Essential Skills for Engineering Cadets and Graduates: Responses from an Industry Survey

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CONTEXT
Charles Sturt University's new civil engineering program is unique amongst Australian universities in that it incorporates a true industry perspective for students whilst they are at university. This helps students develop relevant skills to ease the transition into engineering practice. Current research indicates a disconnect between the skills that industry desire in cadet and graduate engineers and those they actually possess. Thus far, there have been incomplete attempts to identify these skills. This can be attributed to a lack of sufficient engagement between universities and the engineering sector.

PURPOSE
The aim of this research was to identify the skills and attributes that industry requires of cadet and graduate engineers. This helped determine the topics required in the first 18 months of the CSU civil engineering program. Additionally, this research helped identify industry partners for on-going engagement with CSU engineering.

APPROACH
A survey was created using Survey Gizmo, a free online survey program, and was distributed to practicing civil engineers, industry partners and posted to online forums. The qualitative survey consisted of six open-ended questions focusing on respondent's experiences and expectations of cadet and graduate engineers. Questions were deliberately open ended to avoid leading the answers of respondents into particular attributes or skills. The survey was designed to be quick to complete. Responses to open ended questions were analysed qualitatively or quantitatively depending on the data. Preliminary analysis of the qualitative data consisted of identifying themes and then quantifying the percentage of responses identifying each theme, knowledge or skill in our case.

RESULTS
Completed surveys were received from sixty two engineers working in consultancies, local government and government agencies. Results showed a fairly equal preference between specific technical skills and professional attributes, such as communication, problem solving, team work and time management. . Particular technical skills, including surveying, CAD and Excel; were identified and this helped CSU staff identify the list of compulsory topics for the students to complete prior to industry placement. Further analysis will address the similarities and differences between requirements for cadet and graduate engineers as expressed by the different sectors of the civil engineering profession.

CONCLUSIONS
Based on the results it can be inferred that industry desires graduates with well-developed professional skills and technical knowledge but expect to train them in job-specific areas. The unique structure of the CSU program requires that staff help develop these skills in students within eighteen months, prior to their industry placement. There seems to be some technical areas in which graduates are not meeting industry needs that could be looked into further.

KEYWORDS
Industry engagement, Graduate skills, Competency gap, Work Integrated Learning (WIL).

Introduction

The claim that there is a discrepancy between what engineering students are taught at university and what skills the workplace requires of them is one that is often quoted both anecdotally and in literature, and is referred to as the competency gap (Hays and Clements, 2012). Despite being researched for at least two decades there is no clear consensus on how this discrepancy should be addressed.

This paper will provide an overview of a recent industry survey conducted by CSU Engineering. The aim of this survey was to identify specific skills and attributes that employers desire of civil engineering cadets and graduates. Some of the engineers surveyed will be directly responsible for cadet engineers from the CSU Engineering program and as such have a vested interest in ensuring the cadets will be 'job-ready' from day one.

The survey came about as a result of planning the curriculum for the students before their cadet placements. We were interested in finding out if industry requires specific technical skills in cadets or if professional skills are more valued. The survey also included graduates to compare requirements.

The results from the survey list the exact skills and attributes that a particular sector of the engineering industry desires of civil engineering cadets and graduates. This paper will discuss how these results have helped shape the CSU Engineering program along with what potential implications this has for the future of engineering education in Australia.

Background information

Australian research keeps pointing to a gap between graduate attributes and the skills that industry requires (Hays and Clement, 2012; Walther and Radcliffe, 2007). Throughout recent years there has been a considerable effort to engage with industry to identify what these graduate attributes are. Previous studies into this issue have focussed largely on what skills are desirable of recent graduates or skills which recent graduates have themselves identified as useful. Scott and Yates (2002) focussed on recent graduates, identified as 'high performers' by their employers. Their findings determined that skills dealing with emotional intelligence were identified as the most important by employers.

Savage et al. (2009) carried out one of the few studies to involve students in determining their knowledge, in this case final year students. This study was unique in that it involved representatives from students, academia and industry in an effort to gauge the differing views of graduate preparedness for work in the engineering industry. Goldsmith et al. (2011) also considered the viewpoints of "students, academics and industry" and their "shared desire" for a curriculum that meets the needs of all three stakeholders and "industry willingness to engage in the engineering curriculum to enhance authentic learning experiences". The studies by both Savage et al. (2009) and Goldsmith et al. (2011) focussed mainly on what soft skills (i.e. personal, professional and workplace skills) graduates require rather than specific technical skills or attributes.

