Engineering students' perceptions of engineers and engineering work

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Structured Abstract

BACKGROUND

Engineering is well ahead of many other disciplines in terms of establishing strong and evidence-based research and practice relating to employability. Despite this, there are high rates of student and graduate attrition in many countries. One possible reason for this is that students enter engineering study without a sense of motivation and commitment, and without understanding the realities of either their degree program or engineering work.

PURPOSE

Educational institutions provide the learning foundation upon which competence for a professional engineering career is established; however, understanding how students position learning in relation to their future careers is a neglected area of research. Working with engineering students in their first semester of study, this research aimed to extend current understanding of students' thinking about competencies, identity, self-efficacy, motivation, career preview, and both career aspirations and fears.

STUDY DESIGN

Twelve hundred first-year engineering students at an Australian university participated in in-class workshops in which they considered their future lives and work. Responses were coded using the Engineers Australia (EA) graduate competencies as a framework. In this paper we report findings from the first cohort of students (n=260), of whom 49% were international students with English as their second language.

RESULTS

Students most frequently characterised engineers in line with the EA competency *Professional and Personal Attributes*. Striking differences emerged between international and local (domestic) students' perceptions of difference between the characteristics of engineers and their own attributes. These extended to *Engineering Application Ability*, *Knowledge and Skill Base*, and characteristics of engineers that are not EA competencies.

CONCLUSIONS

Implications for engineering education include changes to the information that guides course and career choice; the role and impact of foundation-year, including career-oriented learning; and the structure and delivery of pedagogical approaches that explore engineering identity. In considering these implications, language and cultural diversity warrant further attention.

KEYWORDS

Engineering careers; first year education; career preview

Introduction

Engineering is well ahead of many other disciplines in terms of establishing strong and evidence-based research and practice relating to employability. Despite this, Tilli & Trevelyan (2010) found that only 60% of engineering graduates work in engineering-related roles. A further and widespread concern is attrition of students, with attrition from Australian bachelor-level engineering programs standing at around 35% (Godfrey & King 2011). Male and Bennett (2013) have suggested that these high attrition rates may indicate that some students enter engineering study without a sense of motivation and commitment, and without understanding the realities of either their degree program or engineering work.

The study reported here extended previous research (Male 2012; Male and Baillie 2011; Parkinson 2011) that revealed three troublesome and inter-linked threshold concepts critical to student achievement: namely, students' understanding of the 'roles of engineers'; students' perception of the 'value of learning' new material; and the need for 'self-directed learning', both as students and into professional life. Later, Male and Bennett's (2013) investigation of students' self-efficacy and the development of salient identity concluded that the engagement of students in future-oriented thinking and self-reflection prompts a reorientation of learning in relation to engineering futures. The current study extended this inquiry to investigate the experiences of local (Australian) and international first-year engineering students.

In 2013, international students accounted for 18.8% of the Australian university population. This included over 14,000 students in engineering and related technologies (Department of Education, 2014). Difficulties encountered by international students are known to include differences in culture, language and social environment, homesickness, the loss of personal support structures, and negotiating a new educational system (Facchinetti, 2010). Moreover, Khawaja, Nigar & Dempsey (2008, p. 31) have found that international students encounter "greater incongruence between their expectations and experiences of university life". These difficulties are most pronounced within the first year of higher education, and over the past decade this realisation has resulted in significant attention paid to first-year students (Scutter et. al., 2011). In some cases this has included research with both international and local students, and this has revealed that the academic demands and problems of international students are significantly more troublesome than for their local counterparts.

Of particular relevance to the current study, which focused on perceptions of self and career, Murff (2005) considered the difficulties faced by international students and found their self-esteem to be negatively impacted. It is likely, therefore, that international students self-assess more negatively on their skills and attributes, including those relating specifically to their development as engineers. This finding resonated with the authors of the present study, who are experienced teachers in the engineering foundations year in which the current study was situated and had observed a marked difference between how local and international students interpret learning outcomes and associated assessments and activities.

