Extending the 2015 Capstone Design Survey: Data from Australia and New Zealand

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Abstract

Capstone design courses are common in engineering design programs, but they vary substantially across institution and department. The goal of the decennial capstone design survey initiative has been to capture data from capstone design courses every ten years to identify current practices and changes over time. The 1994, 2005, and 2015 surveys have focused almost exclusively on capstone programs within the United States. This paper documents an initial extension of the 2015 survey to Australia and New Zealand to identify how capstone courses are implemented outside the United States and what strategies can be shared across countries. As in their United States counterpart, the 2015 Australia and New Zealand surveys included quantitative, categorical, and open-ended questions on capstone course information, pedagogy, evaluation, faculty, students, projects and teams, expenses and funding, sponsors, and respondent experience and opinion. This paper presents highlights of the resulting data by country, drawing comparisons where possible across countries: Australia, New Zealand, and the United States. Overall, the essence of capstone design courses in the three countries is quite similar; there are variations in implementation details, but these are often greater across programs or institutions than they are across nations. Collecting data about capstone design practices in different nations is an important step toward the larger goals of understanding and improving capstone design education globally.

1. Introduction

Capstone design courses provide a major design experience for engineering students, usually during their final year of undergraduate study. Although these courses are common across engineering programs in the United States, they vary substantially in the way they are implemented. The first United States survey of capstone courses was conducted in 1994 in an effort to better understand current practices at the time.[1] This was followed in both 2005 and 2015 with subsequent nationwide surveys[2,3] using many of the same questions and including some new categorical and open-ended response questions. Taken together, the results capture trends over time and document strategies and changes in capstone design education across the United States.

In addition to collecting longitudinal data, a logical extension of the capstone survey initiative is to collect data from other countries, to explore how capstone design education implementation varies around the globe. Australia and New Zealand were chosen as the first countries in this survey expansion plan, in part to maximize geographic distance from the United States while minimizing language barriers. Moreover, there is an existing body of work with reference to engineering capstone design in both countries. Several other publications discuss singular engineering capstone programs in Australia and New Zealand.[4,5] An additional report[6] addresses assessment practices at engineering capstone design courses at many institutions in Australia, summarizing the results of a multi-year grant-funded research project.

There seems to be a growing initiative in Australia to study capstone curriculum across a broad range of disciplines and to connect the community of capstone educators nationally. The website capstonecurriulum.com.au provides resources, reports, and blog posts about capstone course pedagogy, assessment, and structure.[7] A recent paper[8] on capstone curriculum provides rich data across multiple disciplines from several countries. The survey covered eight different countries (including the United States and New Zealand), though nearly 80% of the 229 survey respondents were from Australia. The paper includes many comparisons across different structures and emphases of capstone courses, in some cases sorted by discipline. The extracted data about engineering capstone programs (13% of respondents, which includes engineering and information communication technology (ICT) combined) are included where possible for reference in Section 3 below.

2. Methodology

The 2015 United States survey questions were first reviewed and revised by several native Australian and New Zealand engineering educators to ensure relevant terminology. The updated survey was then implemented using SurveyMonkey (an online survey tool), with requests sent via email to representatives of all identified accredited engineering programs in both Australia (345 programs at 47 institutions, per Engineering Australia accreditation in 2015) and New Zealand (35 programs at 6 institutions, per IPENZ accreditation in 2015).

The survey captured data from 31 respondents at 20 institutions in Australia and 8 respondents at 5 institutions in New Zealand. These response rates are comparable to those of the previous implementation in the United States (522 respondents at 256 institutions for the 2015 survey), when normalized by the total number of institutions and accredited programs in each country. All of the Australia and New Zealand respondents had a capstone design course. The results of the online survey (responses plus comments) were compiled and processed electronically. The approach used for analyzing the open-ended responses loosely followed an open coding and integration methodology.[9]

3. Results and Discussion

This section details and discusses the results of the 2015 Australia and New Zealand surveys, both quantitative and qualitative. Data for both Australia and New Zealand are provided for each question; where possible, the Australia and New Zealand data are also presented in comparison with the relevant data from the 2015 survey in the United States (hereafter referred to as "2015USA"). The results and discussion are organized into eight main sub-sections roughly following the order in which these topics were asked in the survey instrument itself: respondent profile, course logistics, pedagogy, faculty and students, projects and teams, expenses and funding, sponsors, and experience/opinion. Where data sum to 100%, the results are typically shown in pie chart format, whereas for questions with multiple responses possible, the data are shown in bar charts or tables. The figures and tables are best viewed in color, but numbers are provided within charts and tables wherever feasible.

