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Engineering graduates professional formation: the connection between activity types and professional competencies

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ABSTRACT

The professional formation of new graduates and their ability to perform well at the start of their career depends on the development of both technical skills and professional competencies. Whilst the latter aspects have become increasingly considered within engineering programs, they are often learnt within an academic context rather than a practice context. This is in contrast with research that argues that professional expertise should be learnt within the context in which it will be applied. This paper reports on an analysis of engineering student reflections on professional engagement activities over the duration of their university study. A text-based thematic analysis examines the link between different types of activities and professional competencies (using Engineers Australia Stage 1 Competencies), and the level of sophistication in the language using Blooms taxonomy. The thematic analysis provides strong evidence that different activity types result in students being more likely to reflect upon specific competencies. The deeper Bloom analysis showed that generally the activity types that have reflections skewed towards higher Bloom levels are those that involve project activities. We conclude that those activities that require student-driven exploration are the most likely to engage students in thinking about the nature of real-world engineering practice..

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Introduction

The ability of new graduates in any professional field to perform effectively in practice depends not only on the specific disciplinary knowledge and skills acquired during their formal education but also upon their understanding of the nature of their profession, and particularly the norms, conventions, cultural practices, and professional language that shape their discipline. These practices are often tacit and complex, but represent the environment within which the graduates must operate.

There is a long history of research that argues that full development of professional expertise can only be developed in 'practice' and hence academic programs on their own cannot be sufficient. For example, the Dreyfus model of skill acquisition (Dreyfus and Dreyfus 1986) explores students' learning stages, and especially the move from analytical to intuitive decision making. Similarly, the theory of situated learning (Lave and Wenger 1991) recognises the importance of the social context in which learning occurs, and hence argues that professional learning should take place (at least in part) within the same context within which that learning will be applied – i.e. practice settings. More recent work comparing various theories of expertise (Gobet and Chassy 2009) notes a common theme that 'an emphasis on the holistic nature of expertise, with the implication that

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experts' understanding cannot by analysed into components, leads to different types of curricula, where engagement in real-life situations is emphasized'.

With a few notable exceptions, such as the work by Trevelyan (2013), the importance of practice contexts to the development of professional understanding is often not clearly articulated and hence not adequately addressed within curricula and professional development frameworks. For example, the Engineers Australia (EA) Stage 1 Competency standards (Engineers Australia 2013) describe 16 categories covering specific knowledge and skills, the ability to apply that knowledge, and broader professional attributes. It does not however make explicit mention of understanding the cultural practices (and hence contexts) of the Engineering profession.

Despite this gap, the desire (or in some countries, the requirement) for Engineering students to have substantial exposure to professional practice prior to graduation nevertheless suggests there is recognition that understanding the professional culture is important to the ability to practice effectively. For example, the EA accreditation criteria states:

> Student engineers need in addition to knowledge, formative experiences of how engineering professionals: a) Think, work and continually learn … EPP must culminate in a set of meaningful experiences that result in the habituation of professional working styles. (Engineers Australia 2018)

If we accept the value of developing graduates understanding of an 'engineering culture', then it raises the question of where and how we engage students with exploring this culture. As already mentioned, the theory of situated learning suggests that the learning ought to occur within a context that is sufficiently similar to professional practice settings. A key challenge however is that professional settings are both very rich and very diverse, suggesting the value (indeed maybe the importance) of exposing students to a diverse range of professional experiences.

At the University of Sydney, we have transitioned from a traditional 'work placement' model of professional engagement where students undertake a single 12-week placement block (or equivalent) in industry late in their degree, to a model where students engage in a much more diverse range of activities continuously throughout the 4 years of their degree. This latter approach is supported through aspects such as scaffolding workshops, structured reflections, and peer assessment. This adoption of this new model provides us with an unparalleled set of rich data that can be mined to inform answering the above questions.

In this paper, we analyse student reflections associated with a wide range of different professional engagement activities. Using a text-based thematic analysis we firstly explore the extent to which different activity types emphasise different professional competencies (using the EA stage 1 competency standard as the relevant framework) and encourage thinking at different levels of sophistication (using Blooms taxonomy). We then consider the specific question of whether different activity types are better suited to encouraging students to engage with, or reflect upon, different elements of the nature of engineering practice. This is achieved through using a thematic analysis of student reflections to position different activities within the epistemic plane of Legitimation Code Theory, and through this to explore the different forms of understanding that each activity type can potentially develop.

It is also worth noting that while this paper focuses on the Engineering profession, most of the discussion, as well as many of the findings are likely to be relevant and translatable across the full spectrum of professions.

Background

The need for engineering graduates to develop an integrated professional capability that merges technical skills with broader professional capabilities is widely acknowledged (Crosthwaite 2019; Passow and Passow 2017). This has been documented in various reviews of Engineering education (Graham 2012; King 2008; National Academy of Engineering 2004) as well as being increasingly reflected in program accreditation criteria (ABET 2011; Engineers Australia 2013; UK Engineering

Council, 2014). Despite this strong interest in the development of an integrated professional capability, and an increasing number of engineering programs that claim to promote integrated capabilities (often through approaches such as open-ended and/or multidisciplinary projects), there has been limited consideration given to exactly what an 'integrated' professional capability might look like in practice. If we can't define this *integrated professional* then we are likely to struggle to ensure that graduates are able to reflect this ideal.

A useful place to start in considering this issue is explore the nature of the professional identities. The formation of professional identity has been widely studied across a wide range of professions (Trede, Macklin, and Bridges 2012) and the literature regularly emphasises the importance of establishing a strong professional identity. For example, Jackson (2016) explores the relationship between professional identity formation and graduate employability. A common theme in the research is an exploration of those factors that contribute to the development of this identity. While it is not uncommon for undergraduates to be shown to have strong disciplinary identities from quite an early stage (particularly in professional disciplines such as medicine and engineering) the evolution of this identity into a form that reflects that of disciplinary professionals often relies on significant exposure to practice. In some cases, this has been shown to be because practice exposes students to specific discordances between their current concepts (often more connected to an 'academic identity') and the nature of practice (Pratt, Rockmann, and Kaufmann 2006).

Within an Engineering context, various studies have shown that work-integrated learning can be a crucial mechanism for achieving this development of a professional identity, and hence the ability to engage constructively within the professional community (Dehing, Jochems, and Baartman 2013; Trede 2012). While this points to the value of engagement within professional settings it doesn't necessarily tell us *why* that engagement is valuable or which of the many forms of work-integrated learning might be most appropriate. Some insight into this can be found in work such as that by Meyers et al. (2012), which explored the factors that lead to students identifying as engineers but stopped short of exploring the nature of that identity. Allie et al. (2009) also explored students development of an identity, though in this case, it was explicitly through their active participation within a professional engineering community. They specifically noted that 'learning in engineering involves taking on the discourse of an engineering community' – in other words, an ability to understand the discourse (including language and customs) of the engineering community is an important element in learning to be an engineer. They went on to assert that we need to 'make more explicit key aspects of the discourse of engineering'. There is however little published research into the 'language of professional engineering'.

We can posit that by engaging students or new graduates in activities that make the various elements of the 'discourse of professional engineering' more visible we will be more likely to assist them in developing a more coherent and realistic professional identity – one that links technical skills with broader professional capabilities as previously discussed. This then leads us to a pair of related questions: firstly, what are the key elements of the discourse of professional engineering that we wish to be more visible and accessible to students; and secondly, what activities might best make visible to students and new graduates these key elements. In terms of the first question, we can draw insights from research into the nature of engineering work itself (see, for example, Stevens, Johri, and O'connor 2013 and Trevelyan 2013). A common theme in studies of the nature of engineering work tends to be recognition of heterogeneity, ambiguity, uncertainty, complexity, and the relevance of socio-technical inter-relatedness. In the context of these aspects we can draw insights from work such as the Cynefin framework (Kurtz and Snowden 2003). This framework was developed to help people make sense of the complexities in knowledge, and especially to distinguish between cause and effect relationships that range across: known; unknown but knowable; complex; and chaotic.

