

Do female and male engineers rate different competencies as important?

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***Abstract:** A study was conducted to identify and select the competencies needed by engineers. Competencies were identified from a broad range of literature and refined to a list of 64 competencies which might be required by engineers. Three hundred established engineers, that is, engineers with five to twenty years of experience since graduating from a degree of four years or more, were surveyed on their work and asked to rate each of the 64 competencies for importance to their work. There were unexpected significant differences between the competency ratings made by men and women. These are partially explained by a difference in the work performed by the men and women who participated. The gender effects have implications for the measurement of competencies.*

Introduction

This paper reports results of a gender-related study which forms part of the overarching Competencies of Engineering Graduates (CEG) Project. The CEG Project will develop a survey instrument to profile the competencies of engineering graduates using ratings made by workplace supervisors. The instrument is being designed to be suitable for use by Australian universities to close the loop in the ongoing alignment of undergraduate engineering programs with industry requirements (Male & Chapman, 2005). This paper reports gender-related results from the third project phase to identify and select the competencies needed by established engineers (i.e., those with 5-20 years of experience).

The CEG Project research plan involves the following:

1. Review of literature to identify competencies that may be required by engineers, and refinement of these into a list.
2. Panel session to complement outcomes of the literature review.
3. Survey of established engineers to select the competencies required by established engineers, and the extent to which these competencies are general or specific to clusters of jobs.
4. Survey of senior engineers to validate outcomes of the survey of established engineers.
5. Analysis and panel session to identify competencies in graduates that indicate aptitude to develop the competencies required by established engineers.
6. Iterative development and testing of survey instrument which will measure competencies of graduates.

This paper reports gender effects in the results of the third stage: the survey of established engineers. This survey asked engineers about their work and, with respect to each of 64 competencies, asked “How important is each of the following to doing your job well?” It was hypothesised that some competencies would be rated as more important by women than men.

The first hypothesis was that women would give higher importance ratings to the competencies “Being concerned for the welfare of the local, national and global communities”, “Acting with exemplary ethical standards”, and “Evaluating / advocating for / improving sustainability and the environmental impact (local/global) of engineering solutions”. This hypothesis was based on the following two indications. First, engineering courses with a focus on helping people or the environment, for example environmental engineering and biomedical engineering, often have higher female participation rates than other engineering courses. Second, recommendations for ways of teaching engineering to help engage female students include demonstration of relevance to real-life examples of applications with a focus on sustainability and social benefits, moving away from the historical focus on abstract technology (Frize, 2002; Roberts & Lewis, 1996).

The second hypothesis was that women would give more importance to “Using 3 dimensional spatial perception or visualisation”. This is a competency that has been found to be related to success in engineering studies and on average is less well developed in women than men (Sorby & Baartmans, 2000).

The next section of this paper describes the research method. The Results reveal significant and unexpected differences in the competency ratings made by men and women. The Discussion presents an interpretation of the pattern of results that emerged, and implications.

Method

Generic competencies that might be required by engineers were identified in a broad range of literature including the following fields: engineering education, higher education, competencies in education, engineering management, and human resource management. While maintaining comprehensiveness, the identified competencies were reduced to a list sufficiently short to be rated in a survey. Despite survey methodology advising against the practice, composite items were formed in order to improve discrimination between items, and limit the number of items. The refined list included 64 competencies.

The CEG Project used an adapted version of the job analysis approach (McCormick, 1979; Schippmann, 1999; Shippmann, Ash, Carr, Hesketh, & al, 2000) to identify and select required competencies. The main feature of job analysis adopted here was the focus on competencies for the job (tasks and work context), rather than the alternative focus on behaviours of high level performers, which is central to competency modeling (McClelland, 1998; Spencer & Spencer, 1993). The CEG Project differs from usual job analysis applications in the large range of jobs being considered. With this large range of jobs, it is not practical to use the detailed face-to-face techniques recommended in job analysis. Instead, a survey of established engineers was used. The questionnaire followed recommendations for a Practise Analysis Questionnaire (Raymond, 2005), asking engineers about their work and the competencies they consider important to their work. The competencies were rated in response to the question “How important is each of the following to doing your job well?” on a scale from 1 to 5 (1 = “Not needed”; 5 = “Critical”). The questionnaire included the following.

