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Engineering Identity and Attitudes to Engineering Professional Practice: A Pilot Study

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ABSTRACT

CONTEXT

Engineering identity has become an area of research interest when considering how to improve the student experience within engineering. Students build their engineering identity during their studies by seeing themselves as engineers, aligning themselves with the values and practices of engineers, and developing a sense of belonging to the engineering community. It is therefore important to understand how a student's engineering identity develops during their studies.

PURPOSE

One approach to measuring engineering identity uses a scale developed by Godwin (2016). However, some have suggested that Godwin's scale only captures the academic aspects of engineering identity. As a result, Patrick et al. (2017) developed the Attitudes to Engineering Professional Practice scale. The approach of combining an engineering identity scale with the Patrick scale has been used to better understand engineering identity in the United States, but there has been little use of this approach elsewhere in the world. This study aims to test these scales with Australian engineering undergraduates to explore the relationships between demographic variables, work-experience completion, and engineering identity development.

APPROACH

Engineering undergraduates at Griffith University were surveyed in May, 2024. Participants provided demographic data and completed the Godwin Engineering Identity scale and the Attitudes to Engineering Professional Practice scale. The results were analysed using a range of appropriate statistical techniques to identify significant areas for discussion.

OUTCOMES

The findings suggested that work experience completion is linked to significant increases on the recognition factor within the Engineering Identity scale. For engineering professional practices, analysis suggested that women rated the significance of project management higher than men, but no other gender differences were found. Mechanical and electrical/electronic engineering students rated the practices associated with 'tinkering' higher than civil engineering students.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Although the results of this study are based on a small sample, the findings suggest that the completion of engineering work-experience supports engineering undergraduates in terms of feeling recognised as engineers. By gender, attitudes to engineering practices differed only for project management, but a larger sample could strengthen the findings. Further research is required to better define and explore the practices associated with the tinkering factor.

KEYWORDS

Engineering identity, engineering professional practice, engineering major

Introduction

Although engineers are crucial to designing and building a safer and more sustainable world several reports have highlighted a shortage of engineers, both in Australia (King, 2021) and globally (Kanga, 2021). Given this challenge, engineering identity has become an area of research interest when considering how to improve the student experience and retention within engineering (Tonso, 2014). Students build their engineering identity during their studies by seeing themselves as engineers, aligning themselves with the values and practices of engineers, and developing a sense of belonging to the engineering community (Tonso, 2006; Stevens et al., 2008; Tonso, 2014). Accordingly, one goal of engineering education is to develop students who can "talk the right talk, walk the right walk, [and] behave as if they believe and value the right things" that engineers do (Gee, 2014, p. 24). It is therefore important to explore ways to better understand student progress on their journey towards becoming engineers.

Engineering Identity is a difficult construct to measure, but several tools have been developed to gain some insight into its development. One of the most promising scales was developed by Godwin (2016), and it builds on research into science identity (Carlone & Johnson, 2007) and physics identity (Hazari et al., 2010). The instrument uses eleven items to measure engineering identity based on three factors: Performance/Competence, Interest, and Recognition (PCIR). Performance/Competence refers to the ability to understand engineering concepts and perform engineering tasks, with Interest describing both interest in the discipline as well as the desire to learn more about engineering. The third factor, Recognition, captures perceptions of being seen to be an engineer by family, peers, and faculty. Table 1 provides a brief overview of the scale.

Table 1: Overview of the Godwin (2016) Engineering Identity scale

Factor	No. of Items	Sample Item
Performance/ Competence	5	I am confident that I can understand engineering in class
Interest	3	I am interested in learning more about engineering
Recognition	3	My peers see me as an engineer

The Godwin Engineering Identity scale has been criticised for focusing on the academic aspects of engineering and overlooking the importance of the professional aspects of engineering (Patrick et al., 2017). Accordingly, Patrick et al. developed the Affect towards Engineering Professional Practice scale. As shown in Table 2, the scale groups engineering professional practice into six factors: Framing and Solving problems, Design, Project Management, Analysis, Collaboration, and Tinkering.

Table 2: Affect towards Engineering Professional Practice Scale (Patrick et al., 2017)

Factor	No. of Items	Sample Item
Framing/Solving Problems	7	Solving problems that allow me to help a lot of people
Design	8	Designing a system, a part/component of a system, or a process based on realistic constraints
Project Management	4	Planning a project and staying organized to complete it
Analysis	3	Applying my math knowledge and skills
Collaboration	6	Working with people with different skills and interests
Tinkering	2	Taking something apart to see how it works

Aims and Objectives

Recent research suggests that combining a PCIR-based Engineering identity scale with the Affect towards Engineering Professional Practice scale can provide better insight into engineering identity development in undergraduates (Patrick et al., 2017; Choe et al., 2019; Patrick et al., 2021). As most research using such a combination of scales has been conducted in the United States, this study aimed to explore engineering identity in engineering undergraduates at Griffith University in Queensland, Australia. Accordingly, this paper describes the results from a pilot study investigating the relationship between student characteristics, major choice, and engineering identity development.

