Perceptions of competency deficiencies in engineering graduates *

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SUMMARY: Engineering education in Australia continues to evolve. This study asks: “Are current changes to engineering education consistent with competence deficiencies in engineering graduates perceived by engineers?” The method is different from previous international and Australian studies, and the findings are consistent with the results of previous studies. Practical engineering competencies and engineering business competencies featured strongly. The findings support continuation of current trends in the evolution of engineering education: cultural change, broadening of curricula, and introduction of non-traditional pedagogies, assessments and learning environments.

1 INTRODUCTION

Engineering education in Australia continues to change (Ferguson, 2006b). Course structures, the breadth of curricula, teaching methods and learning environments are evolving. The University of Melbourne has, and the University of Western Australia (UWA) soon will, replace four-year bachelor of engineering courses with three-year bachelor courses followed by two-year masters in engineering. Project- and problem-based learning, teamwork and peer assessment are becoming increasingly popular. As required for program accreditation, non-technical components, including ethics, lifelong learning, teamwork and communication skills, are now part of engineering curricula. This study is motivated by the view that engineers’ perceptions of deficiencies of past and recent graduates should be considered when engineering education is changed. The study asks: “Are current changes to engineering education consistent with competency deficiencies in engineering graduates perceived by engineers?”

This study is part of a larger one on generic competencies required by engineers graduating in Australia. This study uses qualitative questions from a survey from which quantitative sections are reported elsewhere (Male et al, 2009b).

International studies have identified competency deficiencies in engineering graduates as perceived by various stakeholders. Competency deficiencies in graduates have also been referred to as “skills gaps”, referring to the difference between the level of competence required for employment or alternatively the importance of competencies for employment and the level of competence of graduates. Large-sample surveys have measured competency deficiencies in engineering graduates based on perceptions of engineers or employers.

In a European and US survey, 1372 engineers with bachelor, master or diploma degrees rated engineering competencies and general professional competencies on importance and graduate performance (Bodmer et al, 2002). The largest indicated gaps were in communication, leadership and social skills.

In an international survey of chemical engineers from 63 countries, during their first five years of employment, participants ranked skills and abilities with respect to the quality of their education, and also the relevance to their work (WCEC, 2004). If the average rank for work was lower than that for education, the skill or ability was identified as being in deficit. On average across all 1091 engineers with bachelor degrees, the skill or ability rated as having the highest identified deficit was business approach. Ratings for quality management methods, project...
management methods, management skills, effective communication and leadership also indicated relatively high deficits.

As demonstrated by the variation across countries that can arise in survey results (for example, WCEC, 2004), rather than making the assumption that findings from overseas generalise to Australia, it is prudent to also obtain Australian data.

Communication is the competency that features most frequently as a deficiency in Australian surveys. In a survey by Bons & McLay (2003), among 98 participants, 45 RMIT engineering graduates from 1989 to 1997 with at least five years of experience ranked 27 graduate attributes on importance and also preparation. The graduates’ responses indicated the largest gaps for accountability, teamwork, communication, interpersonal skills, and skills to advocate and influence. In a survey by Ashman et al (2008), among other participants, 40 fourth-year undergraduate chemical engineering students and six managers rated graduate attributes on importance and competence. Mean importance and competence ratings for each sample group were compared. Managers’ and undergraduate students’ ratings indicated a deficiency in communication, and managers’ ratings indicated a slight deficiency in graduates’ business skills. Nair et al (2009) investigated gaps between education and workplace needs of engineers using a survey of 109 engineering-related employers. The largest identified competency gaps were in the areas of communication, problem solving, time-management, teamwork, application of knowledge in the workplace, ability to cope with stress, and capacity to learn.

Emotional intelligence was judged by participants’ ratings to have the largest gap between importance and performance in an Australian survey conducted by Scott & Yates (2002). Survey participants were 20 students and 10 supervisors. Items in the survey were developed using interviews.

A business approach was found to be the skill with the highest deficit based on responses from 70 chemical engineers from Australia with a highest qualification at the bachelor level in the international survey of chemical engineers cited above. Ratings from the engineers from Australia indicated higher deficits than the deficits indicated by average ratings from bachelor participants across all countries (WCEC, 2004). However, the skills and abilities with the highest deficits were consistent with the international results. A business approach, as the skill which was rated with the highest deficit, was followed by quality management methods, project management methods, management skills, effective communication and leadership.

