

Design in mechanical engineering: Australian students' perceptions and expectations

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ABSTRACT

Since 2000, there have been significant changes in the teaching of mechanical engineering design at most Australian universities, to meet changes in industry expectations of graduates entering the workforce. A survey in 2009 asked final year undergraduate mechanical engineering students about their perceptions and expectations for engineering design work as part of their careers. The majority (90%) of the respondents said they had at least some interest in engineering design, with 52% reporting significant or major interest. Similarly, 87% expected to do at least some design work in their career, with 44% expecting this to be a major or significant part of their work.

In text responses to an open question, the most common themes were a need for more applied knowledge in their courses and inadequacy in design teaching (quality and quantity). Analysis of patterns in these comments suggests that these views are widespread, even though mechanical engineering students vary in the amount and level of design work they expect in their careers.

The results suggest that there is room for improvement in the teaching of engineering design in Australian universities. However, more thorough studies are needed to determine the longer term outcomes of curriculum changes currently being introduced.

INTRODUCTION

A number of Australian engineering educators have expressed concern about the extent to which Australian university courses are producing graduates with the engineering design skills that employers need. These concerns are summarised in a position paper (Churches et al., 2007). Several projects funded by the Australian Learning & Teaching Council are aiming to address the need for better engineering design education in universities – see, for example, (Carew et al., 2009, King, 2009, ALTC, 2009, ALTC, 2008).

Internationally and in Australia, the CDIO (Conceive, Design, Implement, Operate) framework is being used as a model for engineering curriculum design (ALTC, 2008). King (2009) gives a number of examples of Australian university

initiatives to improve the engineering education system, and in particular to make undergraduate study more practical and relevant, so that new graduates are 'ready to engineer'. Yet industry reports large variations in graduate performance, ranging from 'brilliant' to 'unemployable' (King, 2009, p 67). This paper focuses on how new engineering graduates themselves view this situation, and particularly on how well they think their degrees have prepared them for engineering design work in their careers.

There has been little empirically based research on the skills required for 21st century engineering practice (Trevelyan and Tilli, 2007). Those studies that have been done (e.g. Carew et al., 2009, King, 2009) cover a broad range of professional skills, including technical ability, communication and management skills. Although these are all necessary components of engineering design work, they are neither a complete nor an exclusive indicator of engineering design competence.

In 2009, the Engineering Design National Committee of Engineers Australia surveyed final year undergraduate mechanical engineering students across Australia to find out about their expectations for design as part of their careers. The survey data provide information about the student perspective on Australian undergraduate mechanical engineering design education. This paper analyses the survey responses in combination with other data, to draw some conclusions about mechanical engineering students' understanding of design as part of their undergraduate and continuing professional education, and to identify what further evaluations of engineering design teaching across Australia might be of value.

This paper represents a particular 'slice' through a complex multifaceted educational context, in which we are examining the perceptions of new graduates about engineering design.

I. METHODOLOGY AND METHODS

The survey on engineering design

There are differences between engineering discipline groups in how technical work is distributed (Trevelyan and Tilli, 2008). The various branches of engineering therefore differ in the way that they define the scope and nature of engineering design work. To ensure that the findings could be

interpreted consistently, the survey focused on mechanical engineering students (broadly defined to include courses like mechatronics, aerospace, materials and manufacturing).

Graduate engineering careers vary from technical specialist roles to broader project management roles. The survey asked final year mechanical engineering students, who were about to enter the workforce, questions about their interests and about the type of engineering work they expect to be doing upon graduation, as well as about their degree experience and future needs. The survey also asked about students' expected grade of degree, to pick up any general differences in confidence or academic performance that might be influencing career expectations.

The survey ran at the end of 2009 semester 2. It consisted of 8 multiple choice or short answer questions and one final question asking for text comments on their current university course – see Appendix 1.

Students in 8 universities were told about the survey by their lecturers, and given the link to a survey website. There were 206 voluntary responses over a period of 6 weeks, covering a variety of mechanical engineering disciplines.

Analysis methods

The responses to Questions 1–8, which were either multiple choice or standard phrases, were converted into a list of respondent attributes as follows

1. University
2. Engineering discipline
3. Interest in engineering design
4. Highest grade of degree expected
5. Amount of design work anticipated
6. Level of design work anticipated
7. Interest in project management
8. Interest in postgraduate design education

We analysed these attributes in relation to each other and the text responses.