Similar research has been occurring in the US. Aanstoos et al. (2001) conducted a survey which grouped desired skills for mechanical engineering graduates into hard, soft and intangible categories. These skills were identified by engaging with professional engineers across a range of companies working in mechanical engineering. They identified that there is a significant gap between the skills that recent graduates self-identified as possessing and those which industry value. Sageev and Romanowski US (2001) surveyed a group of recent engineering graduates (3 – 5 years after graduation) focussing specifically on the importance of communication to working in the engineering profession.. Holcombe (2003) conducted a survey of both recent engineering graduates and their direct supervisors. The graduates identified financial management, working with more experienced engineers and adjusting to

work hours as their main issues. Supervisors identified poor report writing, lack of communication skills and not meeting deadlines as most important.

Existing research focuses on graduate skills and transition to the workforce and the competence that industry expects. There appears to be a gap in the literature regarding what employers require of cadets which is relevant to the CSU context. Engineering is one of the few disciplines where work placements are paid so there is an expectations that cadets will be able to contribute to real work. There also seemed to be no literature or policies outlining technical skills specifically for the civil engineering industry.

CSU Engineering

Established in 2015, CSU Engineering is Australia's newest school of engineering, currently offering only civil engineering. "CSU initiated its engineering course as a response to demand from local government and regional industry to address a shortage of engineers in the regions" (Lindsay and Morgan, 2016). The CSU Engineering curriculum is like no other in the country, combining 18 months of on-campus, project-based learning with four years of paid placement in industry. The key aim of the course "is to train entrepreneurial engineers in a regional setting" (Lindsay and Morgan, 2016). Unlike traditional programs the CSU Engineering course does not include lectures or exams, students are instead assessed on their mastery of knowledge through an online system known as the topic tree.

CSU Engineering has endeavoured to minimise the gap between studying at university and working in the engineering industry (Hays, et al. 2012) as much as possible. This is helped in part by the project-based learning activities student engineers undertaken in their three semesters on-campus. Wherever possible the realities of what it is like to work in the engineering industry are incorporated into the CSU Engineering program. Students are treated as engineers from day one, rather than as students. CSU Engineering also employs three Engineers in Residence, staff who have come directly from industry and are able to provide knowledge to students on industry best practice.

Due to the integral nature of industry placements to the CSU Engineering program it is imperative that CSU engage effectively with the engineering industry. This engagement fulfils two important needs; it provides a steady supply of case studies and site tours and it helps to facilitate potential cadet placement opportunities. Indeed "the success of the program is heavily dependent upon finding a pipeline of work placements for the student engineers" (Lindsay and Morgan, 2016). Effective engagement with industry could help identify exactly what skills and attributes cadet engineers would need in order to make a meaningful contribution to their host organisation immediately and as successful engineers in the future.

Survey Methodology

The approach taken to capture data of what is required by industry of cadets and graduates was to develop an online survey. The survey was designed to be quick to complete and transparent in its length, with all the main questions on one page. The survey questions are shown in **Error! Reference source not found.**.

The survey was created using Survey Gizmo, a free online survey program, and consisted of ten questions. Respondents were initially asked about their background, level of experience and area of expertise. This was followed by six open-ended questions, rather than requiring ranking of a list, on the expectations and desired skills for cadets prior to going on work placement and for graduates prior to completing their studies. These questions covered both specific technical skills and general attributes and attitudes.

1. Where did you study engineering?
2. How many years of experience do you have in the engineering industry? (multiple choice)
   less than 3 years / 3- 10 years / 10 - 20 years / more than 20 years
3. What are your areas of civil engineering specialty? (multiple choice)

   general civil/structural/geotechnical/water/transport/traffic/project management/construction/road/municipal/management/other
4. Have you worked with or supervised cadet or graduate engineers?
5. Our student engineers will go on their first year long cadet engineering placement after 18 months of study on-campus and will continue their study on-line one day per week. We are trying to decide which skills, knowledge and attributes would be most useful for them to have attained at this point.