Purpose

Educational institutions provide the learning foundation upon which competence for a professional engineering career is established; however, understanding how students position learning in relation to their future careers is a neglected area of research. Working with over one thousand first-year engineering students in their first semester of study, this study aimed to extend understanding of students' thinking about competencies, identity, self-efficacy, motivation, career preview, and their aspirations and fears relating to engineering practice. We also hoped that opening a career dialogue with students would prompt more career-oriented conversations and questions from students. Finally, we anticipated that by understanding our first-year student cohort's confidence in relation to the Engineers Australia (EA) graduate competencies (EA, 2011) we would be able to bridge some of the gaps between education and graduate competencies even before those gaps were formed.

Finally, by working across a large student cohort we hoped to compare responses from local and international students to see what, if any, differences emerged. If present, these differences would inform future research, pedagogical practice, and student support.

Approach and theoretical framework

In this study we worked with over 1,000 first-year engineering students at an Australian university to examine individual perceptions of self and career. Students completed activities designed to focus their thinking on self and career, and they were invited to submit their responses for analysis. This paper focuses on six classes in which there were 260 students. Of these, 212 (82%) students returned responses to one or more of the data collection instruments and 49% were international students with English as their second language. Most students had commenced university immediately following high school completion. Only 20 students were mature learners and 34 (16%) participants were female. Ethics clearance was obtained prior to commencement, at which point the study was explained to students and their confidentiality was assured.

Using a workshop approach and adopting the theoretical framework of Possible Selves (Markus & Nurius, 1986), students were encouraged to consider their future lives and work. The possible selves framework is a forward-oriented approach toward identifying both desired and feared conceptions of self. The framework depicts how people plan towards realising their future personas and achieving their career aspirations (Schnare, MacIntyre & Doucette, 2012). We hoped that the future orientation of possible selves would help explain the significance of the previously identified threshold concepts and encourage students to take an active role in developing future selves, considering these in relation to their learning.

The first-year engineering students participated in a 2.5-hour workshop conducted during a unit titled *Engineering Foundations: Principles and Communications* (EFPC). The unit forms part of the common Engineering Foundations Year (EFY) program, which provides students with the basic skills needed for engineering practice and leads to discipline-specific engineering studies from the second year. The generic skills and concepts developed in the EFY support interdisciplinary communication, reflexive practice and teamwork. Students completed a number of activities and reflections, and they were invited to submit copies of their written responses for analysis. The workshops comprised a whole-class discussion on learning and relevance, an individual self-reflection with a focus on aspirations, a group discussion about the characteristics of an engineer, an analysis of any perceived gaps between self and engineer, and future-oriented activities about goals and aspirations. Students also completed an activity on teamwork and completed a short reflective paper.

The length of student responses ranged from short-response answers to paragraphs of text, depending on question and activity. This elicited multiple forms of data including individual reflections, discussion observations and group responses. Data were transcribed, coded and analysed for emergent themes and quasi-quantification was applied as a means of summarising qualitative material. Each researcher conducted initial coding of the responses using the EA stage 1 graduate competencies as a framework. Once initial coding was complete, coding was compared and refinements applied. This led to a final codebook and a database using SPSS quantitative software version 22 (IBM, 2013).

Results

The study findings presented here relate to students' perceptions of the characteristics of an Engineer (Figures 1 and 2) and perceived gaps between these characteristics and their own attributes (Figures 3 and 4). The data are derived from two questions within the individual self-reflection completed by students at the start of the workshop. The two open questions were framed as follows: Q1: *Name 3 characteristics of an engineer;* and Q2: *What differences are there (if any) between the above characteristics and you as a person?*

Mapping against the EA competencies, the gap value for each competency/element for each cohort (international or local) was calculated as below:

a/b X 100 where
a = Number of responses to "What differences are there (if any) between the above characteristics and you as a person? and
b = Number of responses to "Name three characteristics of an Engineer."

As seen at Figure 1 students most frequently characterised engineers using terms associated with EA competency 3, that is, *Professional and Personal Characteristics* (EA3). Eighty-four per cent of all responses elicited in all categories were identified as relating to EA3. Some student responses aligned with EA3, however, they did not fit under any of the existing elements within this competency. For the purposes of this study these were categorised as additional EA3 elements and were titled *Intelligence* (3.7), *Engineering as Challenging Work* (3.8) and *Engineering as High Status* (3.9).

