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Engineering activities differentiated by experience and gender

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ABSTRACT

CONTEXT

Research on 'what engineers do' is typically limited to the study of competencies required for practice (Mazzurco et al., 2021). Studies have identified variations in the importance of competencies (Passow & Passow, 2017; Pons, 2016), but there are limited studies on the frequency and importance of the common engineering activities that enable these competencies. Moreover, prior research has identified that engineering activities are likely gendered (Hatmaker, 2013).

PURPOSE

The goal of this research was to identify differences in the frequency and importance of engineering activities between graduate and experienced engineers. The secondary goal was to investigate if there is a difference in these activity measures by gender. The purpose of this research was to a) support engineering educators with an empirical understanding of practice, and b) to raise awareness of potential gendered engineering activities.

APPROACH

A cohort of 790 practicing engineers were surveyed on the frequency and importance of 85 common engineering activities. Participants were grouped by experience (0 to 4 years', and 5 or more years' experience) and by gender (woman/female and man/male). We normalised response data, then compared the distribution of ranks to test for differences in the frequency and importance of the activities by experience and gender groups.

ACTUAL OUTCOMES

Differentiated activities for graduate engineers related to seeking advice and interacting with materials and equipment. For experienced engineers, differentiated activities were associated with management. Differentiated activities for women/female engineers were associated with people-related activities, while physical activities were associated for males/men.

CONCLUSIONS

The observed differentiation by experience and gender confirms prior research. Further cross-sectional and longitudinal analyses will provide further insights into the determinants and outcomes associated with this activity segregation.

KEYWORDS

Engineering practice, work, competencies, attributes

Introduction

Engineering practice research on 'what engineers do' has typically studied competencies (Mazzurco et al., 2021); the knowledge, skills and attributes associated with the engineering profession. Such studies provide limited insights into the specific activities that engineers undertake in their work, which ultimately enable competencies.

Self-reported importance of different engineering competencies vary with experience (Passow & Passow, 2017, Pons, 2016); with deficiencies in competencies in business and communication often reported for graduate engineers (Male et al., 2010, Pons, 2016). It is not known, however, what engineering activities become more frequent and important at different career stages, to enable business and communication.

It is established that the engineering profession can be gendered (Hatmaker, 2013). Prior literature has identified that men prefer working with things and women prefer working with people (Lordan & Pischke, 2021; Su et al., 2009). These studies were not solely focussed on engineering practice, however gendered segregation of activities has been observed in engineering education contexts, but this segregation was associated with assignment of activities rather than preferences (Aeby et al., 2019; Meadows & Sekaquaptewa, 2011; Natishan et. al. 2000). Bairaktarova and Pilotte (2019) identified differences in work preferences by gender in both engineering students and professionals. Lordan and Pischke (2021) posit that such segregation could negatively impact career outcomes, such as pay gaps. The identification of engineering activities that are segregated (e.g. according to experience and gender) could lead to a better understanding of how engineering activities contribute to career outcomes.

The goal of this paper is to explore differences in the frequency and importance of common engineering activities, based on experience and gender. The purpose of this initial research is to a) support engineering educators with an empirical understanding of practice, and b) to raise awareness of potential gendered engineering activities.

Methodology

This paper leverages research from an international longitudinal study of engineering practice (the BeLongEng Project) described elsewhere (Crossin et. al., 2022). The ethics for this project was reviewed and approved by University of Canterbury's Human Research Ethics Committee (HREC Reference 2021/157), which was ratified to the Australian National Statement by the University of Technology Sydney (HREC Reference ETH23-8064). The ethics includes suppression of reporting of outcomes for a cell size of 5 or less.

The population of interest were people with engineering qualifications, who have either graduated from a tertiary institution, or who are immigrants, in Australia or New Zealand. Recruitment and data collection occurred between February and June 2022. Recruitment channels included advertising in engineering peak-body magazines, e-zines, social media, news articles and invitations emails sent to alumni of 24 tertiary institutions in Australia and New Zealand. A total of 889 participants were recruited. In summary, 72% of participants identified as man or male (n = 635), 27% as woman or female (n = 239), and 1% as non-binary (n = 11). The majority of participants resided in Australia (51%, n = 451) or New Zealand (39%, n = 39%). The majority of participants (588, 66%) have a Bachelor / Bachelor with Honours engineering degree. All engineering disciplines are represented in the sample, across multiple industries. Further details of recruitment and participants' demographics are reported in Crossin et al. (2022). Participants' data were de-identified using a unique identifier.