   List up to ten things you wish every cadet engineer knew when they came to work in your organisation or you wish you knew as a cadet engineer.
6. What technical skills and civil engineering knowledge would be most valuable in a cadet engineer? (eg. computer programs, surveying, fluid mechanics, CAD...)
7. In what ways have you found engineering cadets or graduates particularly satisfactory or unsatisfactory in your organisation?
8. CSU Engineering is striving to produce skilled, work-ready graduates who are passionate about the industry.

   List up to ten things you wish every engineer knew or had experienced when they came to work in your organisation after graduating from university.
9. The CSU Engineering program is designed to produce entrepreneurial engineers who can make a difference in their communities. Which business skills have been valuable in your engineering career or would you liked to have had?
10. Is there anything else you would like to tell us that would help us in the development of a unique and innovative civil engineering program? (Optional)
11. Would you be willing to be contacted again? (multiple choice)
    - □ I would be willing to be contacted again by email for feedback on your course development
    - □ I would be willing to talk to one of your civil engineering academics about relevant practices and example projects in my area of specialty
    - □ I would be interested in talking to CSU Engineering about my organisation employing a cadet engineer in the future

Figure 1: Survey questions

Questions were deliberately open-ended so as not to direct the respondents. For example, questions 5 and 8 which asked respondents to “list up to ten things”, deliberately used the vague word “things” in the place of words likes skills or attributes to avoid impelling respondents to focus on technical or soft skills to see which of these the respondents valued. Multiple choice questions were not used for the same reasons. This allowed respondents to be very specific in their answers. Following questions focussed on technical and business skills and experiences with supervising to gain more specific information.

Invitations to complete the survey were distributed by email by the CSU Engineers in Residence and other academics, personally addressed where possible, via their professional networks in late 2015. The survey was also posted on the Institute of Public Works Engineering Australasia (IPWEA) forum. The invitations were directed at practising civil

engineers rather than human resources departments or management, to get responses from those in roles of direct supervision of cadets and graduates.

Responses to the survey questions on cadet and graduate skills were analysed by identifying themes and then quantifying the percentage of responses corresponding to each theme; knowledge or skills in our case. Responses to open ended questions were analysed qualitatively or quantitatively depending on the data. Although some researchers object to quantifying the themes, the frequency of occurrence clearly indicates that more participants value this particular item which allowed the data to be used for curriculum planning.

Results

There were a total of sixty two completed responses to the survey from professional engineers working in consultancies, local government and state and federal government agencies. A significant number of the responses were from engineers working in local government in NSW.

Table 1 shows the career experience of the respondents to the survey. With 71% of respondents having more than 10 years career experience the survey captured a wealth of knowledge.

Table 2 compares the quantised responses to questions 5 and 8; the things required of cadets and engineers, grouped by identified themes. The values represent the number of responses identified in the theme as a percentage of the total number of listed items from all 62 responses; 558 items for question 5 and 268 for question 8. Since respondents could list multiple responses under one theme it was not possible to represent data as a percentage of respondents. The results do allow identification of priority themes and comparison of themes and between cadet and graduate questions.

Table 3 shows the technical skills and civil engineering knowledge desired in cadet engineers from question 6. These values are a direct percentage of the number of respondents. It is worth noting that the most popular skills were included in the examples in the question, however, the large percentage of responses for the top three skills indicate these are of high importance even if some distortion of the data did occur.

Tables 4 and 5 expand on the information in Table 2 from questions 5 and 8. Table 4 shows the individual areas of engineering knowledge and Table 5 those of professional skills. Although the values in this table appear low, as mentioned above these are percentages of the total 558 and 268 items in the question responses. So a 5% value for attitude and ethics represents 28 items which were identified in this theme which is significant.

Table 1: Question 2 results - Career experience of survey respondents (Question 2)

Career Experience	% Respondents
Less than 3 years	8
3 - 10 years	21
10 - 20 years	30
More than 20 years	41

Table 2: Questions 5 and 8 results - List 10 things you wish every cadet and graduate engineer knew (there were up to 10 responses per survey)