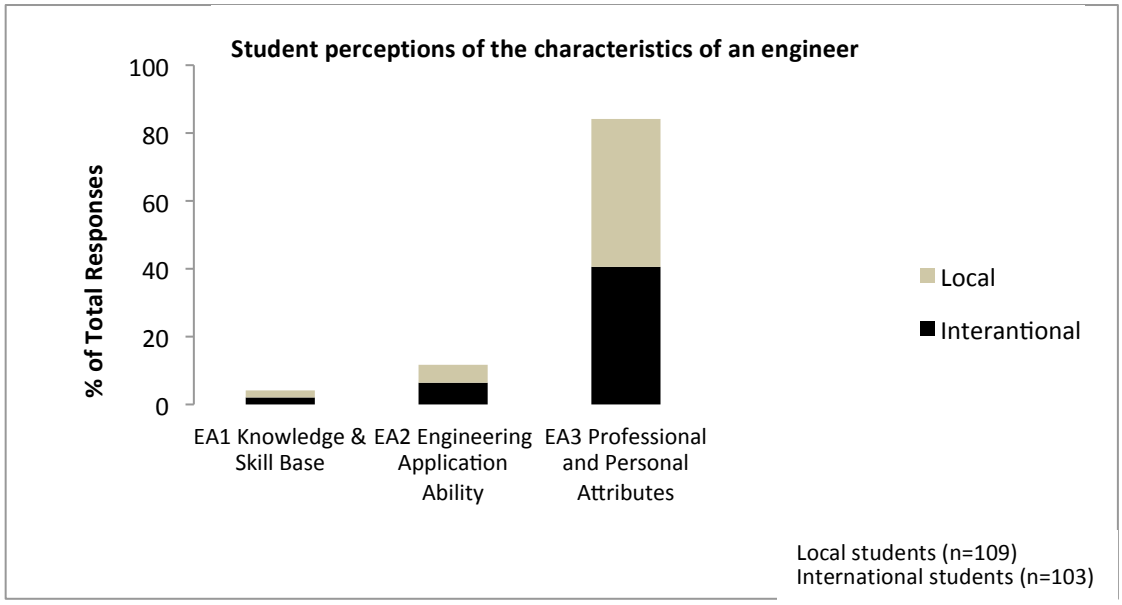

Figure 1: Characteristics of an engineer, coded to EA competencies

Of interest, only 4% and 12% of the total number of responses belonged to the EA competencies *Knowledge and Skill* (EA1) and *Engineering Application Ability* (EA2) respectively. Analysis of responses within EA3, shown at Figure 2, revealed that students regard the elements *Orderly Management* (EA3.5), *Intelligence* (EA 3.7) and *Engineering as Challenging Work (EA 3.8)* as the most important characteristics of engineers. At the level of EA3 elements, comparison of the responses from international and local cohorts yielded noticeable differences: for example, within EA3.7 the number of responses was 38% higher for international students, whereas for EA3.6 and EA3.8, the number of responses was lower for international students by 24% and 36% respectively.

Figure 3 illustrates the striking differences between international and local students' perceptions of all 3 EA competencies when asked to compare their own attributes with those of an engineer. When compared with local students, the number of responses from international students was markedly higher for all three EA competencies: 4-fold higher for EA1 and EA2 and 5-fold higher for EA3. This indicates that international students perceive a greater gap between the attributes they possess and those of an engineer.

Further analysis of perceived gaps within competency EA3, on which the majority of responses focused, suggests that the most pronounced difference between local and international students relates to *Engineering as challenging work* (additional element 3.8).

Illustrated at Figure 4, 12 times more international than local students identified differences for this element. Similarly, international students identified markedly more differences across all but one of the elements within EA3. For international students, the gaps were almost ten times more common for EA3.1, eight times more common for EA3.6, seven times more common for EA3.5, seven times more common for EA3.3, and three times as common for EA3.4. Conversely, for the additional element *Intelligence* (EA3.7) the local students indicated a slightly higher perceived gap (1.2 times higher).