Engineering practice largely deals with complex problems and the solutions require the use of judgement, managing multiple possibilities, competing demands and having to make assumptions to develop considered and reasoned solutions to complex problems. Authentic learning and assessment tasks that require students to manage complexity are absent from many engineering learning activities. If we are to prepare engineering graduates for professional practice and develop the associated skills curriculum must include opportunities for students to engage with and manage complex problems (Willey and Machet 2018).

In terms of the second question we posed above – what activities might enhance the visibility of the key elements described above to students and new graduates – this is the focus of our paper. There are various possible tools that might be helpful in answering this question, but one possible tool for which interesting claims have been made regarding the insights it can support is Legitimation Code Theory (LCT). While the direct relevance to the context explored in this paper has not been clearly shown, other related work is sufficient to suggest that its exploration might be worthwhile. LCT is a broad framework that emerged from research into the sociology of education a little over a decade ago, though drawing on much earlier work, such as that by Bernstein (1975). The focus of LCT is on providing a set of tools through which we can analyse the ways in which knowledge is used within, and shapes, practices: what is known; how it is known; who knows it; how knowledge is built? One key consequence is that it allows exploration of what knowledge and hence practices are considered legitimate within a given field: as noted in (Maton, Hood, and Shay 2015), LCT is a 'framework for exploring practices in terms of their organizing principles or "legitimation codes"' Of significant relevance here is the way in which LCT supports reasoning about different practices and the different forms of meaning that can be drawn from those practices. At the core of LCT is a set of dimensions, where each dimension explores a different set of organising principles underlying practice. For example, the *Semantic* dimension explores knowledge practices in terms of semantic gravity, related to how strongly context-dependent knowledge may be, and semantic density, related to condensation of meaning. For example, civil engineering knowledge about the behaviour of a *specific* beam within an individual building will be highly context specific, and have a very strong semantic gravity. Knowledge of the theoretical relationship between stress and strain will have very low semantic gravity. Another dimension, the *Specialisation* dimension, explores practices in terms of 'knowledge-knower' structures. A knowledge practice in engineering might be characterised as emphasising the primacy of knowledge, whereas a knowledge practice in psychiatry may emphasise the dispositions of knowers.

While widely applied in other domains, and particularly sociology, LCT has only seen limited application within Engineering (e.g. Winberg et al. 2016; Wolff 2015)). However, this limited application suggests that LCT has significant potential as a set of analytical tools. LCT allows for the results of an analysis to be plotted on a cartesian plane, using the strengths of two of relationships. Work on using LCT in Engineering contexts (Pott and Wolff 2019; K. Wolff 2015; K. E. Wolff, Dorfling, and Akdogan 2018) has demonstrated the particular value of the *epistemic* plane, where phenomena (or knowledge practices) are categorised along the vertical axis based on the strength of their ontic relations (i.e. OR – the extent to which the phenomenon is clear and accepted) and along the horizontal axis based on their discursive relations (i.e. DR – the extent to which a standardised approach is adopted). These two dimensions are further described in Table 1, along with a set of terms that would typically be associated with phenomena or approaches at the ends of each dimension.

Wolff et al then went on to highlight that most typical academic activities in engineering curricula sit in a different region of the epistemic plane (the right half of the plane) from most professional activities (the left half of the plane), suggesting that the type of thinking encouraged by academic learning is often disconnected from that required in professional settings. As an example, consider a control systems tutorial where students are calculating the damping ratios for a range of different control systems. This activity involved thinking about a range of different phenomena (OR–) but the application of a standardised calculation that is independent of the context (DR+). As another example, consider a typical civil engineering laboratory (taken from the author's direct experience) where students calculate the theoretical strains on a set of members in a redundant truss and then perform an experiment where they apply a load to a truss and compare their measured values to the predicted values. In this case, the students are applying a known set of formula (DR+) to a known narrow problem (OR+). In both these cases, the activities sit clearly on the right-hand side of the epistemic plane, where known standard approaches are being applied to problem-solving.

In contrast to these academic activities, a professional engineering designer is likely to be working with problems that have varying degrees of definition (OR− to OR+) but where the approach adopted is highly contextual (DR–). This positions the activity on the left half of the plane and involves *situational* thinking. In other words, professional settings typically require significant consideration, and ultimately interpretation of, the *situation* or context in which the practice is occurring and then how this shapes the choice of approach to be taken. This contrasts with much academic activity, where the context is either largely ignored or is predefined, and the focus is on the application of specific techniques, rather than the identification of a relevant technique.

The potential value of LCT in identifying and analysing shortcomings in our curricula with regard to the development of graduate engineers' understanding of professional practice is highlighted through a key study that explores the impact of context in developing knowledge related to problem solving (K. Wolff 2017). This study considered the relative positioning of current engineering curricula (which often focuses on narrow problems constrained by the bounds of the students' sub-discipline) and *real-world* problem solving (which extends well beyond the sub-discipline bounds) on the LCT epistemic plane. The study concludes that engineering problem solving (in practice) draws on insights from within all four quadrants of the epistemic plane, whereas engineering education tends to sit almost entirely in the right half of the plane. Wolff went on to argue that those activities that tend to align with professional thinking are those that address the issues of complexity and uncertainty mentioned previously, including examples such as open-ended projects and industry placements.

In this paper, we extend this previous work, considering the nature of different forms of student engagement with professional practice. In particular, we leverage the opportunity provided by our Professional Engagement Program (PEP – which involves students in a very diverse range of professional activities) to explore the nature of student reflections on each activity type. We identify the professional competencies that tend to be the focus of each activity type and contrast this with the positioning of the activity type on the LCT epistemic plane. This will then provide us with valuable insights into which activity types are most likely to result in students developing approaches to thinking that align with professional practice, and an understanding of the professional 'legitimacy' of different engineering practices. LCT essentially gives us a tool for reasoning about the differences in student reflections for different activities.

Approach

As described in the introduction, at the University of Sydney we previously had utilised a relatively traditional 'work placement' model of student exposure to practice. This involved having students undertake a single summer placement (typically 12 weeks) late in their degree program, and a

Table 1. The two primary dimensions (DR and OR) of the LCT Epistemic plane, along with a list of terms associated with categorisation of activities against those dimensions.

Discursive relations (DR) – approach		Ontic relations (OR) – identity	
The extent to which the approach to engaging with a phenomenon is standardised and prescriptive versus open-ended and contextual		*The extent to which a phenomenon is clear and has a well-defined and accepted nature and scope versus being ill-defined and with unclear bounds*	
DR+	*Standardised approaches:* standard, codes, procedure, norm, specification, law, charter, legislation, mandate, regulation, statute	OR+	*Well-defined phenomenon identity:* common, fundamental, foundation, core, shared, clear
DR-	*Open-ended approaches:* guide, judgement, opinion, experience, intuition, open-ended, uncertain, interpretation, heuristic	OR-	*Undefined phenomenon identity:* contextual, general, ambiguous, vague, range, widespread, universal

(relatively poorly coordinated) smattering of other forms of exposure to practice such as guest lectures from industry practitioners and an occasional site visit. While the placement, in particular, was often transformative for students, it only occurred late in the degree and predominantly exposed the students to a single practice context.

Beginning with the 2018 commencing cohort, we transitioned to a new model – the Professional Engagement Program (PEP) – that encourages and recognises a much more diverse range of activities undertaken continuously throughout the 4 years of their degree. In summary, students are required to undertake a specified number of hours of both in-curricula and extra-curricular self-selected activities during their degree program. As each activity is completed students record an 'activity claim' in an online system, including a description of the activity, a self-reflection on their learning, and categorisation of the dominant focus against the relevant professional learning competencies (using Engineers Australia Stage 1 Competency Framework). The activities are also self-classified by students against a set of activity types that match the terminology used within their degree program (see Table A1 in Appendix, which also includes examples of many of the activity types). The activities are assessed through both peer and tutor evaluations and the overall PEP process is scaffolded through a continuous series of planning and assessment workshops and a large collection of activity suggestions.

The key objective has been to ensure an earlier and more deeply embedded exposure to the nature of professional practice, and a more progressive growth in students' understanding of practice, their own capabilities, and their sense of responsibility for their own continuing development. The students' progress at their own pace through a series of three key stages: self-focused (typically in year 1–2); team-focused (typically in year 2–3); and societal-focused (typically in year 3–4). More complete details of the PEP program can be found in (Kadi and Lowe 2018).