Theme	% Responses	
	Cadet question	Graduate question
Engineering Knowledge	25	21
Professional skills	22	21
Computer skills	10	9
Surveying & GIS	8	2
Communication skills	5	5
Documentation	4	2
Project management	4	11
Construction	4	4
Writing & reports	4	5
Safety & WHS	3	2
Engineering Plans	2	2
Legislation general	2	2
Basic skills	2	2
Budgeting, costs, finance	2	5
Australian standards	2	2
Engineering Workplaces	1	1
Environmental & sustainability	1	2
Drivers licence	1	0
Ethics	1	0
Research	1	1
Business skills	0	1
Local government	0	1
Site experience	0	4

Table 3: Question 6 results - Technical knowledge required for cadet engineers

Skill/Knowledge	Theme	% Respondents
AutoCAD and drafting	Computing Skills	54
Excel and spreadsheets	Computing Skills	31
Surveying	Surveying	31
Microsoft office suite	Computing Skills	24
Civil Design programs	Computing Skills	17
Civil design	Engineering Knowledge	13
General Computing skills	Computing Skills	11
Hydraulic design programs	Computing Skills	11
Project management	Engineering Knowledge	11
Engineering Knowledge	Engineering Knowledge	9
Hydraulics, Stormwater design, Flooding	Engineering Knowledge	9

Table 4: Specific engineering knowledge expanded from Table 2

	% Responses	
Specific area of knowledge	**Cadet question**	**Graduate question**
Structural	4	1
Road design	3	4
Engineering Knowledge general	3	0
Water and wastewater engineering	4	4
Hydraulics, Stormwater design, Flooding	2	5
Asset management	1	2
Design process	1	1
Maintenance	1	0
Concrete	0	1
Geotechnical	0	2
Traffic engineering and management	0	2
Development	0	1
Materials	0	1
Civil design	0	3

Table 5: Specific professional skills expanded from Table 2

	% Responses	
Specific area of professional skills	**Cadet question**	**Graduate question**
Attitude & ethics	5	3
Team work	4	2
Time and task management	4	2
Attributes	4	3
Learning	2	1
Problem solving	1	2
Asking for help	1	1
Resilience	0	1
Career	0	2
Professional skills general	0	5
Leadership	0	1
Management	0	1

Discussion

The results of this survey have been used to directly determine topics for inclusion in the CSU Engineering curriculum, particularly for the 18 months students spend on campus prior to their cadet placements.

These results reinforce the importance of professional or ‘soft’ skills in engineering graduates from an industry perspective as identified in the literature. In the open ended questions 5 and 8, 22% and 21% of the total of 558 and 268 responses, respectively, identified professional skills that are desired in cadets and graduates, as shown in Table 2. Table 5 shows the specific breakdown of desired professional skills, with ‘attitude and ethics’ listed most often for both cadets and graduates. This was supported by answers to question 7 about satisfactory and unsatisfactory experiences with responses including: “Success is based on right attitude” and “Perhaps the difference is the attitudes.” Team work, time and task

management, and ability to learn were other professional skills desired, particularly in cadets. Multiple respondents expressed the sentiment that recent cadets and graduates “Tend[s] to be individualistic”. The desired professional skills are well represented by this comment.

They are most successful when they are keen to learn, motivated to work, ask lots of questions, are willing to do independent research and don't act like they know everything already. Their interpersonal skills are probably the most important factor in their success.

The results for professional skills were almost the same as that for engineering knowledge indicating that in general these are of equal importance to industry. Answers to question 6 which asked about the technical skills and knowledge desired in cadet engineers surprised many of the engineering academics but aligned with the skills that the Engineers in Residence had identified as important to industry. A requirement for AutoCAD drafting skills was given by 54% of respondents, with 31% also desiring Excel spreadsheet skills and surveying. These top three technical skills valued in cadet engineers are not always part of the curriculum of civil engineering courses in Australia, however, they do reflect the duties that are typically assigned to cadets and would allow them to work on “real projects”. As one engineer commented “While they are a cadet, I expect them to get their hands dirty, learning how things happen in reality”. The strong response for these skills does indicate a possible shortfall in current graduates.

The hydraulics, stormwater design and flooding knowledge area was the most desired technical area for graduate engineers, as seen in Table 4. Detailed analysis of the specialty areas of respondents experience has not been performed, however, preliminary analysis does not indicate water engineering as one of the top few areas. One engineer commented that “many cadets (and grads) have had no drainage/flooding/water training at Uni at all. Seems to be a heavy focus on structures”. Some Australian civil engineering courses do not teach stormwater design as a part of civil engineering, and many do not have it as part of the core curriculum.