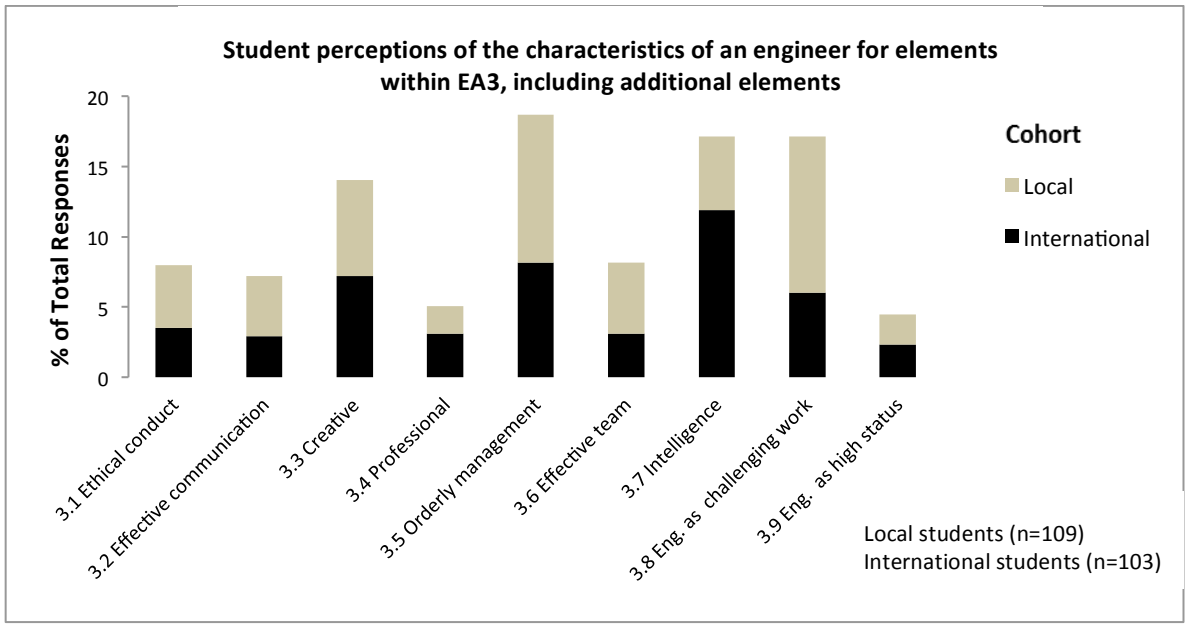

Figure 2: Student perceptions of the characteristics of an engineer (EA3)