At the time of writing, the program has been in place for two and half years, and so we have significant cohorts of students in stages 1 and 2 of the program, though only a small number have progressed into stage 3. This obviously represents a potential limitation in terms of our ability to assess the full development of students understanding of professional practice, but nevertheless there is a sufficient data to assess the effectiveness of the program in moving students toward an understanding of professional practice at a much earlier stage than might normally be feasible.

A data extract containing all activity claims was obtained from the online system. These were then cleaned to remove incomplete or test claims, resulting in $N = 12{,}267$ activity claims. Of these claims, those that were yet to be assessed or had been rejected as being inadequate or inappropriate were then removed, leaving $N = 8{,}628$ valid and assessed claims. The reflections within the claims contained an average of 411 words (a total of 3.54 million words of reflection!).

The nature of the reflections submitted by students can be illustrated through the following extract of a typical reflection:

> This activity was really eye-opening. It was the first time I had ever walked into a [*sic*] actual engineering firm, let alone into one of Australia's biggest engineering firms. Furthermore, as a biomedical engineer, touring XXX was very interesting and gave me insight into what it will be like to work as an engineer in the future. … It also helped develop my way of thinking as when i was walking around, I was able to see the ingenious solutions they had to minimise error as well as to maximise efficiency. Furthermore, it gave me the realisation that a lot of the industry is automated. Thus, in order for me to be more employable, it is highly desired for an individual to have knowledge about coding and programming such that they can help develop, maintain and improve the process.

Given the rich textual data that exists within the student reflections we adopted a thematic analysis based approach to capture both the frequency and impact of the experiences and associated competency development identified by students in their reflections. It is important to note that we are not exploring the level of actual competence achieved by students – as has been previously noted, students' comments on specific experiences and their claimed competence do not necessarily imply actual competence (Sandberg 2000). We do argue however that we can learn from the extent to which students discussed particular competencies.

Student reflections from the PEP activity claims were imported into NVivo and each reflection was then coded in several ways:

– To determine the nature of the competencies being explored within the activity, each reflection was coded against the Engineers Australia Stage 1 Competency Standards (Engineers Australia 2013).
– To determine the level of insight being shown and the level of learning evidenced, each reflection was coded against the cognitive domain of the 2001 revised version of Blooms taxonomy (Anderson and Krathwohl 2001).

With regard to the latter point above, we considered a range of models to use, including SOLO (Biggs and Collis 1982), but chose to use Blooms taxonomy for two key reasons. Firstly, its widespread use means that interpreting the data will be more straightforward. Secondly, despite its limitations, it has heavily influenced the definition of professional standards (particularly the EA competency standards referenced by students in their PEP reflections) and has become widely used in curricula mapping and accreditation activities.

Given the volume of content (more than three and half million words of reflections) a fully manual thematic coding was impractical. The nature of the content however made an auto-coding approach feasible (Guest, MacQueen, and Namey 2012). Each reflection was auto-coded by searching for the existence of key terms associated with each level of Bloom's taxonomy and with each competency within the EA Stage 1 Competency Standards. The terms used for categorising against the Bloom levels are given in Table 2 and drawn from (Anderson and Krathwohl 2001).

A random sample of the coded reflections ($N = 50$) was also manually assessed with the purpose of identifying and removing any systematic errors being introduced during the coding process. For each activity type we then extracted an overall summary of the total number of words of reflection as well as the count of terms associated with each Bloom level and each EA competency. These counts were then converted into a percentage of the total number of words to provide an indication of the density of references. These densities were then normalised as z-scores to reduce the effect of possible variations in the choice of terms. The result was an indication, for each Bloom level and competency type, of which activities tended to have higher or lower densities of associated terms. Whereas the previously described analysis provides insights into the nature of the different types of professional engagement activities, we are also interested in contrasting these insights with categorisation of the activity types against the LCT epistemic plane in order to determine whether there is evidence that LCT can be used to guide the selection of relevant activities. To position the different activity types on the epistemic plane an additional thematic coding was undertaken using a set of terms associated with both Discursive Relations (DR) and Ontic Relations (OR). The terms used were summarised in Table 1. These terms were identified by developing a candidate set based on the descriptions in (Maton, Hood, and Shay 2015; K. Wolff 2017), and then refining by a pilot test against a set of student reflections. As with the previous analysis, the relative density of the use of different terms is then used to rank the activities along the OR and DR axes, allowing each activity type to then be positioned on the epistemic plane.

A final verification was then carried out using two approaches. Firstly, the five authors independently carried out an 'expert prediction' where, for each competency, they identified those activities that they believed would be most likely and least likely to contribute to its development. These results were then analysed to look for cases where these judgements were inconsistent with the data drawn from student reflections. Any cases of significant inconsistency were explored in further detail through a closer examination of the relevant reflections.

The second verification method was focused on assessing whether there was any evidence that the analysis had been excessively skewed by an unusually high density of terms within individual reflections and to assess what level of data was necessary for validity. This involved an analysis of the level of variation in the coding of individual reflections, particularly for those activity types

Table 2. Bloom levels and associated terms used for coding.

Bloom level	Terms
1. Knowledge (remembering)	Choose, Define, Find, How, Label, List, Match, Name, Omit, Recall, Relate, Select, Show, Spell, Tell, What, When, Where, Which, Who, Why
2. Comprehension (understanding)	Classify, Compare, Contrast, Demonstrate, Explain, Extend, Illustrate, Infer, Interpret, Outline, Relate, Rephrase, Show, Summarize, Translate
3. Application (applying)	Apply, Build, Choose, Construct, Develop, Experiment with, Identify, Interview, Make use of, Model, Organize, Plan, Select, Solve, Utilize
4. Analysis (analysing)	Analyze, Assume, Categorize, Classify, Compare, Conclusion, Contrast, Discover, Dissect, Distinguish, Divide, Examine, Function, Inference, Inspect, List, Motive, Relationships, Simplify, Survey, Take part in, Test for, Theme
5. Synthesis (evaluating)	Agree, Appraise, Assess, Award, Choose, Compare, Conclude, Criteria, Criticize, Decide, Deduct, Defend, Determine, Disprove, Estimate, Evaluate, Explain, Importance, Influence, Interpret, Judge, Justify, Mark, Measure, Opinion, Perceive, Prioritize, Prove, Rate, Recommend, Rule on, Select, Support, Value
6. Evaluation (creating)	Adapt, Build, Change, Choose, Combine, Compile, Compose, Construct, Create, Delete, Design, Develop, Discuss, Elaborate, Estimate, Formulate, Happen, Imagine, Improve, Invent, Make up, Maximize, Minimize, Modify, Original, Originate, Plan, Predict, Propose, Solution, Solve, Suppose, Test, Theory

that had small numbers of student activity claims. Where significant variations in the coding density existed, the underlying reflections were analysed to determine the extent to which the results may have been skewed by individual reflections that were anomalous.

Results

The overall results of the initial semantic coding of student reflections are provided in Tables A3 and A4 in Appendix. For each of the different professional engagement activity types the results provide the normalised density within the associated reflections of terms associated with both each Bloom levels (B1 … B6) and each EA competency (E1.1 … E3.6). The data has been normalised by converting the density of terms to a *z*-score. To illustrate the coding of reflections, consider the following extract of a reflection, showing terms associated with EA competency 3.6 (teamwork) highlighted:

> From the humbling experience, it has to an extent, tempered my excitement for working in automotive aerodynamics in the specific context of a small **team**. If I were to go into a race **team** again, it would have to be with due consideration to the other **roles** and responsibilities required to be a part of the **team**. I do however understand that these ancillary **roles** are highly unlikely if entering a vehicle manufacturer's aerodynamic division, or if entering the upper echelons of motorsports. Ultimately in this regard, I would be very remiss if I had to do the most fundamental **roles** in a future position, such as mopping and scrubbing the floors.

To illustrate this calculation, an example of the pre-normalised density data is provided in Table A3 for Bloom level 1 terms (e.g. the column headed 'Density/Bloom B1'). Looking at this raw data for B1, consider the value for activity type 2a (*University-organised site visit*). This shows that 0.25% of the total words contained in reflections on activity type 2a were Bloom level 1 terms. This converts to a *z*-score of −0.62, indicating that this proportion was much lower than the average proportion for all activity types. The tables also highlight those values which are at least one standard deviation above or below the average for that column (i.e. a $|z\text{-score}| \geq 1.0$).