Additionally, reviews of engineering education in Australia have invited industry views. At the time when many of the eldest participants in the current study were undergraduate students, the Williams review received comments noting a lack of realistic problem solving in the curriculum, and poor written and oral communication skills of graduates (Williams, 1988a). Based on engineering courses in 1986, 514 engineering employers rated preferred course content (Williams, 1988b). Among six listed content areas, those for which the highest numbers of respondents would have preferred more content were computing (63% of respondents), engineering professional skills (49%) and humanities and other professional elements (38%). Mean ratings of perceived adequacy of course emphasis identified perceived inadequacy in involvement with non-engineering disciplines in project work, industrial relations/management of people, and the management of costs and resources. The report on the impact of the Williams review noted increased emphasis on the “human element in technology” and communications skills (Caldwell et al, 1994, pp. 9).

For the Australian review of engineering education titled Changing the Culture: Engineering Education into the Future (Johnson, 1996b), 51 structured interviews of engineers and engineering employers, and a large qualitative survey (n = 300), were conducted. Identified graduate competency deficiencies were in interpersonal skills; communication skills; understanding of the broad context of decisions; creativity, innovation, design and problem-solving skills; and teamwork. The requirement for diverse graduate competency profiles was also raised.

During the most recent review of engineering education in Australia (Johnston et al, 2008), engineers’ views on engineering education were collected from focus group discussions, consultations and submissions. The report refers to industry comments on poor written communication skills; fundamental science and engineering knowledge; practical experience; familiarity with industry standards, codes and financial constraints; and engineering-specific project management skills. However, graduates’ oral communication skills, teamwork and use of software tools were perceived to have improved, which suggests a swing in industry’s opinion since the Williams review.

This study contributes Australian data on competency deficiencies of engineering graduates, collected using a research method with a unique combination of features, making it different from and complementary to previous methods.

2 METHOD

This study used open questions at the beginning of a questionnaire in a survey with 300 participants. The method is unique in its combination of three unusual features. First, it asked open questions independently of a large sample. Previously in Australia, only the Johnson (1996b) review has used a
qualitative survey to study competency deficiencies. Second, the survey questions asked directly about competency deficiencies, rather than calculating them by comparing ratings of competencies on two other dimensions. Third, participants were asked about both recent and less recent graduates, thereby revealing perceived changes in graduate competencies. These features of this study’s method are described below.

The previous studies discussed above used surveys or mixed methods, combining interviews and/or focus groups involving relatively small samples; and surveys with larger samples. Competency deficiencies have been identified using ratings or rankings of items in a list. The qualitative components of previous studies have benefited from depth of investigation, and the ability to ask open questions and thereby collect new ideas. The surveys have benefited from larger samples. However, with the exception of the Johnson review, open questions and collecting qualitative data have been avoided in large-sample surveys, because the analysis can be time-consuming. Consequently, generalisable results have been collected from the large-sample surveys, but fresh ideas have been gleaned only from small samples. In this study, brief responses were requested and therefore depth of understanding was not explored. However, this was traded for the opportunity to pragmatically collect and analyse, from a large sample, responses, which were not influenced by previous questions or guided by a finite number of response options. The advantage of a large number of participants is improved generalisability of results.

This study also differed from previous studies, except the reviews, by taking an approach that directly collected perceptions of competency deficiencies, rather than indirectly identifying competency gaps among a list of competencies by using mean ratings of importance and competence. Using the open questions at the beginning of the questionnaire, it was possible to collect, from a large number of engineers, the competency deficiencies that they perceived as important.

Finally, this study asked one sample of participants about both the participants’ graduate competencies and recent graduate competencies. This provided the opportunity to reveal perceived progress in engineering education.

3 SURVEY DESIGN

A survey was implemented online (Male et al, 2009a). Participants were engineers with five to 20 years of experience since completing an engineering degree of at least four years. These engineers were expected to have an understanding of the competency requirements of engineers and not yet to have mostly moved into largely different stages of their careers.

Letters invited participation from 2542 graduates who completed bachelor of engineering degrees at UWA from 1985 to 2001. Calls for participants were also distributed through professional engineering associations and members of industry advisory groups within the engineering faculty. Three hundred usable responses were received.