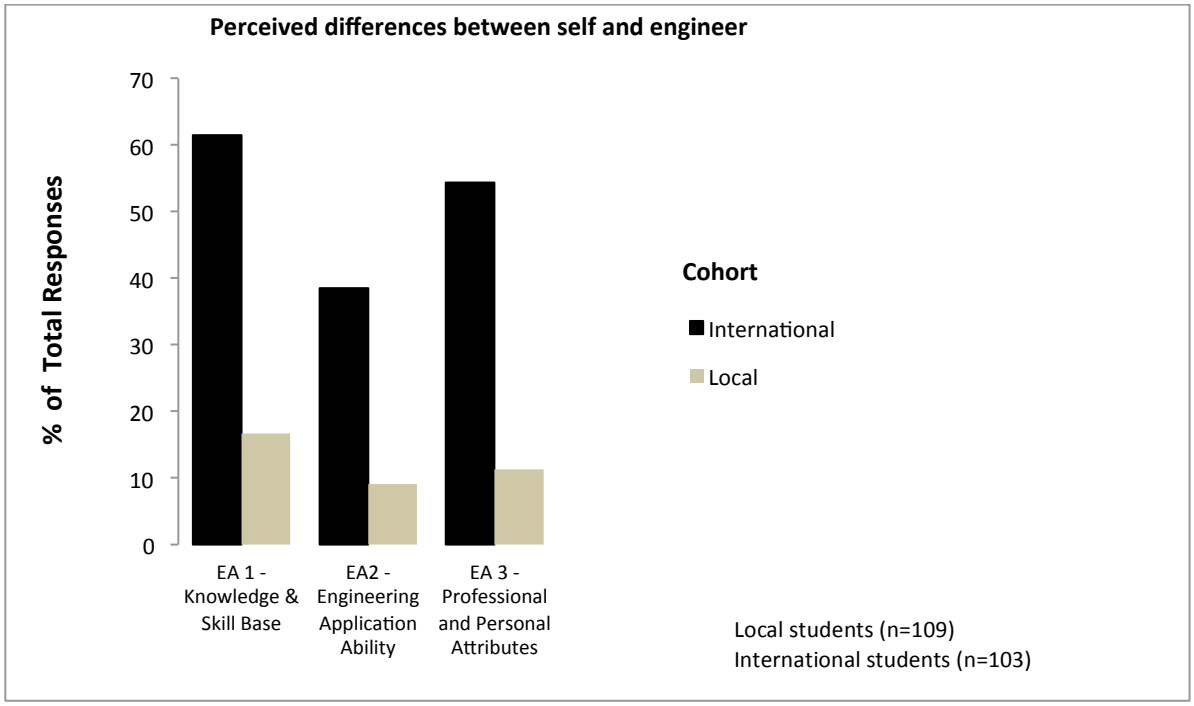

Figure 3: Student perceptions of their own attributes and those of an engineer (multiple response)

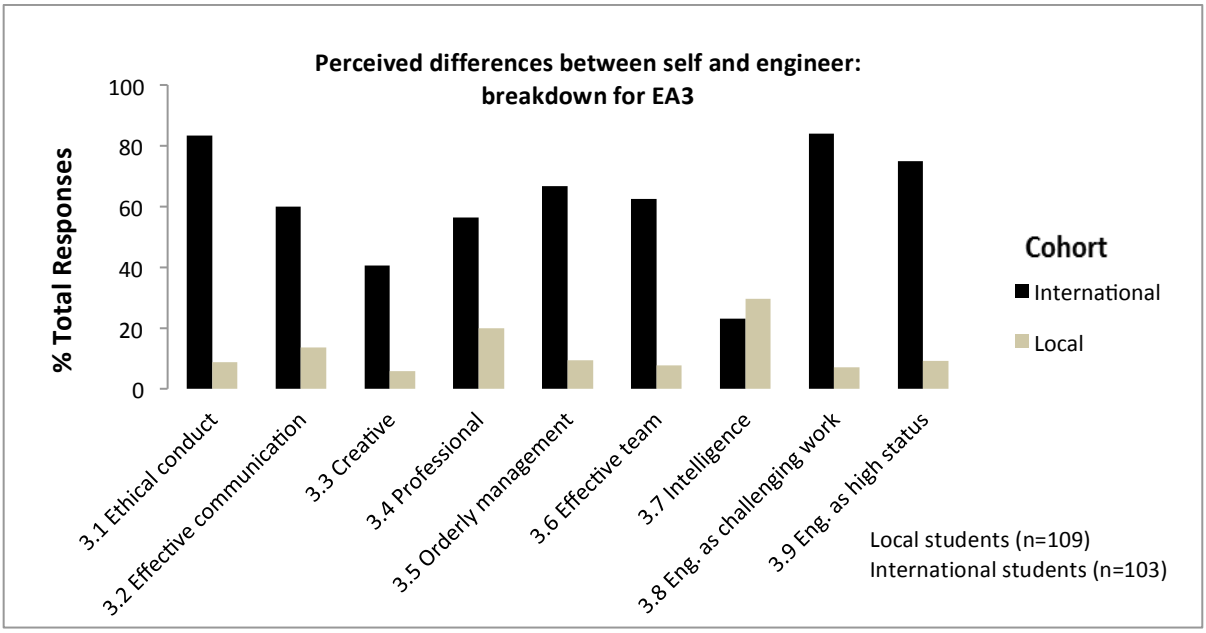

Figure 4: Perceived differences between self and engineer (EA3 and additional elements)

Discussion

This study aimed to extend understanding of students' thinking about competencies, identity, self-efficacy, motivation, career preview, and their aspirations and fears relating to engineering practice. We focus here on two key points: awareness of engineering work (career preview); and differences in the perceptions of international and local students.

First, relatively low responses overall under the competencies *Knowledge and Skill Base* and *Engineering Application Ability* indicate general lack of awareness of the knowledge and technical skills demanded of engineering work. This concurs with Male and Bennett's (2013) observations that students may enter university without a clear idea of their future career-selves. It is of some note that first year students in the EFPC unit were able to identify characteristics related to *Professionalism and Personal Attributes* (EA3) in engineers to a much higher degree than those characteristics associated with *Knowledge and Skill Base* and *Engineering Application Ability*. This may stem from the implementation of units such as EFPC, which have aligned themselves to the outcomes developed in the Stage 1 Competencies (EA, 2011). Thus, the students had been introduced to the importance of effective professional skills shortly before they took part in the current study.