Tables A3 and A4 allow us to look across rows to explore the dominant focus of given activities by identifying more positive *z*-scores. Conversely, we can see which competencies were given least attention for specific activities (by identifying more negative *z*-scores). For example, interviewing professional engineers (activity 2c) tends to provide a focus on, or at least encourage students to reflects more heavily than average upon, EA competencies 1.3 (*In-depth understanding of specialist bodies of knowledge*) and 3.5 (*Orderly management of self, and professional conduct*). It also lets us look down a column and identify what activities might be well suited to encouraging students to reflect more on a given competency. For example, with EA competency 3.1 (*Ethical conduct and professional accountability*), the most useful activities appear to be 3b (*Professional development within academic units*) and 6d (*unpaid employment in a skilled non-professional role*). Conversely, activities 2b (*independent visit to a professional engineering worksite*), 7a (*resume writing courses*) and 10b (*short international exchanges*) seem to be least useful.

In terms of the results for mapping activities to the LCT epistemic plane, a similar approach was taken. The density of terms associated with positive and negative tendencies of both Discursive Relations (DR) and Ontic Relations (OR) were calculated. These densities were then normalised and final values for DR and OR determined by calculating the difference between the positive and negative values (e.g. a high density of positive terms and a low density of negative terms will give a strong positive value whereas when both densities have similar values, either high or low, this will result in a value close to zero). The results of this are shown plotted in Figure 1.

Finally, as mentioned in the discussion on the approach, an additional check was carried out to determine the reliability of the results that have been obtained. There are two primary situations that might lead to anomalous results: (a) individual outlier claims that have an abnormally high level of focus on a given competency; and (b) given competencies that have a uniformly low level of attention generally, and hence allowing small variations to appear much more significant. In both these situations, variations are likely to be much more pronounced when there are only small numbers of claims. To assess these issues, the activity types with the smallest number of claims were identified and explored in more detail: 10b (*Short international exchanges*) with only 8 claims out of a total of 8628 claims; 11a (*Involvement in a business start-up*) with 21 claims; and 10a (*Semester long international exchange*) with 25 claims. For each of these activity types the EA competencies that had the highest average density of terms were identified. The results are shown in Table 3.

Activity type 10b had only 8 claims and so was most susceptible to individual outlier claims causing large variations. These 8 claims only had an average of 5.13 terms in each reflection related to EA competency 3.2, but a high standard deviation (5.25) resulting primarily from one significant outlier with a much higher number (18) of relevant terms. If the top and bottom outlier claims are removed, then the *z*-score changes from 0.69 to −0.52 demonstrating a high level of sensitivity to single outlier claims. If a similar process is applied to the other highly ranked EA competency (EA 3.3) for activity type 10b then the *z*-score only changes from 0.88 to 0.75 suggesting that this sensitivity is only an issue when there both are a small number of claims and the outlier is sufficiently substantial. This point is supported by the data for activity type 10a which has 25 claims and where the standard deviation is similar (5.15) but removing the outliers only shifts the *z*-score from 1.79 to 1.41.

As mentioned above, in some cases there is a uniformly low level of focus on a competency across all activity types, and hence very low term densities. In this situation, relatively small variations in the

Table 3. Data on *z*-scores for various activity type/competency pairs for checking data sensitivity.

Activity type	10b (*Short international exchanges*)		11a (*Involvement in a business start-up*)	10a (*Semester long international exchange*)
Number of claims	8		21	25
EA competency	EA 3.2	EA 3.3	EA 3.1	EA2.1
z-score for term density	0.69	0.88	0.89	1.79
Mean (terms per claim)	5.13	4.25	0.38	3.72
StDev (terms per claim)	5.25	2.33	0.92	5.15
z-score with outliers removed	−0.52	0.75	−0.31	1.41

The final row shows the revised *z*-score that results when the top and bottom 10% of activity (in terms of coding density for the given competency) are removed.

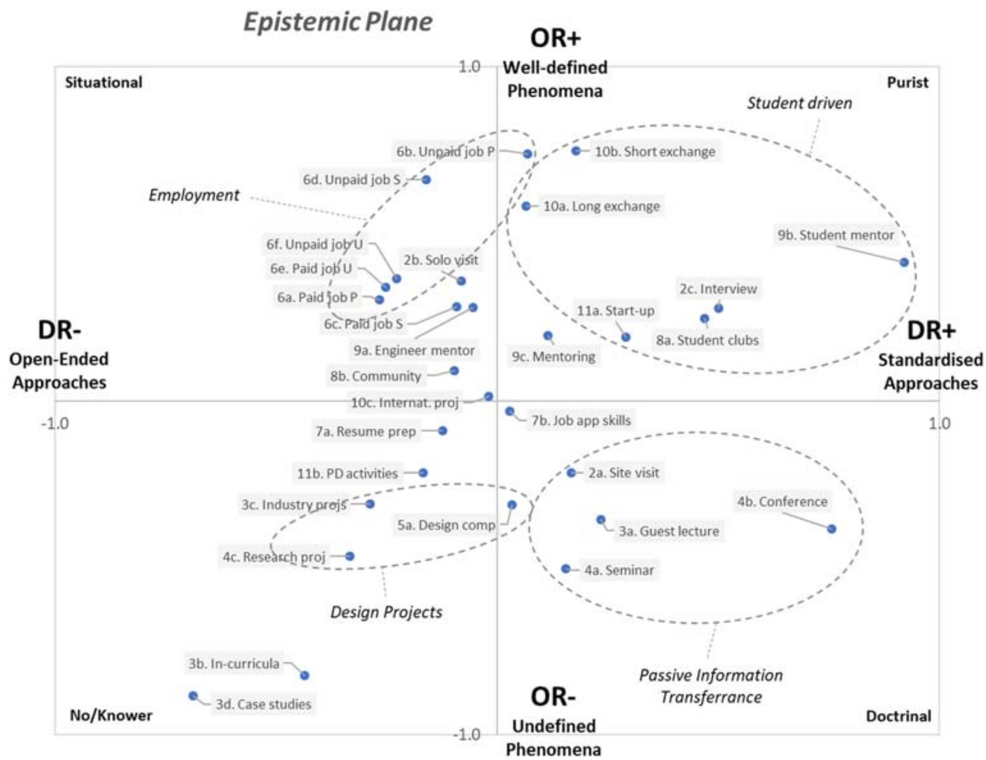

Figure 1. Mapping of the various PEP activity types onto the LCT epistemic plane (see Appendix, Table A1 for a full list of the activity types).

focus on the competency can lead to significant changes in *z*-scores. This was tested with activity type 11a, which has the highest rating for competency EA3.1. The variation in terms associated with the competency is quite low (STD 0.92), but the average number of terms is also quite low (mean 0.38) – and the high *z*-score is because claims across all activity types have low term counts. The observation that removing the outliers results in a significant shift in the *z*-score (even though the variation in term density is low) suggests that care needs to be taken in assessing results associated with those competencies where the average term density is low – in our results, this applies particularly to competencies 1.1 and 3.1.

Analysis

Bloom levels

The above results lead to a range of useful insights. Beginning with the data on terms associated with the various Bloom levels, an interesting pattern exists with regard to Engineering versus non-Engineering-focused activities. Considering the highest bloom levels (B5 and B6), reflections on the Engineering-focused activities had *z*-scores for the word densities of 0.20 and 0.93 compared to reflections on non-Engineering-focused which *z*-scores of 0.01 and −0.49. Conversely, at the lowest Bloom levels, the equivalent values were −0.27 and −0.13 for Engineering-related activities and 0.24 and 0.00 for non-Engineering-related activities. This suggests that Engineering-related activities are encouraging, or at least enabling, students to reflect on higher level and more complex concepts.