Of the 206 respondents, 69 (33%) gave text responses. We used NVIVO software to code these text responses for themes, tagging each response for every theme included, so that the number of respondents mentioning each theme could be counted.

To evaluate the reliability of this evidence as a measure of student perceptions overall, we mapped the frequency of the most common themes against attributes to see if there were any discernable patterns. We also triangulated attribute 4 against degrees actually awarded in two universities, to check that the students responding to the survey are a typical sample, and on average are realistic about their expected academic performance.

Because the sample relied on voluntary online responses and may be subject to variation between the size and nature of different university cohorts and courses, the quantitative analysis is limited to reporting of the pattern of attributes rather than including any statistical analysis of correlation.

Quantitative analysis

Table 1 shows the distribution of respondents from the 8 universities.

Over half the respondents identified as being mechanical engineers, with a significant proportion identifying particular areas within mechanical engineering, such as mechatronics or aerospace (Figure 1).

The responses to the questions on interest in engineering design are shown in Figure 2. More than 50% report significant or major interest, and around 90% have at least some interest. So if the respondents are representative of Australian mechanical engineering graduates overall, then we can conclude that, overall, graduates are motivated to do engineering design work.

Table 1 Distribution of respondents

University	No of respondents
1	65
2	41
3	29
4	29
5	21
6	13
7	7
8	1

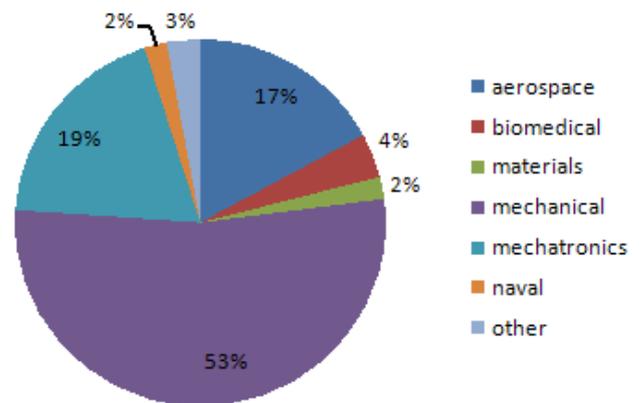


Figure 1 distribution of disciplines

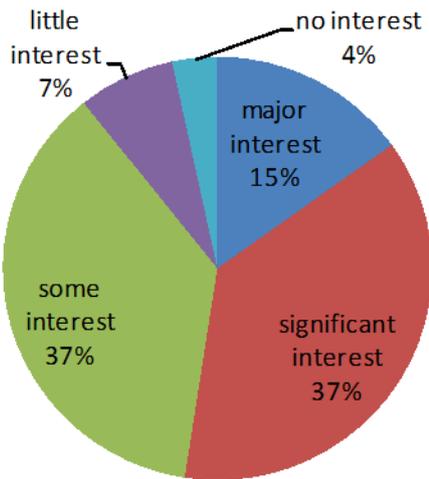


Figure 2. Reported interest in engineering design

Figures 3 and 4 summarise respondents' expectations for design work as part of future careers.

The questionnaire gave the following examples to clarify level of design work:

- high: creative design of original plant or equipment, beginning with concept development.
- substantial: designing an upgrade of an existing machine to perform an established function, using off-the-shelf components
- basic : designing a belt drive or redesigning a failed shaft.

The overwhelming majority of respondents expect to do engineering design work as part of their employment, with over 70% anticipating that this will involve more than just basic design of components or minor improvements.

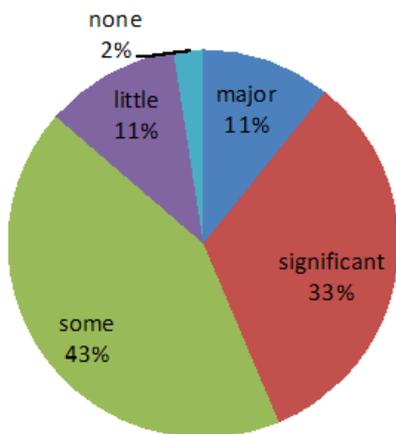


Figure 3 Perceived need for engineering design in career

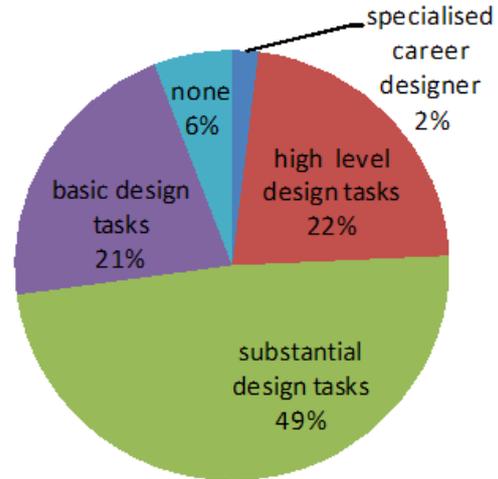


Figure 4 Expected level of design work in career.