Participants were asked to rate the frequency and importance of a list of 85 common engineering activities. The list included all activities developed and reported by Crossin et al. (2023), except 'Marketing products, services or programs' which was excluded due to a coding error. This list of engineering activities was developed using a six-step procedure, which consolidated 1,206 engineering activities through multiple systematic literature searches, interviews and surveys (Crossin et al., 2023). Frequency and importance data were rated via 6 point Likert scales. Frequency response was 0 – Not relevant, 1 – Once per year or less, 2 – More than once per year, 3 – More than once per month, 4 – More than once per week, and 5 - Daily. Importance scores were 0 – Not relevant, 1 – Not at all important, 2 – Slightly important, 3 – Moderately important, 4 – Very important, and 5 – Extremely important. Importance scores of 0 were imputed when frequency scores were 0.

Participants could nominate their engineering discipline(s), or report that they do not practice as an engineer. Years of experience was calculated using the year of the survey (2022) less the graduation year of the highest engineering qualification. Of the 889 participants, 99 indicated that they did not practice engineering; these participants were excluded from this analysis, leaving 790 participants. These participants were grouped by experience; 1) 0 to 4 years' (herein termed graduate engineers), and 2) 5 or more years' experience (herein termed experienced engineers), and by gender: a) female or woman and b) male or man. Other gender groups were excluded due to participants being below the reporting threshold (n = 5). A summary of the participants in each group is reported in Table 1.

Table 1: Groups by sex/gender and experience level

Group	Female/Woman	Male/Man	All
Graduate	71	177	248
Experienced	146	396	542
All	217	573	790

Initial analyses showed that frequency and importance ratings for the activities were typically higher for the experienced engineers than for the graduates. The difference may be a reporting artefact or may be real. This outcome limited the ability to use the raw response data to identify differences between the groups. To account for this limitation, the ordinal frequency and importance ratings were transformed into rank orders, with ties managed by assigning mean ranks. Not all participants responded to all frequency and response questions, therefore, ranks were normalised (0 to 1), based on the rank order and the total number of responses. The strength of the relationship between frequency and importance was assessed using Pearson's correlation coefficient, *r*. The differences between the groups were then tested with the Mann-Whitney U test, which tests the rank sums of two sample groups. The null hypothesis (H_0) is that there is no difference in rank sums between the two groups. The alternative hypothesis (H_1) was that there is a difference in rank sums between the two groups. Statistical significance was set at $\alpha = .05$. All data were processed in IBM SPSS. Results that do not meet this significance threshold are not included in this paper. Outcomes from the analysis by experience and gender were cross-tabulated according to frequency and importance to identify differences in activities between groups.

Results

The results of the correlation analysis are reported in Table 1. Correlation coefficients range from 0.760 to 0.825, and showed a strong linear relationship between the perceived importance of activities and how often those activities were performed. The correlation coefficients for the females/women were consistently higher than for the males/men. The correlation coefficients for the graduate groups was consistently higher than for the experienced groups.

Table 1: Pearson correlation coefficients (*r*) for frequency and importance. ** indicates statistical significance at the .01 level (2-tailed).

Pearson's correlation coefficient, *r*	Female/Woman	Male/Man	All
Graduate	.825**	.785**	.797**
Experienced	.784**	.746**	.757**
All	.800**	.760**	.772**

We identified 5 and 45 activities where there was a statistically significant difference in the frequencies, skewed towards the graduates and experienced engineers, respectively. Test statistics for the top 5 more frequent activities by experience are reported in Table 2. We identified 4 and 43 activities that were statistically more important for graduate and experienced engineers, respectively. Table 3 shows test statistics for the top 5 more important activities.

For the frequency of activities by gender, we identified 7 and 33 activities that were statistically more frequent for females/women and males/men, respectively. Test statistics for the top 5 statistically more frequent activities for the gender groups are reported in Table 4. We identified 6 and 31 activities that were statistically more important for females/women and males/men, respectively. Test statistics for the top 5 statistically more important activities for the gender groups are provided in Table 5.

A cross-tabulation of the statistically different activities by gender and experience level are reported in Table 6. Differences in frequency and importance are indicated by (F) and (I), respectively. In summary, there was one activity that was statistically more frequent/important, for female/women graduates, 4 for experienced females/women, 3 for graduate males/men, and 16 for experienced males/men.

Table 2. Statistical measures for the top 5 most frequent activities by experience (graduates and experienced engineers).