Possibly a more interesting observation (albeit one that is unlikely to be surprising) is that generally the activity types that have reflections skewed towards higher Bloom levels are those that involve project activities. For example, the activity types with the highest proportions of level 6 terms include: involvement in engineering-related design competitions (5a); engineering research projects (4c); and industry-based engineering projects (3c). One non-engineering activity that falls into this same category is involvement in a business start-up (11a) (though many of the activity claims related to technically-oriented start-ups). An interesting exception to this pattern is professional development within academic units (3b). This has the third highest density of Level 6 Bloom terms, but clearly is quite distinct from the other activities mentioned. This may well be because of explicit directions set within assessable activities on professional development, or the linking of professional development activities with project-based learning experiences.

In contrast to the above, the activity types that have reflections skewed away from the higher Bloom levels tend to be those within which students take a more passive role, e.g. interviewing engineering professionals (2c); resume writing courses (7a); being mentored by a senior student (9b).

Overall, this provides strong evidence that higher level skills and abilities (lower-level knowledge being a precondition for putting these skills and abilities into practice) are most likely to emerge through students' active participation in complex tasks, and that this is more likely going to occur, or at least be recognised, within project activities (which often occur within disciplinary contexts).

Engineering competencies

Turning to the data on EA competencies, one expected observation that can be seen from the data in Table A4 is that almost all (though interestingly, not all) engineering competencies are more evident in the reflections on engineering-focused activities than on non-engineering-focused activities (as measured by term density). There are only two cases where this is not true: E3.2 (effective oral and written communication) and E3.5 (orderly management of self, and professional conduct). The reason for these two cases is unclear from the data, but it may be because these tended to be the most obvious options when students were unclear about the classification of a more general, non-engineering, activity and so in the absence of other elements to reflect upon students chose to reflect upon these elements. This would warrant further investigation.

For various competencies, there were often activity types that had particularly high *z*-scores (i.e. a higher than average density of associated terms in the reflections) suggesting that those activity types are worthy of specific attention when a given competency is being targeted. For example, competency E3.2 (effective oral and written communication) had a particularly high *z*-score for activity 7a (Resume writing courses). This may suggest that students are more likely to engage strongly in reflecting on communication skills when it specifically relates to their own immediate career opportunities, or possibly where the framing of the activity has emphasised communication.

Competency E1.2 (conceptual understanding of underpinning mathematics and computing) and competency E1.1 (comprehensive understanding of underpinning sciences and engineering fundamentals) both had their highest *z*-scores (3.16 and 2.48 respectively) for activity 3d (Industry-focused case studies). This suggests the value of clearly visible industry-relevance in engaging students in developing foundational knowledge early in their degree.

Competency E2.3 (application of systematic engineering synthesis and design processes) had its highest *z*-score (2.86) for activity type 5a (involvement in engineering-related design competitions). This emphasises the value that such design competitions can have. Note however that in our case student involvement in the competitions will have been voluntary and self-selected, suggesting stronger motivational elements have potentially contributed to this result.

As was discussed in the section on the approach we also compared the expert predictions from the 5 authors with the results from the data analysis to identify any potential anomalies. There were several results from this which were either subjectively surprising, or which had *z*-scores that were at odds with the expert predictions.

The first of these surprising results relates to competency E1.6 (understanding of sustainable engineering practice in the specific discipline) which had its highest *z*-score for activity type 3b (professional development within academic units). This may suggest that considerations of sustainable practice are either overlooked because students are not expecting to find them (they don't see what they don't look for) or because they become lost amongst other considerations when students are reflecting upon other activity types. In contrast, study within academic units can explicitly emphasise consideration of sustainable practice leading to students reflecting upon it more specifically. This interpretation is supported by a more detailed examination of the relevant reflections. For example:

> This activity involved designing a way to help communities reintroduce vegetation in an urban environment and then presenting this design. I expected this activity to be an introduction into how engineers approach a problem and the process of designing the solution. Through this activity, I learned more than I expected, especially about sustainable engineering practices, thinking about all the different factors when designing something and how to present the design to the public using a design proposal.

One interesting possible consequence of this finding above is that it suggests that students may only be reporting on what they have been 'told' to learn in an activity, rather than deeply reflecting on what they have actually learnt. Stronger development of reflective thinking may be crucial in addressing this issue. Given this observation, it is worth reiterating that the students whose data is used in this study are all in the first two years of their undergraduate studies, and as such are not senior students. This could be a form of bias in that they haven't engaged as much with the higher level activities or more specific engineering activities that will be likely to characterise the later stages of their program.

The second anomalous result is that for competency E3.6 (effective team membership and team leadership) the second highest *z*-score (2.05) was for activity type 4c (engineering research projects). We are encouraged by this data that indicates that students perceive the development of team skills as a major component of research projects, contrary to the view that research is a more solitary pursuit. It may also suggest that when students do group work in a context that actively draws on diverse skills and perspectives (such as research projects) it makes the benefits of effective team membership and leadership more visible. This issue was explored further through reviewing relevant reflections to explore the nature of the relevant comments. The following is an extract from a typical reflection:

> During this semester I was involved in a project called the Dalyell Science Showcase, and our group's research topic is the [topic de-identified]. During this research I gained sufficient knowledge of how a spacecraft works. My involvement in this project includes self-researching on the function of each component of a space craft, group discussion on the quantitative aspects, and writing a report to finalise our research outcome.

There was a similar pattern that indicated that the 'research projects' tended to be in-curricula activities that were largely group-based. While the reflections tended to emphasise the technical aspects of the project, they also invariably included significant commentary on the nature of the group interactions.

In terms of expert estimates, there were 7 items where at least one expert suggested that a given activity might contribute positively to the development of a given competency, but the resultant *z*-score was lower than −1.0 (i.e. there was a significantly lower than average reference to terms associated with that competency in the associated reflections). These items included the following (see Appendix for the full description of activities and competencies):

- Activity 2c (interviewing engineers) Competency 2.1 (problem solving) *z*-score = −1.39
- Activity 8a (student societies) Competency 3.4 (use of information) *z*-score = −1.17
- Activity 11a (business start-up) Competency 3.4 (use of information) *z*-score = −1.11
- Activity 6a (paid profess. employ) Competency 3.3 (creative, innovative) *z*-score = −1.10
- Activity 8b (community service) Competency 3.5 (self-management) *z*-score = −1.09
- Activity 5a (design comps) Competency 3.5 (self-management) *z*-score = −1.07
- Activity 8a (student societies) Competency 3.5 (self-management) *z*-score = −1.00

Similarly, there were 2 items where at least one expert felt that a given activity would be least likely to contribute to a given competency, but the resultant *z*-score was greater than 1.0 (i.e. a higher than average proportion of relevant terms). These were:

- Activity 3d (industry case studies) Competency 3.4 (use of information) *z*-score = 2.64
- Activity 6f (unpaid unskilled empl.) Competency 3.3 (creative, innovative) *z*-score = 1.63

For each of these cases, a review of associated reflections was undertaken. This review tended to indicate that the analyses of the reflections had provided a valid picture of the focus of student reflections, and hence this suggests that relying on 'expert predictions' as to which activities might be most valuable is somewhat problematic (this is not unexpected given that the expert and the students are likely to have highly different awareness and experience, that means that at least in some cases, they will see different opportunities to develop and address competencies within the same activities). As an example of this analysis, consider the last case above (6f/E3.3). Activity 6f (unpaid and unskilled employment) had been identified by one of the experts as being unlikely to encourage students to develop competency 3.3 (creative, innovative and pro-active demeanour), and yet the associated reflections contained a significantly higher than average proportion of terms associated with this competency. Reflections associated with activity 6f included statements such as:

> Having the right demeanor in these situations sets me apart from others … This made me realize how important it is to have the right mindset going into these activities and how important it is to be self-motivated. Therefore, this activity has encouraged me to explore what I am capable of by pushing myself to create … .

> Next time when I do any kind of volunteering work, I will be more active and create my own chance to talk to others.

> Although this is not specifically related to engineering development, I believe it gave me an insight into how important it is to have a proactive and innovative demeanour in all areas of work.

In other words, there appears to be a pattern where unpaid and unskilled work, perhaps by removing expectations of the need to focus on specific engineering skills, allowed students to identify and reflect on opportunities to develop their broader professional skills and attributes and also to recognise their value to their development and preparation for their professional engineering career.