1. 2 questions on graduate attributes
2. 16 questions on demographics
3. 38 questions on the participant’s work context
4. a task inventory with 12 areas with up to 14 tasks per area from which to select, based on the Stage 2 Competencies (IEAust, 1999)
5. 64 competency items to be rated

The questionnaire was developed with advice from the CEG Project Advisory Committee and tested by engineers. Several of the demographic questions, including one on key responsibilities, were adapted with permission, from a well-established survey (APESMA & EA, 2006). Volunteer participants were recruited through the West Australian (WA) newsletter of Engineers Australia (EA), letters to the University of Western Australia (UWA) engineering graduates, and contacts in local engineering organizations including members of the UWA engineering Industry Advisory Board and Panels, the UWA Engineering Foundation, and the WA and National Women in Engineering Committees of EA.

Demographics of the sample

Table 1 shows that most of the engineers who responded to the survey worked in Western Australia and had studied engineering in Australia. The percentage of women in the sample was approximately double that within the engineering profession in Australia. This was probably due to the support from members of Women in Engineering, EA. The over-representation of women overcame the common problem of insufficient female participants for the observation of gender effects.

Table 1: Demographics of participants in the survey of established engineers

Demographic Variable and Values	Number of Responses	Responses as % of Participants
<i>Location where participant worked</i>		
Western Australia	226	75.3
Australia and outside Western Australia	38	12.7
Outside Australia	36	12.0
<i>Country where participant was awarded undergraduate engineering qualification</i>		
Australia	271	90.3
Not Australia	29	9.7
<i>Engineering discipline in which participant was qualified</i>		
Civil/ Structural/ Environmental/ Geotechnical/ Mining	96	32.0
Computer Systems/ Electrical/ Electronic/ Communications/ Software/ IT	92	30.7
Mechanical/ Aeronautical/ Materials/ Mechatronics/ Metallurgical/ Naval architecture/ Chemical	111	37.0
<i>Gender</i>		
Female	55	18.3
Male	245	81.7

Of the women 27.2%, and of the men 52.2%, were aged over 34 years. Of the women 62.3%, and of the men 47.9%, were not caring for dependants. This is consistent with the over-representation of childless women in the results of the *Professional Women's Survey Report* (APESMA, 2007).

Results

Thirty missing competency importance ratings were replaced with the median rating for the given competency. Of the 64 competencies, five were rated significantly differently by men and women ($p < 0.05$, see Table 2). The competency ratings for these are shown in Figures 1 to 5.

The tasks were grouped into the same groups as are the Stage 2 Competencies on which the tasks were based. Within each group the tasks selected by each engineer as tasks that engineer performs, were coded as follows: 0 = Engineer does no tasks in the group; 1 = Engineer does at least one but fewer than half of the tasks in the group; 2 = Engineer does at least half of the tasks in the group. The only group of tasks with a significant difference ($p < 0.05$) between the

percentages of men and women performing the tasks was “Technical sales/promotion” ($\chi^2(2) = 7.37, p = 0.025$) (Figure 6).

Table 2. Significances of differences between competency ratings made by men and women

Competency	$\chi^2(4)$	Sig.
Interacting with people in diverse disciplines/professions/trades	13.2	.010
Managing own communications (e.g. keeping up to date and complete, following up)	$\chi^2(3) = 9.15$.027
Engaging in entrepreneurship / innovation / identifying and commercialising opportunities	11.2	.025
Making decisions within time and knowledge constraints	10.2	.037
Supervising work/people	11.7	.020