The first two questions in the questionnaire, including their online page heading, were:

Section I of V: Graduate Attributes (2 brief questions)
1. Is there a skill, attribute or area of knowledge that you would have liked to gain from your undergraduate engineering studies and did not? If “Yes”, please specify.
2. Is there a skill, attribute or area of knowledge that you have observed to be lacking in engineering graduates who have completed their degrees within the last 3 years? If “Yes”, please specify.

These questions therefore asked the engineers to reflect on competency deficiencies experienced as graduates, and then competency deficiencies perceived in recent graduates. It was expected that differences between the two questions would be affected by the differences between self assessment and assessment of others, changes in the work of engineering graduates, and changes in engineering education between that experienced by participants and that experienced by recent graduates.

Sensitive, threatening and leading questions were avoided. As recommended by Foddy (1993), the two questions were designed to be clear and simple, with abstract terms avoided where possible. However, Foddy also emphasised the importance of clearly defining the nature of the information required and ensuring that the meaning of individual words is not ambiguous. Multiple terms referring to competencies and attributes have been used with different meanings, even within the same context (Barrie, 2006; OECD, 2002). The use of the three terms “skill, attribute or area of knowledge” in the questions was designed to avoid confusion, and to avoid concern among participants about details between different related terminology and concepts.

To collect fresh responses, the questions were open-response, as are more often recommended for interviews than surveys. The questions allowed “yes” or “no” responses. Such questions allow participants to answer briefly and are therefore not recommended for interviews (Merriam, 2009). However, the response rate for surveys can be damaged by forcing text responses. The selected wording also ensured that participants were not encouraged to identify a competency gap if they did not perceive one.

The second question narrowed the focus to engineering graduates “who have completed their degrees within the last three years”. Although this
increased the length of the question, it was stipulated to narrow the focus of the question sufficiently to collect the required responses and allow responses to be compared, as Fodder reminded is essential.

Testing is recommended to improve reliability of open-response questions (Silverman, 2010). Reliable understanding of the questions was evident in responses received from seven engineers, with appropriate experience, who tested the online questionnaire.

4 RESULTS AND ANALYSIS

4.1 Demographics

Respondents’ demographic data demonstrate a diverse sample. Participants completed their first engineering degrees before 2002 (figure 1). Some of the demographic questions were adapted from a survey by the Association of Professional Engineers, Scientists and Managers, Australia (APESMA) and Engineers Australia (APESMA & Engineers Australia, 2005). Most participants worked mainly in Western Australia (WA) (table 1) and the industries represented were similar to those of WA responses in a 2007 APESMA/Engineers Australia survey (table 2 in the Appendix). Key responsibilities were similar to those selected by APESMA/Engineers Australia survey participants across Australia. Management was the key responsibility with the highest representation. Results can be generalised across WA and Queensland, which has similar industries. The over-representation of respondents from WA and from one university is a limitation. However, the similarity of key responsibilities with those across Australia supports the feasibility of generalisation across Australia.

4.2 Analysis of responses to the open questions

4.2.1 Units of data

Initially, units of data were identified in the responses to the two questions. These were the shortest strings of text that made sense and stood alone without leaving remaining adjacent text that alone was meaningless. These units were not removed from the question responses. Instead, units of data were colour-coded and the responses were kept intact to maintain the possibility of gleaning an improved understanding of the meaning intended by a respondent.

4.2.2 Identification of themes

A list of conceptual themes was developed iteratively, to group units of data that indicated similar competency deficiencies. The themes all evolved from repeated concepts in the data, and most were named after words in the data. However, the purpose of the study influenced the dimensions used to identify the themes, and awareness of current and past changes to engineering education in Australia and elsewhere also provided insight. The purpose of identifying competency deficiencies is to assist continuous improvement of engineering education across all disciplines. Therefore, themes were identified to be generic across disciplines of engineering, and the themes were selected to group competency deficiencies that might be addressed simultaneously by the same or similar improvements to engineering education. Awareness of past and current changes to engineering education in Australia, and innovations in engineering education elsewhere provided insight for identifying themes that might be addressed simultaneously.

Figure 1: Years in which survey participants completed their first engineering degrees.
The list of themes was designed to satisfy the criteria specified by Merriam, being: “responsive to the purpose of the research”, “sensitive to the data”, covering all relevant data, “mutually exclusive”, and “at the same conceptual level” (Merriam, 2009, pp. 185-186). A list of the themes, with examples, was developed.