Closer inspection of this competency reveals that some elements scored higher than others. For example, *orderly management of self and professional conduct* was commonly mentioned, whereas *professional use and management of information* received far less responses. This is perhaps to be expected because students have yet to develop an understanding of their chosen career. It is of concern, however, that elements such as *ethical conduct and professional accountability* elicited just 8% of the total responses across both international and local cohorts. This aligns with Stappenbelt's (2012) finding that engineering undergraduates lack awareness of aspects of professional ethics, and implies that education programs in engineering need to develop student consciousness in this area.

Further, responses relating to the elements within EA3 were different for international and local students. For instance, local students were more likely to perceive the work of an engineer as being challenging. Conversely, international students perceived engineers as being intelligent more often than their local counterparts. This variance may reflect cultural differences. It has been reported, for example, that while western cultures view intelligence as a fixed attribute, in Eastern countries it is often viewed as malleable (Willingham, 2009).

Therefore, international students may relate intelligence to the ability and necessity to work hard rather than to the ability to reason. This variation is likely to have influenced multiple responses, particularly as students were in their first year of study. Therefore, cultural and educational background needs to be considered when analysing future data.

Second, the study revealed significant differences in the self-perceptions of international and local students. In this study, the international students did not view themselves in a favourable light when compared to their local peers. In particular, international students regarded themselves as lacking in *professional and personal attributes*, *knowledge and Skill*, and *engineering application ability*. Moreover, international students felt deficient in eight of the nine EA3 characteristics. On the surface it would appear that international students have lower self-esteem, as observed by Gholamrezai (1995); however, confidence in English language competency is another likely factor. Reports on Work Integrated Learning (c.f. Gribble, 2014) conclude that the standard of professional workplace communication skills for international students from non-commonwealth countries is poor, and that this manifests itself in what the employers regard as inadequate communication skills. It is quite possible that international students from non English-speaking countries are aware of the importance of communication skills in the workplace and are not confident that they will meet the required standards before beginning work. This reinforces recent recommendations (cf. Gribble, 2014) regarding the need for engineering undergraduate courses to incorporate the development of English language proficiency throughout the curriculum.

One area where international students seem more confident concerns intelligence (Figure 4). As mentioned previously, there are cultural differences in the perception of intelligence (Sternberg 2004). This highlights the need to consider how differences in cultural and educational backgrounds contribute to how students perceive themselves and their future selves for all the characteristics discussed above. Researchers such as Rambruth and McCormick (2001) have signalled that this translates into learning diversity that requires the incorporation of inclusive teaching and learning strategies. Another point to consider is that international students cannot be regarded as a homogeneous group, and represent a range of countries (Australian Bureau of Statistics, 2011). Likewise, the local cohort also represents cultural diversity. This implies that all students undertaking engineering studies bring with them perspectives that education institutions must consider when developing and refining their programs. Future studies should, therefore, include a comprehensive profile of each student's cultural and educational background. Moreover, the transition between the students' actual identity and their designated identities, which has the "potential to become a part of one's actual identity" (Sfard & Orusak, 2005), can be prompted by multiple factors including labels of giftedness, significant others, changes of circumstance, and education-related decisions such as those made prior to and during higher education. The current study reinforces the need to also consider the cultural and educational background of students in facilitating this transition.

Conclusion

This study draws attention to the need for students to develop salient identities as a core component of their professional learning, and it raises the possibility of employing a future-oriented approach to achieve this. Most research relating to international students' ability to cope across a range of domains has focussed on expectations of course and experience, and difficulties associated with culture, language, social environment and the loss of personal support structures. However, individual self-concept and self-efficacy is also crucial, and is potentially negatively impacted by any of these factors. The fact remains that engineering students in many Australian universities have little exposure to engineering practice in the early years of engineering study and the international students undertaking university studies in Australia are predominantly from the Asian and Middle Eastern countries (AEI, 2010). Although we expect that the importance of exploring possible future selves and self-efficacy

crosses international boundaries, the above factors indicate that students' awareness and self-efficacy could differ across contexts.

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