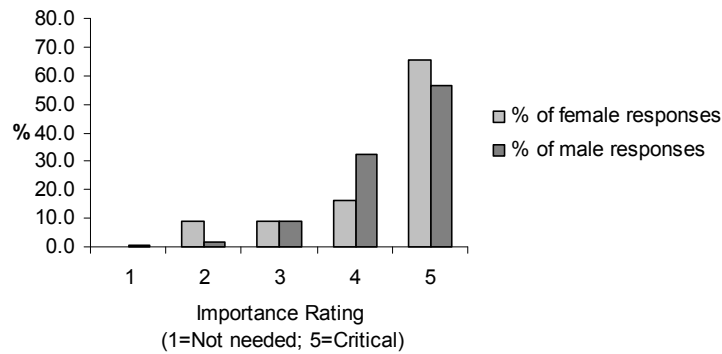


Figure 1: Importance ratings for “Interacting with people in diverse disciplines/professions/trades” by gender

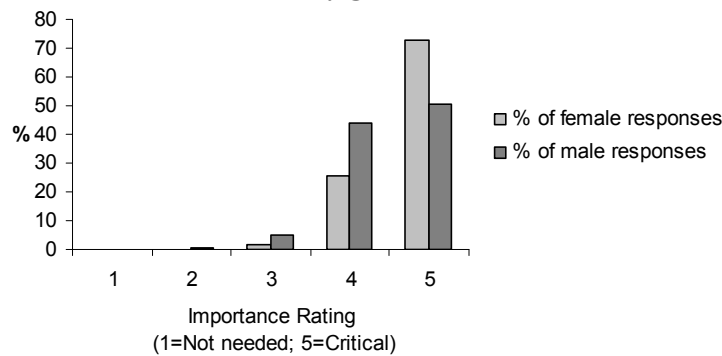


Figure 2: Importance ratings for “Managing own communications (e.g. keeping up to date and complete, following up)” by gender

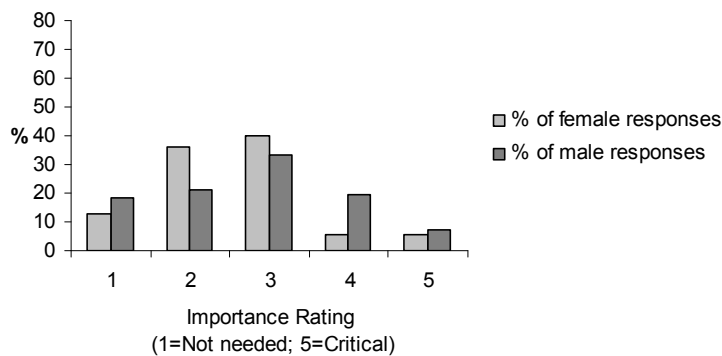


Figure 3: Importance ratings for “Engaging in entrepreneurship / innovation / identifying and commercialising opportunities” by gender

The competencies which had the most significant differences, between ratings of importance made by engineers performing and not performing technical sales/promotion tasks, were “Evaluating marketing issues / applying a customer focus” ($\chi^2(8) = 68.0, p = 1E-11$) and “Engaging in entrepreneurship/innovation and commercialising opportunities” ($\chi^2(8) = 49.0, p = 6E-8$).

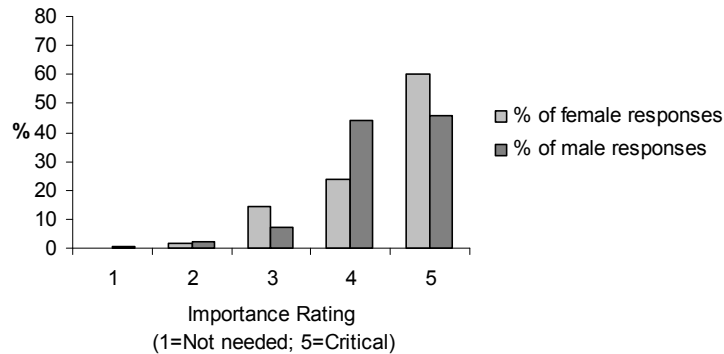


Figure 4: Importance ratings for “Making decisions within time and knowledge constraints” by gender