Methodology

After receiving approval from the university's human research ethics committee, undergraduate engineers were emailed invitations to participate in an online survey in week nine of Trimester One (T1), 2024, with a reminder email sent two weeks later. The survey was hosted on the Lime Survey platform, and open for a period of three weeks. To encourage survey completion, participants could enter a prize draw to win one of four $50 gift cards. The survey collected demographic data, asked students to indicate if they had completed any engineering-related work experience, and included the Engineering Identity (EI) and the Affect towards Engineering Professional Practice (AEPP) scales. Although the survey presented the 12 items on the EI scale in the published order, the order of the 30 items on the AEPP scale was randomised for each participant to minimise any item-order effects and improve response quality (Galesic & Bosnjak, 2009; Şahin, 2021).

Survey results were downloaded and processed in Microsoft Excel and IBM SPSS (Version 29). From the initial 78 survey responses, six incomplete responses were removed, and one more was removed due to being ineligible for the survey, leaving 71 valid responses. Responses on the EI scale were recoded to range from zero (‘Strongly Disagree’) to six (‘Strongly Agree’), and means were calculated for the Performance/Competence (PerComp), Interest (Int), and Recognition (Recog) factors for each participant. Similarly, AEPP scale responses were recoded to range from one (‘Not at all’) to five (‘Very much’), allowing for the calculations of means for the six factors in the scale. After testing for normality, statistical tests were selected as appropriate. In cases where the Mann-Whitney *U* test (Mann & Whitney, 1947) was used, effect sizes were calculated using the Wendt (1972) approach as outlined by Kerby (2014).

Results and Discussion

As there were a total of 1107 undergraduate engineering students enrolled during T1, 2024, the response rate was low at 6.4%. The demographic details of the survey respondents and the full undergraduate engineering cohort are shown in Table 3, although the distribution of majors in the full cohort is an approximate measure based on numbers of students who have formally declared the relevant major within the university computer systems. When comparing the survey sample to the full cohort, it appears that female students (n = 21, 29.6%) are over-represented in the responses, and more responses from first and second year students would have been beneficial, as fourth-year students provided the largest number of responses (n = 25, 35.2%), although they form 19% of the cohort.

Table 3: Profile of 2024 Survey Respondents

Variables	Values	Survey Responses		Undergraduate Cohort	
		n	%	N	%
Gender	Male	50	70.4	923	83.4
	Female	21	29.6	181	16.4
	Other / Prefer not to say	0	0	3	0.3
Campus	Gold Coast	54	76.1	675	61.0
	Nathan	17	23.9	432	39.0
Student Type	Domestic	67	94.4	987	89.2
	International	4	5.6	120	10.8
Age Group	17-19	13	18.3	396	35.9
	20-24	42	59.2	515	46.5
	25-29	8	11.3	117	10.6
	30-39	7	9.9	63	5.7
	40+	1	1.4	11	1.4
Year Level	First	16	22.5	392	35.4
	Second	14	19.7	259	23.4
	Third	11	15.5	193	17.4
	Fourth	25	35.2	210	19.0
	Fifth	5	7.0	53	4.8
Major	Mechanical	27	38.0	341*	38.4
	Civil	20	28.2	264*	29.7
	Electrical / Electronic	19	26.8	169*	19.0
	Software	3	4.2	75*	8.4
	Mechatronic	1	1.4	32*	3.6
	Environmental	1	1.4	8*	0.9

Note: *Describes the number of undergraduates who have formally declared the relevant major.

Internal Consistency

Internal consistency describes how well the items within a scale correlate with some of the other items on the scale, and is commonly calculated using Cronbach's alpha (Gardner, 1995). Table 4 displays Cronbach's alpha values for each factor on the relevant scales. Guidelines described in (Gliem & Gliem, 2003) were used to classify alpha values between 0.6 and 0.69 as 'questionable', 0.7 to 0.79 as 'acceptable', and 0.8 and 0.89 as 'good'. A high alpha value indicates the relevant items are "measuring something similar to *some* of the other items" (Taber, 2018, p. 1292), although Taber noted that approaches to interpreting Cronbach's alpha vary considerably, and values between 0.6 and 0.7 have been previously described as adequate, moderate, or even slightly low. As the factors of Framing Problems, Project Management, and Analysis had weaker internal consistency, further research is required to explore the suitability of the scale items linked to those factors, and findings for these factors should be treated cautiously.