Group	Activity	Mean ranks				U	Sig. 2-tail
		Graduates	n	Experienced	n		
Graduates	1. Seeking advice from others on own career	461.14	238	350.09	530	44831	<.001
	2. Seeking advice from others on technical matters	434.58	238	362.01	530	51151	<.001
	3. Preparing materials or equipment for processing, testing or use	414.82	238	370.13	529	55615	.005
	4. Resolving computer problems	411.45	238	371.65	529	56418	.02
	5. Inspecting physical systems, products, equipment or structures	409.97	238	373.06	529	57009	.032
Experienced	1. Managing human resources (e.g. recruiting staff, managing staff)	283.19	238	430.63	531	38958	<.001
	2. Advising others on business or operational matters	284.2	238	430.18	531	39198	<.001
	3. Directing operations, activities or procedures	296.69	238	424.58	531	42172	<.001
	4. Managing resourcing of activities	297.54	238	424.2	531	42373	<.001
	5. Advising others on technical matters	299.46	238	423.34	531	42832	<.001

Table 3. Statistical measures for the top 5 most important activities by experience (graduates and experienced engineers).

Group	Activity	Mean ranks				U	Sig. 2-tail
		Graduates	n	Experienced	n		
Graduates	1. Seeking advice from others on own career	455.19	238	351.19	528	185426	<.001
	2. Preparing materials or equipment for processing, testing or use	416.09	238	368.81	528	194733	.003
	3. Seeking advice from others on educational or vocational matters	411.99	238	370.66	528	195707	.016
	4. Seeking advice from others on technical matters	407.52	238	372.67	528	196772	.038
Experienced	1. Managing human resources (e.g. recruiting staff, managing staff)	281.34	238	429.55	528	66958	<.001
	2. Directing operations, activities or procedures	292.69	238	424.43	528	69661	<.001
	3. Advising others on business or operational matters	297.46	238	422.28	528	70797	<.001
	4. Managing budgets or finances	299.83	238	421.22	528	71359	<.001
	5. Assessing the capabilities, needs, or performance of others	300.71	238	420.82	528	71568	<.001

Table 4. Statistical measures for the top 5 most frequent activities by gender.

Group	Activity	Mean ranks				U	Sig. 2-tail
		Man / male	n	Woman / female	n		
Woman / female	1. Seeking advice from others on own career	365.73	558	435.96	211	48115.5	<.001
	2. Seeking advice from others on environmental or sustainability matters	367.17	558	432.16	211	48919	<.001
	3. Conferring with clients to determine needs, rules or specifications	370.81	558	424.17	212	50950	.003
	4. Conversing socially or informally with others	371.77	558	421.65	212	51484.5	.002
	5. Coordinating and negotiating with colleagues to resolve problems	372.75	557	417.17	212	52221.5	.01
Maan / male	1. Diagnosing system or equipment problems	416.69	557	299.53	211	40834.5	<.001
	2. Maintaining systems, tools, equipment or structures	416.32	557	300.5	211	41040.5	<.001
	3. Operating systems, tools, or equipment	412.11	557	311.6	211	43382.5	<.001
	4. Resolving computer problems	410.54	557	315.75	211	44257	<.001
	5. Preparing materials or equipment for processing, testing or use	408.57	557	320.95	211	45354.5	<.001

Table 5. Statistical measures for the top 5 most important activities by gender.

Group	Activity	Mean ranks				U	Sig. 2-tail
		Man / male	n	Woman / female	n		
Woman / female	1. Seeking advice from others on environmental or sustainability matters	362.38	556	440.98	211	46636	<.001
	2. Conversing socially or informally with others	371.9	556	417.55	212	51929.5	.01
	3. Seeking advice from others on own career	371.89	556	415.92	211	51923.5	.014
	4. Coordinating and negotiating with colleagues to resolve problems	371.93	555	415.6	212	52131.5	.011
	5. Conferring with clients to determine needs, rules or specifications	373.94	556	412.19	212	53066	.027
Maan / male	1. Maintaining systems, tools, equipment or structures	413.83	556	305.4	211	42072.5	<.001
	2. Diagnosing system or equipment problems	413.7	556	305.73	211	42144	<.001
	3. Operating systems, tools, or equipment	410.65	556	313.77	211	43839.5	<.001
	4. Installing, implementing or commissioning systems, equipment or structures	409.31	556	317.31	211	44586.5	<.001
	5. Preparing materials or equipment for processing, testing or use	408.55	556	319.3	211	45006.5	<.001

Table 6: Cross-tabulation of statistically significant differences in activities by gender and experience level for frequency (F) and importance (I).