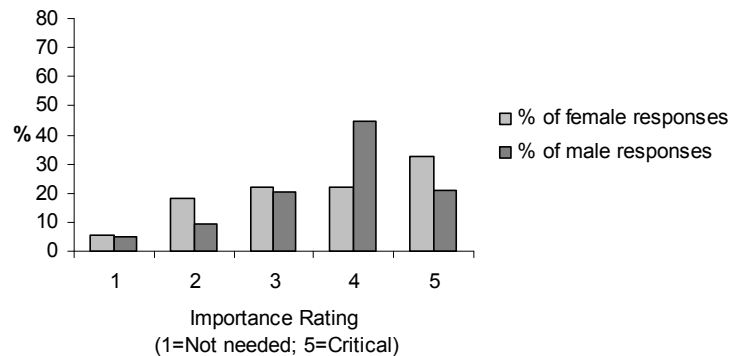


Figure 5: Importance ratings for “Supervising work/people” by gender

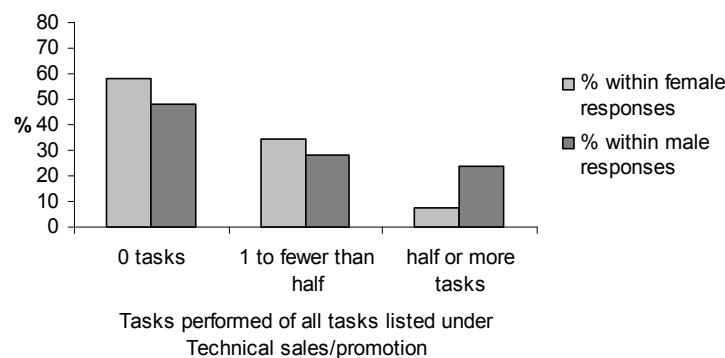


Figure 6. “Technical sales/promotion” tasks performed by respondents as a fraction of all tasks listed under “Technical sales/promotion” by gender

Of the key responsibilities, only “Construction supervision” was performed by significantly different percentages of men and women ($\chi^2(1) = 6.63, p = 0.010$) (Figure 7). Age did not have a significant effect on whether construction supervision was a key responsibility ($\chi^2(3) = 4.76, p = 0.190$). Considering a related characteristic of the engineers’ work, 29.0% of all the male participants and only 10.9% of all the

female participants directly supervised more than four people, and at every age the percentage was higher for men than women.

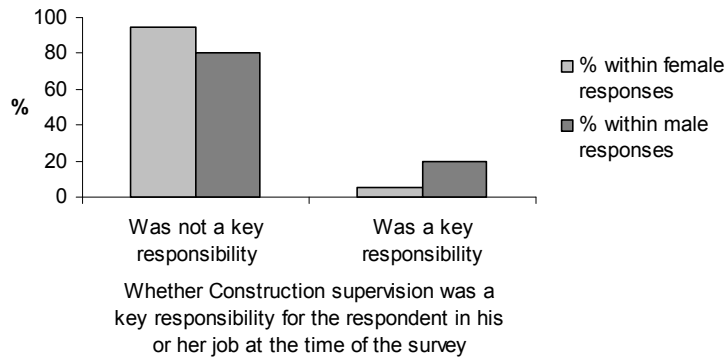


Figure 7. Whether “Construction supervision” was a key responsibility, by gender

Not surprisingly, the competency which had the most significant difference, between ratings of importance made by engineers performing and not performing construction supervision as a key responsibility, was “Supervising work/people” ($\chi^2(4) = 21.7, p = 0.0002$).

Discussion

Neither of the hypotheses about gender differences in the competency ratings was upheld. Referring to the first hypothesis, although the choices made by female engineering students have suggested that they appreciate opportunities to help people and the environment, the results of this survey indicated that their jobs do not need competencies related to concern for ethics, or the community and environment, significantly more or less than other jobs.