Figure 5 shows responses to a question about interest in project management work. The proportional responses are similar to those for interest in engineering design. So to find out if individuals' interest in project management is associated with less or more interest in engineering design, we tabulated the results in matrices of paired categories (Tables 2 and 3)

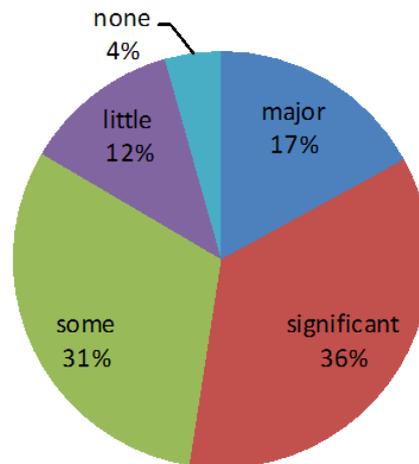


Figure 5 Interest in project management

Table 2 Amount of design work expected and interest in project management

amount of design work expected	interest in project management				
	Major	Significant	Some	Little	None
Major	2.4%	3.9%	2.4%	1.5%	0.5%
Significant	6.3%	11.2%	11.2%	3.9%	0.5%
Some	5.8%	14.6%	14.6%	5.3%	2.4%
Little	2.4%	4.9%	1.9%	1.5%	0.5%
None	0.0%	1.0%	1.0%	0.0%	0.5%

Table 3 Level of design work expected and interest in project management

level of design work expected	interest in project management				
	Major	Significant	Some	Little	None
Specialised career designer	0.0%	0.0%	1.0%	1.0%	0.0%
High level design tasks	2.9%	7.8%	8.3%	2.4%	1.0%
Substantial design tasks	8.3%	18.4%	16.0%	4.9%	1.0%
Basic design tasks	4.9%	7.3%	4.4%	3.4%	1.5%
None	1.0%	1.9%	1.5%	0.5%	1.0%

Table 4. Amount of design work expected and interest in postgraduate design course

amount of design work expected	interest postgraduate design course				
	Very interested, would definitely enrol	Would seriously consider enrolling	Would enrol if sponsored by employer	Unlikely to enrol	Definitely not interested
Major	2.9%	2.4%	3.9%	0.5%	1.0%
Significant	1.5%	4.9%	19.5%	5.9%	1.0%
Some	1.0%	3.9%	19.5%	12.2%	6.3%
Little	0.0%	1.0%	3.4%	5.9%	1.0%
None	0.0%	0.0%	0.5%	0.5%	1.5%

Table 5. Level of design work expected and interest in postgraduate design course

Level of design work expected	interest in postgraduate design course				
	Very interested, would definitely enrol	Would seriously consider enrolling	Would enrol if sponsored by employer	Unlikely to enrol	Definitely not interested
Specialised career designer	1.0%	0.5%	0.0%	0.0%	0.5%
High level design tasks	1.5%	5.4%	10.7%	1.5%	2.9%
Substantial design tasks	2.9%	4.4%	27.3%	4.9%	9.3%
Basic design tasks	0.0%	1.0%	7.8%	2.9%	9.8%
None	0.0%	1.0%	1.0%	1.5%	2.4%

From Tables 2 and 3, it seems as if those with greater interest in project management are expecting less and lower levels of design work. Note, however that these numbers need to be interpreted in relation to the distributions in Figures 3-5.

Finally, students' interest in a postgraduate specialist course in mechanical engineering design are shown in Figure 6.