Table 4: Overview of Internal Consistency for the factors within each scale

Scale	Factor	No. of Items	Cronbach	Interpretation
EI	PerComp	5	.732	Acceptable
	Interest	3	.763	Acceptable
	Recognition	3	.736	Acceptable
Scale	**Factor**	**No. of Items**	**Cronbach**	**Interpretation**
AEPP	Frame Problems	7	.682	Questionable
	Design	8	.820	Good
	Project Management	4	.691	Questionable
	Analysis	3	.644	Questionable
	Collaboration	6	.833	Good
	Tinkering	2	.716	Acceptable

Normality testing

Prior to commencing analysis, survey responses on factors of interest were tested for normality using the Shapiro-Wilk test. The results indicated that the responses on all relevant variables were not normally distributed: Engineering work experience completion (EngWex) and Interest ($p < .001$), Performance/Competence ($p = .011$), Recognition ($p = .026$), and all variables from the Attitudes to Professional Practice scale ($p < .001$). Therefore, a non-parametric statistical test such as the Mann-Whitney *U* test was used when comparing differences between two groups, and the Kruskal-Wallis test was used when comparing multiple groups (Mohr et al., 2022).

Differences by Engineering Major

As some majors had few responses, students from smaller majors were grouped into larger majors for analysis in line with their parent department at Griffith University. Accordingly, the one student in environmental engineering was placed into a larger Civil / Environmental group (CivEnv). Similarly, the three students in software engineering, and one student in mechatronic engineering were placed into the wider Electrical and Electronic engineering group (EEE). Kruskal-Wallis tests were used to identify any significant differences in scale factors by major. The results showed that attitudes to Tinkering differed by major, $H(2) = 17.315$, $p < .001$, with the effect size ($\varepsilon^2 = 0.25$) suggesting that the student's major has a moderate impact on attitudes to Tinkering. No other significant differences by major were found. Post-hoc comparisons were conducted using Dunn's method with a Bonferroni correction to control for multiple comparisons. As shown in Table 5, students in CivEnv have significantly lower scores for Tinkering than Mechanical ($p < .001$), or the EEE ($p = 0.019$) group of majors. However, there were no significant differences on Tinkering between Mechanical or EEE majors.

Table 5. Descriptive Statistics for Tinkering by major

Major	*n*	*M*	*Mdn*	*SD*
CivEnv	21	3.79	4.0	.930
EEE	23	4.46	5.0	.689
Mechanical	27	4.72	5.0	.487

Although these results are based on a small sample, findings suggest that students in the CivEng group, which primarily consists of civil engineering majors, may not value the practices associated with tinkering as much as students in mechanical or electrical/electronic engineering majors. Previous research has shown that interest in the activities associated with a particular engineering major is one of the primary reasons for choosing a specific engineering major (Main et al., 2022; Howell et al., 2023; Young et al., 2023). Accordingly, it is possible that interest in tinkering is more likely to be associated with those in mechanical or electrical engineering. However, in comparison to the other factors on the AEPP scale, the Tinkering factor is calculated from responses to only two items: 'Taking something apart to see how it works' and 'Fixing things'. When developing the AEPP instrument, Patrick et al. (2017) suggested there may be benefits to adding additional items to better capture tinkering to identify if it is a practice generally enjoyed by engineers, or if is "a distinct professional practice". Accordingly, further research could be conducted to gain better insight into attitudes to tinkering across different engineering majors.

Gender Differences

Mann-Whitney *U* tests were used to test for differences on scale factors by gender. As shown in Table 6, the results indicated that female students had significantly higher scores on Project Management, $U = 346.0$, $p = .022$, although the effect sizes were small ($r = 0.34$). Significance testing did not identify any other differences.

Table 6: Descriptive Statistics for the Project Management factor

Gender	*n*	*M*	*Mdn*	*SD*
Female	21	4.61	4.75	0.42
Male	50	4.25	4.5	0.63

Although the responses for the Project Management factor had questionable internal consistency ($\alpha = .691$), the finding that women had higher scores on Project Management matches some previous research into attitudes to engineering practice. While this study only noted significant gender differences on the Project Management factor, Patrick et al. (2021) described finding that women had higher scores on Project Management, as well as for Framing and Solving problems, with men having higher scores on Design, Analysis, and Tinkering. They argued that many of these gender differences are in line with gender-related stereotypes, which implies that men and women form their engineering identities in different ways. Patrick et al. suggested that engineering educators could promote engineering identity development in women by widening the range of problems and activities used in the classroom, and showing a broader range of engineering practices. Such recommendations are in line with calls for curricular reforms to better prepare the engineers of the future (Crosthwaite, 2021).

