processes for addressing this competency to ensure it is achieved. Further research is required to define this competency for better alignment and understanding of learning outcomes.

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1. Introduction

Insight into the competencies that are required of engineers can be gained from various stakeholders, including accreditation providers, educational institutions, industry, government, current and future students, graduates and

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experienced engineers. The environment in which each stakeholder operates is important, as this impacts their priorities and the value placed on certain competencies. Industry values communication skills, drive and knowledge of industry and work experience [1] and attitude [2]; established engineers place greatest value on communication skills, working in diverse teams and self-management [3]; academics value 'technical knowledge and skills', while students perceive an overlap of both attitude and technical knowledge to be important [2]. What is clear is that engineers are required to go beyond scientific knowledge and problem solving [4] and much research exists to identify the range of competencies that engineering graduates should possess [5, 6, 7].

In Australia, the Engineers Australia (EA) Stage 1 Competency Standard for the Professional Engineer [8] describes the competencies that must be demonstrated at the point of entry into the profession. This standard highlights the value placed on both the professional and personal attributes of engineers. Accreditation of engineering degrees provide assurance that the structure and content of the degree meets national and international standards of the profession for which the degree prepares its graduates. The Washington Accord, the Sydney Accord and the Dublin Accord, to which EA is signatory, also acknowledge the significant equivalence of accredited degrees across international boundaries [9] allowing graduates to work and use their skills around the world.

The accreditation process considers the 'appropriateness of educational objectives and targeted graduate capabilities, the integrity of the educational design and review processes and the means employed to deliver and monitor outcomes' [10]. The Stage 1 Competency Standard [8] used by EA during this process consists of three overarching competencies (knowledge and skill base, engineering application ability, and professional and personal attributes) which are elaborated into 16 Elements of Competency. Each element is also described using 'indicators of attainment' which provide insight into the scope of ability expected for each element. Engineers Australia does not dictate the structure, objectives or the content that needs to be covered in an engineering degree for accreditation requirements to be met. The indicators of attainment provide insight into the 'breadth and depth' of the elements of competency and are not seen as specific objectives that must all be addressed in order for the competency to be achieved. Engineers Australia tests for the attainment of each element of competency in a holistic sense and innovation and diversity in educational design and delivery are encouraged [11].

1.1 Knowledge of Contextual Factors

The need for change in the engineering education context continues to be acknowledged with the need for development of professional skills, as opposed to just the technical [12]. Accordingly, more emphasis needs to be placed on the role of an engineer. Spinks, Silburn and Birchall [13] report the importance of technical ability but also the value of 'practicality', with graduates needing a more realistic view of the world. King [14] also reports the need to engage more intensively with industry to strengthen the authenticity of engineering students' education. Consequently, this paper focuses on contextual factors of the engineering discipline as opposed to any of the other EA competencies, considering the overarching themes covered within this element of competency.

'Knowledge of contextual factors impacting the engineering discipline' formed element 1.5 (hereafter referred to as E1.5) of the 2011 Stage 1 Competency Standard for the Professional Engineer [15]. Following revision in 2013, E1.5, in its current state, also incorporates a design element: 'Knowledge of engineering design practice and contextual factors impacting the engineering discipline', forming one of the 16 competencies required of engineering graduates upon completion of an accredited engineering degree in Australia. Element 1.5 associates with the context of engineering, highlighting the need for students to understand the role and interaction of engineering and engineers within society, the importance of human factors and the context of 'real' engineering practice in terms of operating contexts and fundamentals of the workplace and the workforce. The six indicators of attainment for E1.5 include [8]:

a) Identifies and applies systematic principles of engineering design relevant to the engineering discipline.
b) Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline.
c) Appreciates the issues associated with international engineering practice and global operating contexts.
d) Is aware of the founding principles of human factors relevant to the engineering discipline.
e) Is aware of the fundamentals of business and enterprise management.

f) Identifies the structure, roles and capabilities of the engineering workforce.

The relevance of each of these indicators to the work of an engineer is clear and each education provider has the freedom to address the overarching competency (E1.5) in their own way. Considering the importance of developing best-practice engineering education which promotes student learning that is aimed at delivering intended graduate outcomes [14], this research critically analysed E1.5 with the aim of understanding how universities perceive E1.5 and how it is addressed within the undergraduate curriculum.

2. Methodology

This research uses document analysis and thematic content analyses of documentation used in the formal accreditation process of the degree of Bachelor of Mechanical Engineering (Honours) at two universities (U1 and U2). This information provided insight into which subjects (of the 4-year (full time study) degrees) were associated with addressing E1.5 of the Stage 1 Competency Standard for the Professional Engineer [8]. It is noted that this analysis does not take into account the engineering design practice aspect (E1.5a) as both universities had mapped their data against the 2011 version of the Standard [15]. Using the data provided, detailed information about each of the relevant subjects addressing E1.5 was sourced from the respective universities websites.

The learning outcomes that were specifically stated as addressing E1.5 were analysed to determine their content and relevance to E1.5 as described by EA. The type of learning activities and assessment tasks used in the subjects were also determined, to ascertain any similarities and significances.