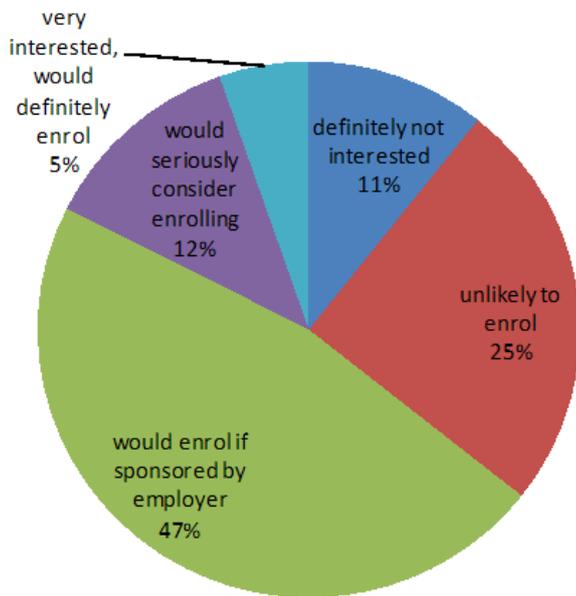


Figure 6 interest in postgraduate engineering design courses

The largest proportion of respondents indicated that employer sponsorship would determine whether such a course would be of interest to them. Tables 4 and 5 show analysis of how these responses relate to the amount and level of design work expected in future employment.

Those who are more interested in a postgraduate design course are those who expect more and higher levels of design work in their careers. However, some of those who do expect to do substantial design tasks are also uninterested in further design study.

Qualitative analysis results

Since the number of responses was relatively small, the coding of each response for its thematic content was done manually. Table 6 shows the thematic analysis results.

To find out if the third of students giving these text responses are typical of the whole group, we analysed the distribution of the top three themes in relation to the respondent attributes. Distributions by discipline and university are shown in Tables 7 and 8, arranged in decreasing order of the number of respondents in each category.

The proportion of comments does not vary significantly from the average by discipline or institution, taking into account the sample sizes. However, University 2 had a larger number of comments on the need for more applied knowledge, while at university 1, there were more comments

on the poor quality of design teaching, and university 3 had more comments on insufficient design in the course. These differences may reflect different curriculum design and are worth investigating further, to relate them to specific programs.

Similar analyses in relation to grade expectations, interest in design, work expectations showed no discernable patterns.

Triangulation

We obtained data on the actual distribution of degrees awarded in mechanical engineering disciplines for universities 1 and 2, to compare with the reported student expectations. The results are shown in Table 9.

The responses show a broadly similar pattern to the proportion of actual degrees awarded in universities 1 and 2. There are no indications that the sample is skewed towards high or low achievers. The data is consistent with an assumption that the respondents are typical mechanical engineering students who are realistic about their own abilities.

Table 6 Thematic analysis results

Theme	students commenting on this theme
need more applied knowledge in course	20
poor design teaching	14
not enough design in course	11
enjoyed course	7
insufficient depth in discipline	6
poor learning facilities	4
drawing and CAD	4
course workload too heavy	3
career	3
unfair	2
design well taught	2
poor course structure	2
too easy	2
wants PG design course	1

Table 7 distribution of comments by discipline

Discipline	Q9: comment given	Q9: no comment	total	%	need more applied knowledge in course	poor design teaching	not enough design in course
4 : mechanical	37	71	108	34.3%	10	5	9
5 : mechatronics	17	22	39	43.6%	8	5	1
1 : aerospace	10	25	35	28.6%	2	3	0
2 : biomedical	2	6	8	25.0%	0	0	1
7 : other	0	8	8	0.0%	0	0	0
3 : materials	1	3	4	25.0%	0	1	0
6 : naval	2	2	4	50.0%	0	0	0

Table 8 distribution of comments by university

University	Q9: comment given	Q9: no comment	total	%	need more applied knowledge in course	poor design teaching	not enough design in course
1 :	23	42	65	35.4%	1	7	1
2 :	19	22	41	46.3%	11	3	1
3 :	11	18	29	37.9%	3	1	6
4 :	5	24	29	17.2%	2	1	1
5 :	5	16	21	23.8%	3	0	1
6 :	4	9	13	30.8%	0	2	0
7 :	2	5	7	28.6%	0	0	1
8 :	0	1	1	0.0%	0	0	0

Table 9. Reported expectations of degree grades and actual awards

degree grade	reported expectations for university 1 respondents	% of actual degrees awarded in university 1	reported expectations for university 2 respondents	% of actual degrees awarded in university 2	reported expectations for all universities
Hons 1	31%	38%	22%	27%	29%
Hons 2/1	20%	29%	17%	24%	25%
Hons 2/2	14%	14%	27%	22%	17%
Good pass	28%	19%	24%	14%	22%
Borderline pass	8%		10%	13%	6%

III. INTERPRETATION AND IMPLICATIONS

This study has provided a snapshot analysis of final year students' perspective on mechanical engineering design across Australian universities in 2009.