Frequency	Female/Woman	Male/Man
Graduate	• Seeking advice from others on own career (I)	• Inspecting physical systems, products, equipment or structures (F) • Preparing materials or equipment for processing, testing or use (F,I) • Resolving computer problems (F)
Experienced	• Advising others on environmental or sustainability matters (F) • Conferring with clients to determine needs, rules or specifications (F, I) • Coordinating and negotiating with colleagues to resolve problems (I) • Performing administrative or clerical activities (e.g. writing and responding to emails, scanning documents) (F)	• Advising others on business or operational matters (F,I) • Advising others on educational or vocational matters (F,I) • Advising others on technical matters (F,I) • Determining values or prices of goods or services (F,I) • Directing operations, activities or procedures (F,I) • Estimating costs (F,I) • Gathering information about organisational behaviour, processes, or performance (F) • Implementing procedures, processes or systems (F) • Investigating criminal, ethical or legal matters (F,I) • Investigating organisational or operational problems (I) • Managing budgets or finances (F,I) • Managing human resources (e.g. recruiting staff, managing staff) (F,I) • Negotiating contracts or agreements (F) • Presenting information in legal proceedings (I) • Resolving personnel or operational problems (I) • Seeking advice from others on business or operational matters (F)

Discussion

The strong correlation between activity frequency and importance (r = .797) suggests that the more often someone undertakes an activity, the more important they perceive this to be, or vice versa. The higher correlation coefficient for females/women (.800) than for males/men (.760) indicates that females/women generally place a higher level of importance on their work activities, relative to men/males. This finding is consistent with prior research which reports that women care more than men about their work (Lordan and Pischke, 2021). The differences in the correlation coefficient between the graduates and experienced engineers requires further analysis, and may be associated with the more experienced engineers undertaking activities that they view as less important more frequently, relative to graduates.

The top 5 differentiated graduate activities (Tables 2 and 3) relate to interacting with equipment and objects, and seeking advice. The advice seeking behaviour of the graduates is not surprising given their career stage. For the experienced engineers, the differentiated activities relate to guiding and directing activities, and providing advice to others. These experienced engineers' activities are best described as those associated with management. That such management activities are more important is consistent with research from Pons (2015), who found that less experienced engineers are less involved in engineering management and that this involvement increases with experience.

The top 5 differentiated activities for the female/women engineers (Table 4 and 5) are associated with people-related activities, such as advice-seeking and social interaction activities, while for the men/males, the activities are best described as physical interaction with materials and equipment. When expanded to beyond the top 5 activities (Table 6), clerical activities are also differentiated towards females/women. This segregation of activities by gender is consistent with prior research (Lordan & Pischke, 2021; Su et al., 2009). The determinants of these results warrant further investigation; these could be a result of preference (as described by Lordan and colleagues), and/or stereotyped assignment of activities (e.g. by the engineers' supervisors or colleagues), as has been observed in engineering education environments. The engineering profession has been described as a socio-technical enterprise (Faulkner, 2007; Styhre et al. 2012; Trevelyan 2010), with collaboration activities accounting for a significant proportion of engineering work. Lordan and Pischke (2021) suggest that occupations which require social interactions are at direct conflict with workplace flexibility required by women (e.g. due to family commitments), and this conflict could be a limiting factor for career progression and pay. In the future, by following the career progression of these engineers, we will be able to assess the impact of the segregation of activities on career outcomes. There was a skew in the engineering management activities towards males/men at the experienced level, Table 6. We have not examined the determinants for this, but factors could include a skew in our sample towards male/men in management roles, which could be caused by a differentiation in career progression, which we can assess following further surveys. The observed differentiation in engineering activities also raises questions about experiences at the tertiary level which could pre-empt activity segregation in the workplace. Whilst some activity segregation has been observed in engineering education, the resolution of this data is limited. Regardless of when these differences emerge, engineering educators need to be aware of stereotyped engineering activities, and to understand the impacts this has on their students and their outcomes.

This research has limitations: all data were self-reported, which may introduce bias. The calculated rank order used may not reflect the actual ranking, had participants been asked to sort activities by order. A proxy measure was used for calculating years of experience, we will employ a better measure in future surveys. Activities that were beyond the statistical significance level ($\alpha = .05$) were not analysed, but these activities could be at the 'core of the profession', irrespective of experience level. The observed differences could be attributable to factors not considered in this preliminary analysis such as occupational context (e.g. occupation, industry, company size, discipline), labour force and personal factors (e.g. hours of work, family commitments), and personality traits. We intend to explore these variables in future work. Furthermore, qualitative studies could yield a deeper understanding on the perception of engineering activities, and the gendered nature of these, in the workplace.

In conclusion, our initial analyses identified differentiation of activities towards management activities for experienced engineers, people-related activities for female/women engineers, and physical activities for male/men engineers. Further cross-sectional and longitudinal analyses will provide insights into determinants and outcomes associated with this segregation.

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