Referring to the second hypothesis, although other studies have found that first year female engineering students on average have worse spatial visualisation skills than first year male engineering students, the results of this survey did not demonstrate a significant gender difference in the ratings of importance of spatial visualisation by established engineers. A suggested explanation follows. Fowler *et al.* (2001) revealed that despite a broad range of learning styles amongst first year engineering students, the learning styles of final year engineering students were relatively homogeneous and matched those of the lecturers. If these results extrapolate to spatial visualisation skills, then students without spatial visualisation skills are likely to be filtered out of engineering courses, or develop spatial visualisation skills during their engineering courses. In either case, the possible difference between the average spatial visualisation skills of women and men entering engineering courses is unlikely to persist in practicing engineers. This argument may explain the lack of gender effect in the importance ratings of spatial visualisation skills to the jobs of the established engineers.

Gender differences were present in the ratings of importance for five competencies. Two of these competencies were related to differences in the work performed by the engineers. “Supervising work/people” was rated 1, 2 or 3 by higher percentages of women than men. This was consistent with construction supervision being a key responsibility for a higher percentage of male than female participants. The result was also consistent with the higher percentage of women than men, directly supervising more than four people. The result is consistent with the persistent evidence in the results of many studies including the recent APESMA *Women’s Survey Report* (2007), that women are under-represented in high responsibility levels.

Similarly, “Engaging in entrepreneurship / innovation / identifying and commercialising opportunities” was given an importance rating of 4 or 5 by higher percentages of men than women. This was probably because higher percentages of men than women performed tasks listed under technical sales/promotion.

Surprisingly, this did not also cause women to rate “Evaluating marketing issues / applying a customer focus” as less important to their work than men rated the competency.

The remaining three competencies rated significantly differently by women and men are not easily explained. Perhaps more women than men rated “Interacting with people in diverse disciplines/professions/trades” as critical, because the necessity for this competency is more visible to women than men due to the dominance of men in engineering workplaces. A higher percentage of women than men rated “Managing your own communications” and “Making decisions within time and knowledge constraints” as critical. Interestingly, “Making decisions within time and knowledge constraints” was inspired by a leadership presentation by Hammer (Male, 2004), the only woman in the history of the Australian Defence Force to have achieved Two Star rank.

As suggested by the literature, any expectation that as a minority group within engineering, women might sympathise more than men with the need for diversity, and therefore might give higher ratings of importance to “Actively promoting diversity within your organization” and “Interacting with people from diverse cultures / backgrounds”, was unfounded. Similarly the results revealed no significant gender difference in the importance of “Understanding social and political dimensions of workplaces”. This competency was included in the survey in response to an Australian study of engineering workplace culture and women in engineering (Gill, Mills, Sharp, & Franzway, 2005). The study recommends that engineering education programs should include education about social and political factors in engineering workplaces. The lack of gender difference in the ratings of importance of these competencies, is consistent with the findings of qualitative studies, that a common strategy of women in male-dominated organizations is to condone the masculine culture (Jolly, 1996), and that both men and women adopt the dominant culture in workplaces (Acker, 1990; Fletcher, 1999). Such findings suggest that women would not see any more importance than men to promote diversity or understand the social dimensions of workplaces.

Implications are that, despite the gender differences, communication, decision-making, and interaction across disciplines, professions and trades are important to both women and men. These should be developed in engineering courses, and measured in graduates for ongoing improvement of courses. In contrast, supervision and entrepreneurship are not important to some jobs. These competencies should be developed in engineering courses. However, the planned method of evaluating courses using ratings of graduates made by their workplace supervisors, will need to avoid measurement of supervision skills and entrepreneurship, in jobs where these are not important.

The gender effects in the importance given by engineers to some competencies, may affect the way supervisors with different genders will rate the performance of graduates. When the final survey instrument to rate graduates is developed, it will be necessary to confirm inter-rater reliability for items related to the five identified competencies in this paper.

Conclusions

Higher percentages of women than men gave supervision and entrepreneurship low ratings of importance to their work, and this was consistent with their key responsibilities and tasks. Higher percentages of women than men considered the following competencies to be critical to their work: Interacting across disciplines/professions/trades, Making decisions within time and knowledge constraints, and Managing their own communications. Awareness of these differences is relevant to comparison of judgements engineers make about the performance of other engineers. Women and men did not show significant differences in their ratings of the importance of competencies related to the community, environment, sustainability, ethics, or diversity.

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