At an early stage, “design” was named a theme. However, the criterion that themes be mutually exclusive, meaning that any unit of data should belong to only one theme, caused a problem. The following examples belonged to the practical theme and also the design theme: “practical electrical engineering design skills”, “practical hardware design”, “practical pit design”, “practical structural design examples”, and “practical design work”. Therefore the design theme was made part of the practical theme.

A borderline decision was required for “water treatment technologies” and “traffic engineering”. These were originally coded as theory because they were considered to be more theoretical items.

Twelve themes were identified. Any one item alone was not considered a theme. The health, safety and environment (HSE) theme was not represented in the responses to the first question because only one unit of analysis, “electrical safety”, was related to it, and this also fitted the practical theme. The risk theme was not present in responses to the second question. Although the first level of analysis was designed to be relevant to all disciplines of engineering, a second level of analysis reduced the practical theme into general competencies and those raised by graduates from each of three broad disciplines. This breakdown was clear in the data.

Responses from UWA and other graduates were separated to reveal any bias due to the high portion of responses from UWA graduates.

### 4.2.3 Data display

Responses to each question were displayed separately. The units of analysis within each person’s response to each open question were colour-coded by theme.
For example, in Response 1 below, “Australian Standards” was coloured red to indicate the business theme and “PLC programming” was coloured blue to indicate the practical theme. Every question response was then coded with a value for each theme (0 = response does not include a unit of analysis fitting the theme; 1 = response does include a unit of analysis fitting the theme). Response 1 was coded 1 for each of the business and practical themes, and 0 for all other themes. The number of people whose responses included a particular theme was the sum of the values for that theme.

Response 1. Australian Standards, PLC programming (response to Q1 from Electronic/Communications engineer who completed engineering at UWA in 1989)

4.3 Responses to Question 1. Is there a skill, attribute or area of knowledge that you would have liked to gain from your undergraduate engineering studies and did not?

Responses under the theme of engineering business were received from engineers spanning the complete range of graduation years in the sample (1984 to 2001), across all disciplines, and even including graduates who combined their engineering degrees with economics or commerce degrees. Responses relating to practical awareness included those related to familiarity with equipment and sites, and discipline-specific responses related to applications relevant to employment industries.

Understanding of engineering business and practical awareness featured most frequently (figures 2 and 3). Responses were collated in two groups: those from engineers who completed their degrees before 1996 and those who completed their degrees in or after 1996. These ranges were selected to place sufficient responses for comparison in each group, and also to reveal any significant change following the major Australian review of engineering education published in 1996 (Johnson, 1996a). The most apparent difference between responses from engineers who completed their degrees before 1996 and the more recent graduates, is that a lower percentage of the engineers who completed their degrees in or since 1996 identified competencies related to engineering business. Engineering management was added to many engineering curricula at UWA in 1989, following the Australian review of engineering education published in 1988 (Williams, 1988b).

Themes identified among responses to Question 1 of Survey 1:

- No
- Yes, with no specification
- Practical:
  - General: “practical design work”, “hands on practical experience”, “applying knowledge to practical work”, “more real world applications to theory”, “practical skills”, “practical hands on content”, “more practical experience on site”, “more practical exposure to work places & methods”, “more knowledge regarding the mining industry” (environmental graduate), “more case studies”
  - Civil: “more direct learning in civil design area”, “practical structural design examples”, “water treatment technologies”, “traffic engineering”, “transport/traffic management”, “more on

Figure 2: Themes among responses from graduates of 1984-1995 to survey Question 1. Is there a skill, attribute or area of knowledge that you would have liked to gain from your undergraduate engineering studies and did not? ($n_{UWA} = 131; n_{Other} = 39$).
road construction”, “practical pit design”, “grade control”

- Electrical: instrumentation and industrial control/PLC programming/SCADA (mentioned by five electrical engineers), “electrical safety”, “practical electrical engineering design skills”, “more practical circuit design”, “lighting design”, “practical industrial control exposure”, “practical hardware design”, “better hardware design skills”

- Mechanical: pumps (mentioned by nine mechanical engineering graduates), “piping knowledge (materials, fittings, calculations)”, “materials handling”, “applications of mechanical equipment in Australia”