Differences on Scale Factors by Year Level

Kruskal-Wallis tests were used to identify any significant differences on scale factors by year level, with the results showing no significant differences for any of the factors on the EI or AEPP scales. This contrasts with Godwin and Lee (2017) who found fourth-year students had higher scores for Recognition and Performance-Competence than first-years. The difference in results may be due to the smaller sample in this study, and warrants further investigation.

The Role of Work Experience Completion

Engineers Australia requires that students complete at least twelve weeks of work-experience during their studies before they are able to graduate. Accordingly students were asked if they had completed any engineering-related work. Students were able to select 'Yes', 'No', or 'Unsure', with students who had selected 'Unsure' being treated as if they had selected 'No'. Table 7 presents a breakdown of engineering work experience completion by year.

Table 7: Overview of Engineering Work Experience Completion by year level

Year Level	Total (*n*)	No *n* (%)	Yes *n* (%)
First	16	16 (100%)	0 (0%)
Second	14	14 (100%)	0 (0%)
Third	11	7 (63.6%)	4 (36.4%)
Fourth	25	8 (32%)	17 (68%)
Fifth	5	0 (0%)	5 (100%)

A Kendall's tau-b correlation was run to determine the relationship between year level and work-experience completion. There was a statistically significant positive correlation between year level and work-experience completion, $\tau b = .630$, $p < .001$. As students must complete work-experience before graduation, it is not surprising that later year students are more likely to have engineering-related work-experience.

A Mann-Whitney *U* test was also conducted to explore if students with engineering-related work experience differed on any survey factors. As shown in Table 8, results indicated that students with work experience had significantly higher Recognition than those without work experience, $U = 384$, $p = .016$, although the effect size ($r = 0.34$) was small. No other differences were found.

Table 8: Descriptive Statistics for Recognition by Work Experience Completion

Work Experience Completion	*n*	*M*	*Mdn*	*SD*
Yes	26	4.44	4.67	1.15
No	45	3.86	4.00	1.07

Students complete engineering work-experience in a range of ways, either through internships, or through an industry-based thesis placement in their final-year capstone course. Although the survey did not ask where and how students completed their work experience, several researchers have concluded that completion of capstone courses promotes engineering identity development, with recognition by industry professionals playing a major role (Lutz & Paretti, 2017; Ju & Zhu, 2023).

While our findings support the view that students who have successfully completed work-experience should have stronger recognition, and therefore have stronger engineering identities, research into internship completion and engineering identity has mixed findings. It is often difficult to make direct comparisons due to the use of different measurement instruments, but some researchers concluded that internship completion did not influence engineering identity (Hughes et al., 2018; Ju & Zhu, 2023), although internship completion appeared to increase the likelihood of continuing into an engineering career (Hughes et al., 2018). Furthermore, findings from focus group research suggest that students consider internships as an important stage on the journey towards becoming an engineer (Hughes et al., 2021). As recognition is crucial for identity development, further research is warranted to explore when and how students feel they have been recognised as engineers.

The results of this pilot survey are only based on students at one institution, and are limited due to small number of responses. Further research with a larger sample across multiple universities would make it possible to verify the internal structure of the scales through the use of techniques such as factor analysis. A larger sample, followed by focus groups to explore student attitudes to the different engineering practices, could also yield useful insights regarding potential differences across the engineering majors and how this influences their engineering identity development. It would also be beneficial to explore when and where students complete their work experiences, and how this influences their perceptions of being recognised as engineers.

Conclusion

In conclusion, this study provides some insight into the relationship between demographic variables, the completion of engineering-work experience, and factors within the Engineering Identity and Attitudes towards Engineering Professional Practice scales. Although the results of this study are based on a small sample, the findings suggest that the completion of engineering work-experience provides some support to engineering identity development in undergraduates through being recognised as engineers. In terms of engineering professional practices, as attitudes to project management appear to vary by gender, engineering educators should ensure that the curriculum exposes students to a diverse range of practices associated with the engineering profession, which can then foster engineering identity development across the wider student cohort. The findings also suggest that further research is required to explore the internal structure of the attitudes to engineering professional practice scale, as it may prove to be a useful tool to understand engineering identity development in undergraduates as they progress through their chosen engineering majors and onwards to their chosen careers.

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