3. Results and Discussion

3.1 Addressing contextual factors through the curriculum

The two universities show clear differences in their approach to addressing contextual factors (E1.5) within the curriculum. U1 and U2 offer seven subjects and nine subjects respectively to address learning outcomes associated with E1.5. U1 offers three subjects in the first semester of the first year of study, while U2 appears not to address it at all in the first semester but does address it in one subject in the second semester. Table 1 below shows the number of instances where E1.5 is said to be addressed within the 4-year Mechanical Engineering (Honours) degrees at the two Universities.

Table 1. Number of subjects addressing E1.5 within Mechanical Engineering (Honours) degrees.

	Year 1		Year 2		Year 3		Year 4	
University	Semester 1	Semester 2	Semester 1	Semester 2	Semester 1	Semester 2	Semester 1	Semester 2
University 1	3				1	2	1	
University 2		1	1	1	2	1		3

Considering the opportunity that E1.5 provides to highlight to students the role of engineering in society and the role of an engineer, it is surprising that this element is not addressed at the beginning of the U2 degree. U1 appears to address E1.5 extensively within the first semester and this would seem appropriate, considering the ability E1.5 provides to give students insight into the type of skills and knowledge they will need as a professional engineer and the environment in which they will operate. Providing this knowledge at the beginning of a degree also provides opportunity to give students awareness of what to expect from their university education and the reasons behind it.

There appears to be little correlation between the ‘type’ of subjects that are used to address E1.5, although both universities do offer mandatory industry placements. Both universities also have somewhat of a link to ‘management’ subjects which are said to address E1.5, with U1 offering one subject and U2 offering two. Both universities also offer two subjects that are dedicated to research projects in the final year of study, yet neither of the universities recognise these subjects as addressing E1.5. While detailed information was not available for U1, it is interesting to see that at U2, these two research subjects are stated as addressing 15 of the 16 Engineers Australia competencies; the one competency that is excluded is E1.5.

Further, five subjects at U2 are stated to address either 15 or all 16 of the EA competencies. While detailed information was not analysed in terms of what is taught in these subjects, it is clear that the learning outcomes should be better aligned to the subject matter, and vice versa, to ensure successful student learning [18].

3.2 Learning Outcomes

The learning outcome statements associated with E1.5 may also encapsulate other competencies. For example, in some instances, one learning outcome may be stated as encapsulating even more than five competencies. While it may be reasonable that one learning outcome associates with several, perhaps, similar or interrelated competencies, it is evident that some learning outcomes are simply not clear while some are clearly not related to E1.5, even though they have been stated to be so, as described below. After reconstructing some learning outcome statements for clarity, it was determined that U1 describes E1.5 using 26 different learning outcomes, while U2 uses 24.

It is acknowledged here that the data analysed may not provide a complete view of what is taught and addressed in the entire subject throughout a teaching semester. Nevertheless, it is essential to note that the learning outcomes that have been analysed have specifically been stated as directly addressing E1.5. With this in mind, it is both surprising and alarming to see that the majority of these learning outcomes do not address E1.5.

Both universities refer to learning outcomes that clearly do not encapsulate E1.5 and are more ‘knowledge’ and ‘application’ focused and would better associate with Competencies 1.1, 1.2, 2.1 and 2.2 [8]. For example, U1 refers to students being able to identify the various components, functions and types of a certain device, while U2 refers to students being able to apply literature and theories to design and implement a project in a teamwork environment.

While the above mentioned knowledge and application focused learning outcomes are quite apparent, further analysis also reveals that those learning outcomes that do not address E1.5 can be categorised into certain themes. For example, U2 refers to three learning outcomes that are not associated with E1.5, but rather directly link to element 2.4, associated with project management. The ability to ‘identify and deal with ethical issues which may arise when working as a professional’ is said to address E1.5 at U1, yet this is better associated with competency 3.1, ‘ethical conduct and professional accountability’. Similarly, U1 refers to students being able to communicate in a professional manner, which associates with competency 3.2 ‘effective oral and written communication in professional and lay domains’. The concept of engineering standards was also presented, twice by U2, referring to students being able to generate engineering drawings according to standards and being able to appreciate the role of standards in engineering design. While the opportunity for interpretation of the competency by each university is acknowledged, it is clear that the emphasis on engineering standards is more appropriately represented by competencies 2.1g and 2.3c [8].

In total, 17 of the 26 Learning Outcomes described by U1 and 15 of the 24 learning outcomes described by U2 do not relate to E1.5, which means that over 60% of the learning outcomes described by both universities do not address E1.5. This demonstrates a misrepresentation of E1.5 in the learning outcome statements and, more importantly, highlights misunderstanding of what E1.5 encapsulates and aims to develop in students.

The learning outcomes that do address E1.5 can be categorised under five themes: requirements of a project; sustainability; professional practice and organisational context; human factors; and, the role of an engineer. U1 focuses mostly on E1.5b (identifying and understanding the interactions between engineering systems and people, taking onto consideration various contexts), while U2's focus is mainly on E1.5(e) and (f) (Consideration of the engineering workforce and the fundamentals of business and enterprise management). An area that lacks attention by both universities is E1.5(c) which refers to students being able to appreciate issues associated with international engineering practice and global operating contexts. While it is not mandatory to address all indicators of attainment for accreditation purposes, this finding is quite alarming considering (i) an intent of the accreditation processes is to facilitate the mobility of engineering graduates internationally and (ii) the value placed on ‘global perspectives’ as one of the most important graduate attributes [16].