- Communication: communication, presentation, report writing, interpersonal skills
- Teams: teamwork, leadership, negotiation, conflict resolution
- Theory: digital signal processing, image processing, cryptography, “more petrochemical knowledge”, numeric modelling, radiofrequency propagation, radio communications design, computer-communications networking theory, hydrogeology, non-linear feedback control
- Problem solving: problem solving, systems engineering, “design skills – unstructured problem solving”
- Risk management: risk management, reliability, maintenance
- Computing: “More relevant software unit eg C rather than pascal, gopher”, databases, “more relevant computer skills”, “modern programming languages”, “better programming skills”, “programming”
- Self management/attitude: “Understanding of attitude required & industry expectations” “reminded to use the knowledge of the people already doing it”, “admitting shortcomings”, “stress management”
- Drawings: reading drawings, using CAD
- Health, safety and environment: “HSE awareness”

Note: Quotation marks indicate direct quotation from a response. These have been included to allow readers to see nuances. Where no quotation marks are used, such as for the examples under the risk management theme, the term is usually an interpretation for similar units of data from multiple responses. Otherwise the term is a direct quotation, but reveals no unique nuance.

4.4 Responses to Question 2. Is there a skill, attribute or area of knowledge that you have observed to be lacking in engineering graduates who have completed their degrees within the last 3 years?

Responses to the second question were analysed using the themes developed from the first question. The theme HSE was additional. Responses to the second question were expected to be more limited than responses to the first question. Not all of the survey participants had experience of recent graduates, and responding to the second question relied on generalisation more than the first question. This explains the higher number of responses saying “no” than for the first question. Responses to the second question mainly included the same themes as for the first question, with practical engineering most frequently mentioned and engineering business third most frequently mentioned, although neither as frequently as in response to the first question. However, the second question raised a stronger emphasis than the first on the themes of communication, problem solving, and self management and attitude (figure 4). Samples of the comments under these themes are listed below.
Themes raised more frequently in the second question than the first:

- **Communication**: literacy, report and letter writing, “reasoned arguments”, “cohesive/persuasive argument”, listening skills, verbal communication skills, technical communication

- **Self management/attitude**: “being grateful to have employment” (possibly a function of the employment market rather than the engineering education), “high standard of work is lacking”, “the drive to do the work”, “attitude has changed to work”, less committed to work”, “willingness to exploit opportunities (eg. site work)”, “community awareness”, “Recent graduates all want to be Project Managers”, “inability to work on multiple projects/jobs at the same time”, “time management”, “time/workload management”, “pragmatism”, “a sense of balance”, “lack of awareness of their limitations”

- **Problem solving**: problem solving skills, analytical skills, “logical thought process (eg. scientific method)”, critical thinking, “question assumptions”, “systems (holistic) approach”, “look at total systems”, “systems engineering”, “trouble-shooting”, “lateral thinking”, making decisions with limited information, “ability to apply their knowledge to engineering design”, “ability to work independently on problems”.

4.5 Validation

People would identify competencies as gaps, only if they are important. Although no other part of this study validated the competency gaps identified here, other components of the overarching project studied the importance of competencies to engineers’ work. In later questions in the survey, and in a second survey of senior engineers, 64 competencies were rated on importance.

Competencies related to communication, teamwork, problem solving, self management and practical engineering were rated highly (Male et al, 2009a). Senior engineers emphasised the importance of competencies similar to those categorised as engineering business in this study. In a panel session held to validate outcomes of the surveys, a sound understanding of fundamental science and mathematics was considered the first priority. These support the necessity of the competencies identified as gaps in this study.

5 DISCUSSION

The engineers’ opinions collected in this survey provide insight for engineering educators. The outcome areas most frequently reported as desirable but missing from engineers’ undergraduate education were practical engineering and engineering business. Additionally, communication skills, self management, attitude, problem solving and teamwork were identified as competency deficiencies in engineering graduates.

One of the difficulties hindering the development of graduate attributes in engineering is the lack of a consistent definition of the attributes (Carew & Therese, 2007). By asking engineers about their own graduate experience, and due to the open-response format, this study collected specific examples of competencies that are named more generally in other studies. Consequently, the responses contribute to a better understanding of possible meanings of the competencies.

Practical engineering competency deficiencies included both familiarity with sites, tools and methods, and also applications in common industries in which the engineers were employed, for example instrumentation and control, pumps, and road and...
pit construction. Design featured among responses in the practical engineering theme.