An interesting sidenote also emerges from this final case. Reflections associated with Activity 6f (unpaid and unskilled employment) rated highly in terms of density of terms associated with competency 3.3 (creative, innovative and pro-active demeanour). Drilling into the reflections highlighted that there was a strong tendency towards commenting on the 'pro-active' element, but little related to being creative or innovative. This highlights the limitations of the current competency wording, where essentially distinct items are grouped together. This has potentially important implications for how we map competency development and warrants further exploration.

Epistemic plane

Whereas the above analysis provides a fine-grained evaluation of individual activity types and competencies, the LCT epistemic plane allows for a more broad examination by looking for general patterns. We can explore the relative patterns that exist in the positioning of the activities. Considering the left versus right halves of the epistemic plane, on the right-hand side (i.e. DR+, more standardised approaches) we tend to find activities such as interviewing professionals (2c), participating in conferences (4b), guest lectures (3a) and industry seminars (4a). While there is significant variation in these activities, one thing they do have in common is that a strong articulation of a particular approach, and hence the students are not expected to explore the relevance of different possible engineering approaches that might be appropriate. The activities tend to either involve students adopting a relative prescriptive approach (e.g. an interview script) or the approach being described by someone else (e.g. a guest lecture). The result is an absence of responsibility for the student in considering alternatives and hence they are not required to engage in managing complexity. This contrasts with those activity types that sits on the left half of the epistemic plane (DR−, more open-ended approaches) such as paid employment (6a, 6c, 6e), industry-based projects (3c), and personal development activities (11b). In these cases, the activity is only weakly coupled to defined approaches and hence participants involved in the activity must take greater responsibility for identifying the approach to be used (opportunities to manage complexity), accessing the resulting opportunities for wider learning, application of skills and development of judgement.

It is also worth considering the activity type split between the top and bottom of the epistemic plane. Those activities in the top half of the plane (OR+, more well-defined phenomena) tend to focus on phenomena where specific knowledge is relevant such as employment (6a–e) and mentoring (9a–b). Those activities in the bottom half of the plane (OR−, more open-ended phenomena) tend to focus on more broad-ranging phenomena that avoid prioritising specific knowledge. It is this half of the plane that you find most industry connected activities (3a–d, 4a–c).

Combining the observations from the previous paragraphs suggest that it is the activities in the bottom left-hand quarter of the plane that avoid prioritising specific knowledge, are only weakly coupled to defined approaches and require participants to exercise autonomy and take greater responsibility for identifying and choosing the approach to be used, provide the best opportunities to engage with and hence develop the skills required to manage complexity and exercise judgement. These are the skills identified in the background section of this paper as being absent from and/or at least less visible in many engineering curriculum learning activities but are needed and in fact essential to be successful in professional practice. Not surprisingly this quadrant contains research and industry projects and industry focused case studies. Perhaps less recognised or obvious is that professional development within academic units and personal development activities are also located in this quadrant. This highlights both the importance and relevance of these types of activities to the development of engineering students for professional practice that is often overlooked with the predominant focus of many faculty and students on technical knowledge and abilities. This also explains in part the opportunities previously identified by students in regard to unpaid unskilled employment. Free from the blinkered and in some cases probably unconscious focus on the importance of technical knowledge and skills, students were able to use these activities to access opportunities associated with the bottom left-hand corner of the epistemic plane. For example, in the students' own words, being more active in creating their own chances, self-motivation and being proactive. One final interesting observation relates to variability within individual activity types. Specifically, the activity types that have the highest variation in the DR position (i.e. the strength of connection to specific information on approaches) between individual cases are professional development within academic units (3b), independent visits to professional engineering worksites (2b), and industry-based engineering projects (3c). The activity types that have the highest variation in the OR position (i.e. strength of connection to specific knowledge) are collaborative projects with international partners (10c), and international exchanges (10a, 10b).

Overall, the above findings are consistent with those in the literature. Considering the observation that 'our current curricula and pedagogy are predominantly located on the right-hand side of the plane, and that real-world problem solving occurs on the left-hand side' (K. E. Wolff, Dorfling, and Akdogan 2018) we can conclude that those activities which are less prescriptive about an approach to be adopted and rather require students to explore for themselves which might be the most appropriate approaches are the most likely to engage students in thinking about the nature of real-world engineering practice. One interesting consequence of these observations relates to possible useful alternatives to conventional student placements and internships. As finding placements for students becomes more difficult, this analysis suggests that activity types that might be the best alternatives include mentoring by a professional engineer (9a), service within community associations (8b) and independent visit to engineering workplaces (2b). Interestingly, there is a strong tendency in these towards individual initiative and judgement.

This also highlights the benefits of programs such as PEP, which allow students to experience a more diverse range of professional activities than would be achieved through more conventional, and narrower, placements (usually undertaken in one organisation). The fact that PEP allows students to reflect and develop professionally and in practice situations early on in their studies means they can then build on this development as they progress through their degree program.

Dealing with complexity

One key element that has emerged in the above analysis has been the development of students' ability to handle complexity. Engineering practice involves complex problems and the solutions require the use of judgement, managing multiple possibilities, competing demands and having to make assumptions to develop considered and reasoned solutions to complex problems. As was noted in the analysis of the epistemic plane, it is those activities that sit in the left half of the plane – requiring open-ended approaches, especially to ill-defined problems – that most require students to engage with complexity and develop judgement. Examples include employment and design projects.

This naturally raises the question of how we best leverage these activities in supporting student learning related to complexity. In the background section, reference was made to the Cynefin framework (Kurtz and Snowden 2003), and we can potentially use this to help in answering this question. The framework identifies four decision-making contexts or domains, each offering a perspective from which to analyse behaviour and make decisions:

1. Known: cause-and-effect relationships repeatable, perceivable and predictable
2. Knowable: cause-and-effect separated over time and space
3. Complex: cause-and-effect are only coherent in retrospect and do not repeat
4. Chaos: no cause-and-effect relationship perceivable

The methods and techniques used in the 'known and knowable' domains do not work when managing complexity and you can't readily move from a truly complex problem to a known solution. The authors of Cynefin note that in dealing with complexity:

> The decision model in this space is to create probes to make the patterns or potential patterns more visible before we take any action. We can then sense those patterns and respond by stabilizing those patterns that we find desirable … Narrative techniques are particularly powerful in this space. (Kurtz and Snowden 2003, 469)

Ongoing research could potentially benefit by exploring the extent to which the 'left-plane' activities identified in this paper also embody the range of methods identified by Kurtz and Snowden as relevant to stimulating emergent patterns in complex knowledge interactions.

Conclusions

This paper has used text-based analysis of detailed student reflections to identify correlations between different professional practice activities and the potential development of an understanding of engineering professional competencies. We have used a Blooms taxonomy approach to interpret the depth of engagement and plotted those activities within the epistemic plane of Legitimation Code Theory. The approach outlined in this paper has demonstrated a valuable new way to explore graduate competencies, using a semi-automated coding of large data samples couple with a statistical analysis identify patterns.

The results help in developing a clearer understanding of the specific types of activities that are most likely to promote an understanding by graduates of specific engineering competencies relevant to their professional practice. It is also useful in guiding decisions about the ongoing professional development of new graduates. For example, if a graduate engineer has a competency gap with regard to professional conduct (E3.5) then the results suggest that either or both of interviewing professional engineers and finding a good mentor might be the most effective pathway to improvement.

Our findings were consistent with several other studies, namely that activities which are less prescriptive about an approach to be adopted and rather require students to explore for themselves which might be the most appropriate approaches are the most likely to engage students in thinking about the nature of real-world engineering practice.

Our results also suggest areas of further research using a similar methodology, such as the application of the techniques explored in this paper to conventional industry internships and placements, and the subsequent comparison of those findings to the results reported here. This will allow a more direct consideration of the extent to which alternative forms of exposure to professional practice might be able to achieve similar (or even better) outcomes than internships.

Probably the most critical area of future research will be to extend the data collection and analysis longitudinally through the entire degree program once a sufficient cohort of students is available. This will allow consideration of questions such as the when transitions in student understanding are most likely to occur and how this transition affects student learning in other areas (such as technical disciplinary knowledge).

A parallel stream of existing research is also exploring, through structured surveys, students' views on the nature and relevance of different engineering competencies. This research includes consideration of questions such as which competencies are more important in obtaining a job as a new graduate engineer, which competencies might best be developed during formal study versus 'on-the-job', and their perceived level of current proficiency with regard to different competencies. Connecting the outcomes of this research with the findings in this paper will help understand opportunities for changing students' perspectives and attitudes and hence to improve the professional capabilities of graduate engineers.