3.3 Learning Activities and Assessment

Both universities place similar emphasis on lectures and tutorials, which accompany almost all subjects that are stated to address E1.5. They are the most utilised method of teaching, with laboratory work and workshops also playing a large role. Online learning activities are mentioned thrice and only by U1. Both universities provide two research projects in the final year, providing the opportunity for independent research; however, U2 does not recognise these subjects as addressing E1.5 in accreditation material; hence, these subjects have been omitted from this part of the analysis. The independent research referred to by U1 is accompanied by meetings with supervisors. Both universities also offer the opportunity for industry experience, with U1 requiring the equivalent of six months full time and U2 requiring the equivalent of 12 weeks full time experience.

In terms of assessment requirements, both Universities emphasise exams and tests, but these are complemented with other tasks such as assignments, reports, presentations, tutorial work and reflective works.

The purpose of this paper is not to analyse the effectiveness of teaching methods or assessment tasks in achieving learning outcomes, yet it is interesting to note that both universities mentioned *assessment* of class 'participation' as part of the tutorials, reflecting that simply being present and completing set questions within a tutorial session is not sufficient and contribution to class discussions with others is valued. Both universities also emphasise group work through such tasks as assignments, reports, presentations and within tutorials.

In relation to the industry experience component, both universities utilise similar assessment tasks. U1 uses two reports (one interim and one at the end of the placement), a reflective logbook and an assessment of the student by an industry supervisor; U2 uses a reflective journal and a portfolio, which may also incorporate reports, although this information is not clear with the available data.

Considering the opportunity that industry experience provides for students to learn about the 'reality' of engineering, it is promising to see this component emphasised by both universities. As U1 describes, this experience offers practical application of skills and knowledge and a strong link to E1.5 in considering complex, real-world problems and the ability to engage with the workplace, taking into account the business context, different stakeholders and the various responsibilities of a professional engineer. The use of portfolios in this regard is consistent with literature which suggests the value of reflective practice to aid in the understanding of the context of engineering [17].

4. Implications

A university curriculum must be 'aligned' if it is to deliver successful learning. This requires learning outcomes that are clear, learning activities that are designed to assist students to achieve the stated learning outcomes, and assessment tasks that allow students to demonstrate attainment of the learning outcomes [18].

This research highlights a clear misunderstanding within the university context of what E1.5 should encapsulate as outcomes for students. Considering the data analysed in this research has been officially submitted for accreditation purposes, the following recommendations are made:

- Both universities and accreditation providers must review their processes for addressing E1.5 to ensure compliance. Accordingly, universities and EA must better educate academics and curriculum developers on what E1.5 aims to address, with the aim of then producing more aligned and clear learning outcomes. EA could also encourage better sharing of good practice between education providers.
- While the accreditation process looks at competency achievement in a holistic sense, there is evidence that EA could better investigate and educate education providers on whether E1.5 (and other competencies) are being addressed within a curriculum and, further, provide insight into how it could be better addressed.
- Considering the danger of students falling into a surface approach to learning E1.5, further research is required to define E1.5 to allow better alignment and representation of learning outcomes.

5. Limitations and Further Research

This research looks at the textual data related to E1.5 and associated subject information for the same engineering discipline offered at two universities. It is limited in that interpretation is only possible on the textual data and other forms of data (e.g. conversations with academics and curriculum developers) could provide a more holistic view of the subjects and what is taught at the classroom level. Conversations with students and graduates who have studied the subjects that are said to address E1.5 could also provide insight into how effective the subjects are in addressing the learning outcomes and whether (and how) they are achieved. This would provide guidance to not only the universities involved, but also to other engineering education and accreditation providers on how best to address E1.5.

Investigation into other universities and disciplines of engineering could also provide insight into whether these findings are limited, or not, to the mechanical engineering degree and to these two universities.

Further, considering the majority of learning outcomes were stated as addressing more than one competency and the disparity observed in addressing E1.5, it would be interesting to see how the other competencies are addressed and whether they are addressed holistically within the curriculum.

6. Concluding Remarks

The knowledge of contextual factors that impact the engineering discipline highlights the need for students to understand the role and interaction of engineering and engineers within society, the importance of human factors and the context of 'real' engineering practice. Understandably, this competency is interpreted and addressed in various ways within the undergraduate curriculum at different universities. Findings show, however, that over 60% of the learning outcomes used to describe E1.5 do not address it, highlighting a misunderstanding or misrepresentation of the competency. Further, while it is not stipulated as to how E1.5 should be addressed for accreditation purposes, the lack of attention placed on international engineering practice and global operating contexts is of concern, considering its value from both an accreditation perspective and as an essential graduate attribute. Universities and accreditation providers must review their processes for addressing this competency to ensure it is achieved.

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