Engineering business competency deficiencies included awareness of how engineering is done, for example the relationships between contractors, consultants and their clients. Engineering business competency deficiencies also included skills in engineering work such as planning, specification, estimation, project management, cost control, risk management and maintenance management. These examples explain the comments received in the Johnston review, emphasising the need for engineering business competencies, rather than general business competencies only. This is a critical point that offers an opportunity for the engineering profession to enhance its identity. Engineering business competencies, in addition to the more readily recognised technical engineering competencies, distinguish professional engineers from other professionals.

All of the six highlighted competency deficiencies – practical engineering, engineering business competencies, communication skills, self management and appropriate attitude, problem solving, and teamwork – continue to be candidates for improvement in engineering curricula. Themes raised by the survey responses are consistent with previous studies. The three themes most prominent among the competency deficiencies identified in this study were practical engineering, business and communication. Practical engineering was highlighted as a competency deficiency in the UK study (Spinks et al, 2006), and Australian reviews. Communication featured in many previous studies, and business competencies were highlighted by the UK study, the chemical engineering study (WCEC, 2004), the Australian study by Ashman et al (2008) and Australian reviews.

The introduction to this paper discussed some of the ways in which engineering education in Australia is evolving. Course structures, pedagogies, assessments and learning environments are changing. Are these changes aligned with the competency deficiencies identified by engineers in this study?

The results of this study suggest that engineering education has improved in at least two areas over the last two decades. Engineering business competencies and practical engineering competencies were identified in a smaller portion of the named competency deficiencies in responses to the second question, which asked about recent graduates, than in responses to the first question, which asked the engineers about their own experiences. This could be due to improvements in engineering education. It could also be due to self management, attitude and problem solving competencies being more recognisable in others than in self assessment, and therefore eclipsing practical and business deficiencies in the second question. Comparison of the results of the previous studies that asked employers or managers to rate graduates and those that asked engineering graduates to rate their own performance is inconsistent with this second explanation for the apparent improvement in business and practical competencies of graduates. Therefore, among the participants in this study, perceptions of graduates’ competency deficiencies imply that the development of practical engineering and engineering business competencies in engineering graduates has improved since the participants graduated. This conclusion is consistent with broadening of engineering curricula to include business subjects during and since the mid 1980s, and engagement with engineers from industry, which has been stipulated by criteria for accreditation of engineering education programs (IEAust, 1999). Increased opportunities for project based learning could have contributed to improvement in the development of practical engineering competencies.

This study supports continued broadening of engineering curricula, strategic collaboration with engineers in industry, and continued opportunities for students to develop practical engineering competencies. Engineering business competencies should be considered for inclusion in the graduate attributes stipulated by Engineers Australia (2005) and the program outcomes stipulated by the Accreditation Board for Engineering and Technology (2008). Business competencies are explicitly listed under transferable skills stipulated in Europe (ENAE, 2008).

Current developments in engineering education are aligned with competency deficiencies identified by engineers in this study. Communication, self-management and attitude, problem-solving, and teamwork are now within engineering curricula and have now been stipulated for program accreditation for many years (IEAust, 1999). Engineering educators have recognised that development of these competencies requires non-traditional pedagogies such as problem- and project-based learning (Ferguson, 2006a; Mills, 2002; Shuman et al, 2005), and non-traditional learning environments in which to practise these (Norton et al, 2007).

Cultures within engineering and engineering faculties remain critical. Assessment methods and cultures must encourage learning in the required areas, and the best intentions can fail some students (Tonso, 2007). Status for non-traditional competencies is required (Florman, 1997). Education systems reinforce their cultures (Ihsen, 2005). Part of many engineers’ identities is affiliation with a culture giving technology higher status than business and people (Faulkner, 2007). Therefore it can be difficult for engineering academics to give communication and teamwork the necessary status to be taught and learnt seriously within traditional engineering faculties, without cultural change. Further, the
importance of research in universities has caused an increasing proportion of engineering academics to be without industry experience (Prados, 1998). The Johnston review noted the growth of research-only staff in universities (Johnston et al, 2008). This trend is likely to limit the status of practical engineering and engineering business within engineering faculties. Further cultural changes will be required to improve the success of current initiatives at addressing the competency deficiencies identified in this and previous studies.

6 CONCLUSIONS

This study used a different method from previous studies to identify competency deficiencies among engineering graduates as perceived by engineers. It confirms generalisation of large scale international studies to the Australian context. Engineers identified competency deficiencies in engineering graduates. Dominant themes among the identified competency deficiencies were practical engineering, engineering business competencies, communication skills, self management and appropriate attitude, problem solving, and teamwork. Current changes to engineering education in Australia seek to address these deficiencies.