Finally, it worth noting that while the research results outlined in this paper provide valuable insights, even greater understanding will emerge by coupling these results with a more fine-grained analysis of the detailed data. This will be the subject of ongoing research.

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No potential conflict of interest was reported by the author(s).

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Appendix. Key data and results

Table A1. List of PEP Activity Types and examples in selection categories. (Note that students self-categorise their activities using this taxonomy. The categorisation is checked during the assessment process).

Engineering focused	
2a	University-organised site visit to a professional engineering worksite (e.g. class visit to a
2b	construction site)
2c	Independent visit to a professional engineering worksite
3a	Interviewing engineering professionals
3b	Guest lecture from industry representative
3c	Professional development within academic units (e.g. ethics classes)
3d	Industry-based engineering projects (e.g. industry-sponsored honours project)
4a	Industry-focused case studies
4b	Industry seminar/workshop on engineering topics
4c	Engineering conference
5a	Engineering research project (e.g. research-focused honours project)
	Involvement in engineering-related design competition
Non-engineering focused	
6a	Paid employment in a professional role (e.g. accountancy)
6b	Unpaid employment in a professional role
6c	Paid employment in a skilled non-professional role (e.g. carpenter)
6d	Unpaid employment in a skilled non-professional role
6e	Paid employment in an unskilled role (e.g. packing shelves in supermarket)
6f	Unpaid employment in an unskilled role
7a	Resume writing courses
7b	Job application skills development
8a	Service within student societies
8b	Service within a community association (e.g. volunteer for Rural Fire Service)
9a	Being mentored by an Engineer
9b	Being mentored by a senior student
9c	Undertaking mentoring of others
10a	Semester-long international exchange
10b	Short international exchange (e.g. 4-week winter study-abroad program)
10c	Collaborative project with international partners
11a	Involvement in a business start-up
11b	Personal development activities (e.g. Toastmasters)

Table A2. Engineers Australia Stage 1 competencies. See (Engineers Australia 2013) for full details.

1. KNOWLEDGE AND SKILL BASE
1.1. **Comprehensive, theory-based understanding** of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.
1.2. **Conceptual understanding** of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.
1.3. **In-depth understanding** of specialist bodies of knowledge within the engineering discipline.
1.4. **Discernment** of knowledge development and research directions within the engineering discipline.
1.5. **Knowledge** of engineering design practice and contextual factors impacting the engineering discipline.
1.6. **Understanding** of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline.
2. ENGINEERING APPLICATION ABILITY
2.1. **Application** of established engineering methods to complex engineering problem solving.
2.2. **Fluent application** of engineering techniques, tools and resources.
2.3. **Application** of systematic engineering synthesis and design processes.
2.4. **Application** of systematic approaches to the conduct and management of engineering projects.
3. PROFESSIONAL AND PERSONAL ATTRIBUTES
3.1. **Ethical** conduct and professional accountability.
3.2. **Effective** oral and written communication in professional and lay domains.
3.3. **Creative**, innovative and pro-active demeanour.
3.4. **Professional** use and management of information.
3.5. **Orderly** management of self, and professional conduct.
3.6. **Effective** team membership and team leadership.

Table A3. Normalised (*z*-score) ratings for each professional engagement activity type against Bloom levels (B1–B6). Outliers (with a |*z*-score| ≥ 1) are shown shaded and with either a dotted border (high) or solid border (low).

Activity type	Total Activities	Total Words	Density Bloom B1	Normalised (*z*-score) word density Bloom B1	B2	B3	B4	B5	B6
PEP All Activities	**8628**	**3,543,772**	**0.305%**	**0.01**	**−0.06**	**0.12**	**−0.05**	**0.10**	**0.16**
PEP: engineering focused total	***3898***	***1,626,958***	***0.280%***	***−0.27***	***−0.13***	***0.50***	***0.33***	***0.20***	***0.93***
2a. University-organised site visit to a engineering worksite	111	43,639	0.247%	−0.62	−0.11	−1.37	0.02	−1.19	−0.27
2b. Independent visit to a professional engineering worksite	190	85,353	0.261%	−0.47	−0.17	1.11	0.87	−0.02	0.12
2c. Interviewing engineering professionals	212	74,297	0.342%	0.41	−0.37	−0.38	−1.53	−0.32	−1.47
3a. Guest lecture from industry representative	593	203,333	0.307%	0.03	0.65	−0.49	−0.66	−0.27	−0.49
3b. Professional development within academic units	537	224,820	0.269%	−0.38	−0.28	1.08	0.75	1.28	2.06
3c. Industry-based engineering projects	378	190,865	0.255%	−0.53	−0.77	1.20	0.67	0.25	1.70
3d. Industry-focused case studies	72	31,413	0.427%	1.34	2.70	1.00	1.25	2.40	0.84
4a. Industry seminar/workshop on engineering topics	377	135,318	0.285%	−0.21	0.71	−0.12	−0.83	−0.63	−0.35
4b. Engineering conference	136	55,172	0.303%	−0.02	−0.65	−0.86	−0.53	−1.17	−0.46
4c. Engineering research project	393	174,336	0.323%	0.21	0.04	0.09	0.59	1.46	2.09
5a. Involvement in engineering-related design competition	381	180,314	0.225%	−0.87	−1.14	0.96	1.27	0.14	2.77
Other	518	228,098	0.261%	−0.47	−0.17	1.21	0.81	−0.34	0.56
PEP: non engineering focused total	***4730***	***1,916,814***	***0.326%***	***0.24***	***0.00***	***−0.21***	***−0.37***	***0.01***	***−0.49***
6a. Paid employment in a professional role	340	153,152	0.243%	−0.67	0.52	−0.45	−0.75	−0.28	−0.29
6b. Unpaid employment in a professional role	83	40,662	0.243%	−0.66	−0.73	−0.12	−0.27	−0.39	−0.50
6c. Paid employment in a skilled non-professional role	561	265,083	0.233%	−0.78	−0.09	−0.82	−1.17	−0.92	−0.51
6d. Unpaid employment in a skilled non-professional role	136	62,371	0.358%	0.58	1.68	−0.47	−1.25	−0.33	−0.72
6e. Paid employment in an unskilled role	481	226,338	0.227%	−0.84	−0.74	−1.19	−1.53	−1.03	−0.53
6f. Unpaid employment in an unskilled role	90	39,206	0.242%	−0.67	−1.16	−1.57	−0.70	−0.72	−0.99
7a. Resume writing courses	232	74,501	0.470%	1.81	1.09	0.33	−0.70	1.38	−1.38
7b. Job application skills development	844	280,194	0.591%	3.13	1.29	2.58	0.53	1.67	−0.71
8a. Service within student societies	223	98,729	0.246%	−0.63	−0.94	−0.32	−0.50	−0.83	−0.25
8b. Service within a community association	148	65,315	0.207%	−1.06	−1.05	−1.36	0.04	−1.20	−0.78
9a. Being mentored by an Engineer	70	25,881	0.309%	0.05	−0.11	−0.42	−0.44	−0.65	−0.78
9b. Being mentored by a senior student	45	16,448	0.371%	0.73	−1.11	−0.82	−1.01	−2.09	−1.03
9c. Undertaking mentoring of others	100	42,823	0.299%	−0.06	1.07	−0.68	−0.69	0.44	−0.28
10a. Semester-long international exchange	25	8888	0.450%	1.59	0.85	1.54	1.35	1.44	0.11
10b. Short international exchange	8	3666	0.136%	−1.83	1.24	1.19	1.59	−0.39	1.07
10c. Collaborative project with international partners	30	12,481	0.377%	0.79	0.83	−0.87	1.93	0.10	0.17
11a. Involvement in a business start-up	21	9653	0.176%	−1.40	−2.24	0.31	−1.27	0.32	0.40
11b. Personal development activities	749	285,010	0.314%	0.11	−0.29	−0.65	0.72	0.77	−0.12
Other	544	206,413	0.325%	0.23	−0.66	−0.70	−0.28	−0.08	−0.43

Table A4. Normalised (z-score) ratings for each professional engagement activity type against EA competencies (E1.1–E3.6). Outliers (with a $|z\text{-score}| \geq 1$) are shown shaded and with either a dotted border (high) or solid border (low).