The analysis of the survey responses indicates that the majority of new graduates in mechanical engineering have a substantial interest in engineering design and are expecting it to be a significant component of their future careers. However relatively few see this as the primary focus of their careers and few are interested in further study in this area unless it is sponsored by their employers. Project management is also a significant interest, and may be seen as an alternative career path to technical design specialism. This is consistent with other research, which indicates that engineering professional work involves a wide variety of activities and skills beyond technical design (Trevelyan and Tilli, 2008). So if employers are dissatisfied with the graduates' abilities in engineering design, the results of this survey would indicate that sponsoring further study in this area could be a viable solution.

In the text responses to an open question about their degree programs, the dominant theme is a need for more applied knowledge in university undergraduate degree programs. There is also concern about the amount and quality of design teaching.

The design teaching quantity and quality comments occur across all responding institutions. But respondents from one university made proportionally more comments than those in other universities about there being too little applied knowledge in their undergraduate courses. A more rigorous and extensive study would be needed to support any conclusions about the university's degree program. Also, such effects can be transitory. Several universities are in the process of redesigning their engineering degree programs. Negative comments could be the result of temporary teething troubles with new curricula, or legacy effects from older programs that are being phased out.

Although there are some positive comments, the majority of comments are negative. Any interpretation of the thematic analysis results needs to take into account the possibility that those students who are happy with their courses felt no need to make any specific comment.

Overall, we can conclude from this study that:

1. If employers need higher levels of mechanical engineering design expertise in graduate engineers, then sponsoring participation in specialist postgraduate engineering design courses is a potential solution.

2. It is not clear whether universities are yet able to provide sufficient quality and quantity in engineering design teaching. A more rigorous longitudinal study, taking into account recent curriculum change, is needed to determine whether Australian universities are improving their capacity to teach mechanical engineering design at undergraduate and postgraduate levels.

A more thorough study of students' perceptions of engineering design education, using similar methods to those used in this study, could mine the qualitative data already gathered in national and institutional surveys to provide a longitudinal analysis of progress.

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Appendix 1: Questionnaire

This survey is for the purpose of assessing the level of interest in mechanical-engineering design amongst current fourth-year students in Australian Universities. The principal purpose is to try to match the aims and content of current design courses with your foreseeable or intended career paths and the knowledge you will need. Please do not conclude that, since you are not interested in a design career, this does not apply to you. One of the aims will be to help develop a balanced design course which will best equip students for general industrial work, as well as perhaps a different course for those who would like to make design a significant part of their career.

The survey is intended to include students in mechanical engineering, broadly defined, including manufacturing, mechatronics, robotics, naval architecture, automobile, aerospace, etc., as well as double-degree students majoring in mechanical engineering.

The survey is to be completed on-line to make it easy for you to respond and to facilitate the statistical analysis of results. The success of the survey depends on a truthful, thoughtful and complete response from a large majority of students, so please do everything you can to assist and to persuade your colleagues to contribute.

1. Please select your university from the drop-down list below:

2. What course did you take: (type in keyword, e.g. "mechatronics", "manufacturing", etc)

3. What is your current interest in engineering design resulting from your course:

- None
- Little
- Some
- Significant
- Major

4. What is the likely grading of your performance in the undergraduate course:

- Hons I
- Hons 2/1
- Hons 2/2
- Good pass
- Borderline pass

5. What is your perception of your need for engineering design in your intended employment:

- None
- Little
- Some
- Significant
- Major

6. What is your assessment of the level of design knowledge you are likely to require for your intended work in industry:

- None
- Basic design tasks (e.g. a belt drive, redesign of a failed shaft)
- Substantial design tasks (e.g. design an upgrade of an existing machine to perform an established function, using off-the-shelf motors, gearboxes, etc)
- High level design tasks (e.g. creative design of original plant or equipment, beginning with concept development)
- Specialised career designer

7. What is your level of interest in working in project management?

- None
- Little
- Some
- Significant
- Major

8. If there were a postgraduate course in mechanical-engineering design available in Australia, what would be your level of interest:

- Definitely not interested
- Unlikely to enrol
- Would enrol if sponsored by employer
- Would seriously consider enrolling
- Very interested, would definitely enrol

9. Any relevant comment on the current course and/or its structure at your university or any other aspect?