Many responses to question 7 about satisfactory and unsatisfactory experiences referred to the lack of ‘practical’ and ‘real-life’ experience. Comments included “Not enough practical knowledge”, “Great theoretically, poor practically” and “Recent graduates typically do not have real life work experience and you basically start from scratch in training them.” This highlights the traditional disagreement between university and industry about whose job it is to provide this experience. Table 2 shows that 4% of responses (18% respondents) specified site experience as desirable for graduate engineers but there was no expectation of this for cadets. This indicates the that many practicing engineers expect that students will gain site experience in their cadetships.

Whilst the studies described in the background information above show a general trend over time towards more and more engagement between industry, students and academics there is overall a major focus on ‘soft skills’ of engineering graduates. There is very little focus on specific technical skills. Indeed when technical skills are mentioned at all it is generally as a cover-all category, there is minimal exploration of the specific technical skills required. This can be attributed in part to the general nature of these studies, they are trying to identify trends which apply across all engineering courses.

Where the CSU Engineering program is different is in preparing students for a relatively narrow part of the industry. All of our current students are civil majors and we have broadly identified the specific sectors, and in some cases the specific institutions, they will be undertaking their work placements. This enables CSU Engineering to engage with these companies and determine exactly what skills they require in an engineering cadet to be able to make a meaningful difference.

Future Directions

This survey identifies some technical areas of civil engineering that may be lacking or perceived by industry to be lacking in current courses in Australia. These include AutoCAD and drafting skills, Excel spreadsheet skills, surveying and hydraulics, stormwater design and flooding knowledge area. These gaps may be worth considering by other civil engineering courses in Australia

Further of analysis of the survey data, particularly the responses to question 7 regarding experiences with cadets and graduates and question 9 regarding business skills, will be useful for further course development and supporting the cadets during their placements.

Most previous studies have focussed on the attributes of graduates, whereas the CSU survey also focusses on the role of cadets. This highlights the importance of identifying early on in a student's development the skills that they will need as a professional. It also acknowledges the fact that some skills can't be replicated in a classroom setting and need to be taught on the job.

It seems the many years of research into this area has produced insufficient change in engineering education as it is still an area of disagreement and ongoing research. A major measure of this process will be feedback on how successful the first cohort of student engineer are on placement. We are intending to conduct regular surveys and request feedback from employers of our cadets to ensure that the skills and attributes we are imparting to the next generation of engineers are reflective of industry needs and meeting the engineering needs of the future. The close integration of the CSU Engineering course with industry should give the opportunity to enact change based on these results and ultimately reduce the competency gap for our graduates.

References

Aanstoos, T. A., & Nichols, S. P. (2001). Bridging the Gap: Student Perceptions of What the Workplace Demands. *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition,* Albuquerque, New Mexico

Goldsmith, R., Reidsema, C., Campbell, D., Hadgraft, R. & Levy, D. (2011). Designing the Future, *Australasian Journal of Engineering Education*, 17:1, 1-9

Hays, J., and Clements M. D. (2012). Transition - Bridging the Gap between Study and Work. *Proceedings of the 9th International Conference on Cooperative & Work - Integrated Education*. 2012. http://hdl.handle.net/1959.3/226459

Holcombe, M. (2003, June). *ET grads - How'd The Transition Go?* Paper presented at 2003 Annual Conference, Nashville, Tennessee. https://peer.asee.org/12078

Sageev, P., & Romanowski, C. J. (2001). A Message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills. *Journal of Engineering Education*, *90*(4), 685-693

Savage, S. M., Davis, R. M. & Miller, E. (2009). *Exploring graduate transition from university to the workplace: employer, academic and graduate perspectives.* In: 34th AUBEA Annual Conference: Managing change - challenges in education and construction for the 21st century, 7 - 10 July, 2009, Barossa Valley, South Australia. (In Press)

Scott, G. & Yates, K. W. (2002). Using successful graduates to improve the quality of undergraduate engineering programmes, *European Journal of Engineering Education*, 27:4, 363-378, DOI: 10.1080/03043790210166666

Walther, J. & Radcliffe, D. F. (2007). The competence dilemma in engineering education: Moving beyond simple graduate attribute mapping, *Australasian Journal of Engineering Education*, 13:1, 41-51