	EA competencies															
Activity type	E1.1	E1.2	E1.3	E1.4	E1.5	E1.6	E2.1	E2.2	E2.3	E2.4	E3.1	E3.2	E3.3	E3.4	E3.5	E3.6
PEP all activities	**−0.04**	**0.06**	**0.01**	**0.07**	**0.04**	**0.10**	**0.02**	**0.02**	**0.07**	**0.03**	**0.11**	**0.03**	**0.00**	**0.10**	**0.27**	**−0.04**
PEP: engineering focused total	***0.48***	***0.82***	***0.85***	***0.65***	***0.93***	***1.02***	***0.39***	***0.79***	***1.02***	***0.63***	***0.38***	***−0.37***	***0.26***	***0.41***	***0.09***	***0.06***
2a. University-organised site visit to a engineering worksite	−0.41	0.35	0.92	0.44	0.37	0.34	−0.52	1.19	0.58	−0.48	−0.25	−1.02	−0.20	0.27	−0.61	−0.53
2b. Independent visit to a professional engineering worksite	1.03	0.06	1.45	−0.21	−0.11	0.21	−0.29	2.19	0.36	−0.42	−1.23	−1.78	0.05	−0.39	0.24	−1.00
2c. Interviewing engineering professionals	−0.95	−0.40	2.79	0.40	−0.52	−0.58	−1.39	−0.61	−0.54	−0.96	−0.71	−0.46	−0.50	−0.95	2.06	−0.93
3a. Guest lecture from industry representative	0.58	−0.19	2.30	1.29	−0.02	0.31	−0.84	−0.18	−0.06	−0.61	0.75	−0.18	−0.12	0.77	0.67	−1.07
3b. Professional development within academic units	0.73	1.74	0.01	0.48	1.54	2.50	0.98	1.20	1.41	1.68	1.55	−0.12	0.55	0.69	0.61	0.52
3c. Industry-based engineering projects	0.40	0.96	0.28	0.09	1.40	1.24	1.07	1.13	1.48	2.31	0.23	−0.15	−0.26	0.67	−0.85	0.59
3d. Industry-focused case studies	2.48	3.16	0.51	0.87	0.78	1.05	1.71	0.97	1.48	0.84	−0.29	−0.99	−0.22	2.64	0.89	−0.41
4a. Industry seminar/workshop on engineering topics	1.24	0.62	1.48	1.02	0.25	1.36	−0.49	0.32	0.19	−0.84	1.19	−0.83	0.17	0.29	0.56	−1.15
4b. Engineering conference	−0.58	−0.43	1.00	3.08	−0.58	−0.49	−0.61	−0.58	−0.42	−0.74	−0.77	0.20	−0.38	−0.06	0.74	−0.58
4c. Engineering research project	0.10	0.76	−0.15	2.13	2.29	0.85	1.31	0.52	2.27	2.59	0.51	0.91	0.31	1.13	−0.76	2.05
5a. Involvement in engineering-related design competition	−0.56	0.80	0.44	−0.07	2.47	0.70	1.69	0.95	2.86	0.62	0.13	−0.13	1.42	−0.95	−1.07	1.43
Other	1.29	1.60	0.74	−0.23	0.29	1.49	0.20	1.46	0.45	0.10	0.08	−1.23	0.46	0.73	0.32	−0.65
PEP: non engineering focused total	***−0.48***	***−0.59***	***−0.71***	***−0.42***	***−0.71***	***−0.68***	***−0.29***	***−0.63***	***−0.73***	***−0.47***	***−0.12***	***0.36***	***−0.22***	***−0.16***	***0.42***	***−0.13***
6a. Paid employment in a professional role	−0.34	−0.20	−0.75	−0.87	−0.59	−0.52	0.31	−0.67	−0.69	−0.10	0.43	0.12	−1.10	0.41	1.06	−0.45
6b. Unpaid employment in a professional role	−0.03	0.21	−0.13	−0.29	−0.28	−0.38	−0.15	−0.39	−0.60	0.20	0.77	0.60	−0.87	0.28	−0.09	0.69
6c. Paid employment in a skilled non-professional role	−0.77	−0.38	−0.86	−1.22	−0.88	−0.56	0.25	−0.61	−0.73	−0.18	0.48	−0.12	−0.80	−0.77	0.23	−0.17
6d. Unpaid employment in a skilled non-professional role	−0.80	−0.52	−0.96	−0.93	−0.58	−0.76	0.13	−0.79	−0.59	−0.41	1.55	0.27	0.36	−0.07	−1.11	0.56
6e. Paid employment in an unskilled role	−0.80	−0.97	−0.89	−1.16	−0.88	−0.48	0.37	−0.93	−0.81	−0.07	−0.04	−0.41	−0.88	−1.06	0.52	0.07
6f. Unpaid employment in an unskilled role	−1.06	−1.19	−1.04	−0.92	−0.76	−0.84	−0.36	−0.84	−0.84	−0.32	−0.96	0.41	1.63	−0.90	−1.66	0.77
7a. Resume writing courses	−0.88	−1.25	−0.93	0.13	−1.28	−1.09	−1.95	−0.78	−0.84	−1.93	−1.46	4.06	0.01	1.24	−0.53	−1.56
7b. Job application skills development	−0.79	−0.89	−0.72	0.79	−0.85	−0.96	−1.24	−0.66	−0.96	−1.28	−0.65	0.25	−0.43	0.88	0.91	−1.29
8a. Service within student societies	0.05	−0.57	−0.91	−0.99	−0.91	−0.96	−0.25	−0.53	−0.78	0.26	−0.41	0.26	0.58	−1.17	−1.00	1.29
8b. Service within a community association	−0.54	−1.09	−1.02	−1.01	−0.57	−0.56	−0.70	−0.63	−0.90	−0.34	0.37	0.34	0.42	−1.16	−1.09	1.07
9a. Being mentored by an Engineer	0.94	−0.17	0.56	0.61	−0.44	−0.28	−1.35	−0.29	−0.77	−0.52	0.24	−0.45	0.06	−0.68	2.16	−0.58
9b. Being mentored by a senior student	−1.20	0.14	−0.11	−0.46	−0.81	−0.57	−1.25	−0.25	−0.73	−0.62	−0.91	−0.91	−0.26	−0.57	0.02	0.08
9c. Undertaking mentoring of others	−0.25	−0.30	−0.77	−1.40	−0.95	−1.02	−0.10	−0.50	−0.90	−0.77	−1.02	0.17	0.02	−1.10	0.11	−0.21
10a. Semester-long international exchange	−0.76	−1.16	−0.58	0.22	−0.42	−0.88	1.79	−0.76	−0.18	0.17	−0.62	0.22	1.81	−0.32	−0.61	−0.10

(Continued)

Table A4. Continued.

Activity type	EA competencies															
	E1.1	E1.2	E1.3	E1.4	E1.5	E1.6	E2.1	E2.2	E2.3	E2.4	E3.1	E3.2	E3.3	E3.4	E3.5	E3.6
10b. Short international exchange	0.62	−1.47	−1.00	−1.40	0.32	−0.93	0.51	−0.45	0.44	0.23	−1.67	0.69	0.88	−1.91	−0.17	−0.92
10c. Collaborative project with international partners	0.57	0.21	−0.78	0.58	0.83	0.46	1.63	−0.59	0.34	1.97	−0.92	1.02	1.37	1.55	−1.19	3.07
11a. Involvement in a business start-up	−1.72	−0.05	−0.70	−0.11	−0.33	−0.02	−0.99	−1.02	−0.62	−0.37	0.89	−1.32	−0.52	−1.11	−0.29	−0.08
11b. Personal development activities	0.14	−0.17	−0.62	−0.15	−0.42	−0.65	−0.02	−0.36	−0.55	−0.47	−0.30	0.75	0.45	0.07	1.35	0.12
Other	−0.40	−0.75	−0.30	0.20	−0.63	−0.65	−0.68	−0.65	−0.63	−0.64	−0.20	0.62	−0.07	0.01	0.69	−0.02