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REFERENCES

Accreditation Board for Engineering and Technology (ABET), 2008, Criteria for Accrediting Engineering Programs, Effective for Evaluations During the 2009-1010 Accreditation Cycle, Baltimore, MD.


Association of Professional Engineers Scientists and Managers Australia (APESMA) & Engineers Australia, 2005, Professional Engineer Remuneration Survey, Spring.


Engineers Australia, 2005, Engineers Australia Policy on Accreditation of Professional Engineering Programs, No. P02, Barton, ACT.


Ferguson, C. 2006a, “Attributes for Australian Mechanical Engineers through Proximal and Distance Education”, Doctor of Technology thesis, Deakin University.


Institution of Engineers Australia (IEAust), 1999, Manual for the Accreditation of Professional Engineering Programs, Barton, ACT.


World Chemical Engineering Council (WCEC), 2004, How Does Chemical Engineering Education Meet the Requirements of Employment?, Frankfurt.


## APPENDIX

### Table 2: Industries represented in survey (n = 300).

<table>
<thead>
<tr>
<th>Industries in which participant was mainly engaged</th>
<th>Number of responses</th>
<th>Responses as percentage of participants</th>
<th>Responses as percentage of industry selections (b)</th>
<th>Responses in APESMA/EA survey as percentage of APESMA/EA participants</th>
</tr>
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<tbody>
<tr>
<td><strong>Non-manufacturing industries</strong></td>
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<tr>
<td>Consulting/technical services</td>
<td>111</td>
<td>37</td>
<td>18</td>
<td>17</td>
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<tr>
<td>Construction/contract/maintenance</td>
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<td>23</td>
<td>11</td>
<td>13</td>
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<tr>
<td>Mining/quarrying</td>
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<td>28</td>
<td>14</td>
<td>6</td>
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<tr>
<td>Oil/gas exploration/production</td>
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<td>17</td>
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<td>2</td>
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<td>Electricity/gas supply</td>
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<td>Water/sewerage/drainage</td>
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<td>15</td>
<td>7</td>
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<tr>
<td>Communications (inc. Telstra)</td>
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<td>4</td>
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<tr>
<td>Defence</td>
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<td>5</td>
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<td>Public administration (Federal/State/Local)</td>
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<td>2</td>
<td>9</td>
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<tr>
<td>Transport/storage</td>
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<td>Education</td>
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<td>29</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Steel production</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fabricated metal products</td>
<td>20</td>
<td>7</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Transport equipment (inc. motor vehicles)</td>
<td>11</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Photographic/scientific equipment</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Appliances/electrical equipment (inc. electronic equipment)</td>
<td>20</td>
<td>7</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Industrial equipment/machinery</td>
<td>23</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Participant was working for a consulting engineering firm</td>
<td>110</td>
<td>37</td>
<td>N/A</td>
<td>25</td>
</tr>
</tbody>
</table>

Notes: Response options adapted from APESMA/Engineers Australia “Spring 2005 Professional Engineer Remuneration Survey”. Survey statistics are for responses from engineers with 5 to 20 years’ experience in the “Autumn 2007 Professional Engineer Remuneration Survey” (P. Angerame, APESMA, personal communication, 27 June 2007).

\(b\) This study’s participants were able to select multiple industries. Participants in the APESMA/Engineers Australia survey were asked to select the industry in which they were “mainly engaged”. The third column was calculated as percentages of the industry selections made in the study, including many cases of multiple selections made by one participant. Western Australia is the state from which the survey was conducted.
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Sally Male is a PhD student studying engineering competencies. She has a BE (Hons) (Electrical) from the University of Western Australia (UWA). Sally has taught electrical engineering at UWA and Curtin University of Technology, and conducted the Women in Computing and Engineering Project at Curtin. She has served on state and national women in engineering committees of Engineers Australia, and is the Link Co-ordinator for Western Australia for the Women in Science Enquiry Network.

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Winthrop Professor Mark Bush is past Dean of Engineering at UWA. He has a BE (Hons) (Mechanical) from the University of Queensland and PhD from the University of Sydney. He has received awards for teaching and is a Fellow of Engineers Australia. His research interests include engineering education and bioengineering.

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