3.1 Respondent Information

Figure 1 shows the Australia and New Zealand respondents sorted by the closest engineering disciplinary grouping. The "Other" category included specific disciplines such as mining and maritime engineering, as well as responses that were across a school of engineering or otherwise could not be categorized. In contrast, the United States data from the 2015USA survey included these primary categories as well as Biomedical, Industrial, and Multidisciplinary (referring to collaboration across disciplines). The Australia survey also asked about accreditation type; 91% of 35 respondents noted the "Professional Engineer" designation.

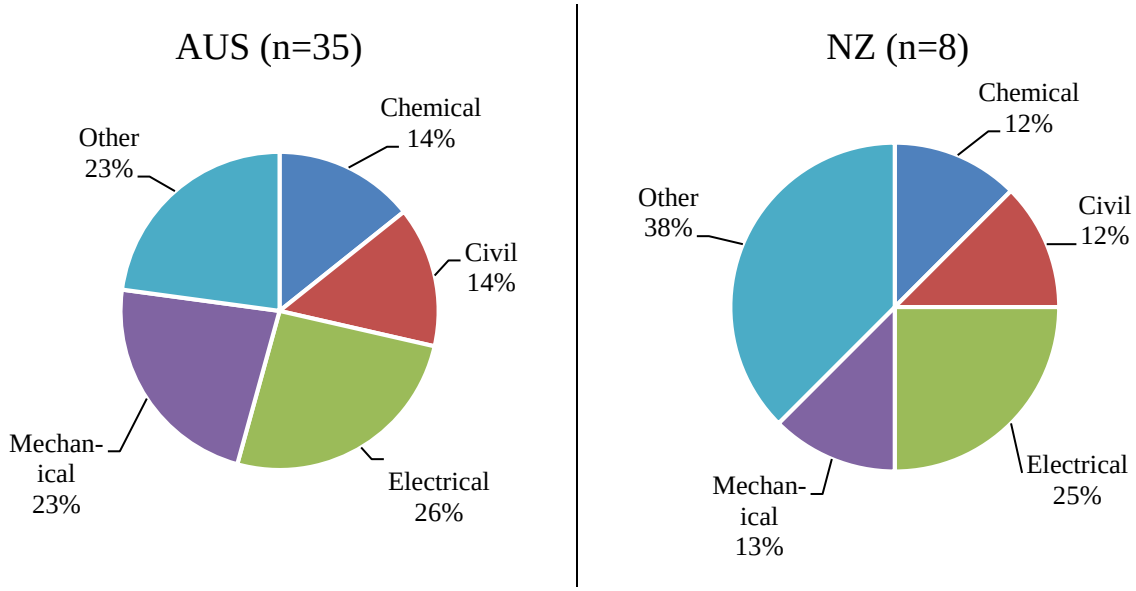

Figure 1 – Survey Respondents by Disciplinary Grouping

Figure 2 shows the Australia and New Zealand responses to the question "How many years has your capstone design course existed?" The Australia programs are more evenly distributed across the different age brackets, whereas the New Zealand programs are divided between much older and much younger programs (there were no New Zealand responses for age brackets from 15-39 years). Both countries have 20-25% of programs that are 50 or more years old; the oldest program for both countries had been in existence for 65 years in 2015. These data are in contrast to the 2015USA data in which only 7% of capstone programs were in the oldest (50+ years) age bracket. These data match those from the broader capstone survey in Australia by Lee and Loton[8], which reported that for Engineering/ICT programs, 88.5% were greater than 6 years old and 11.5% were less than 6 years old.

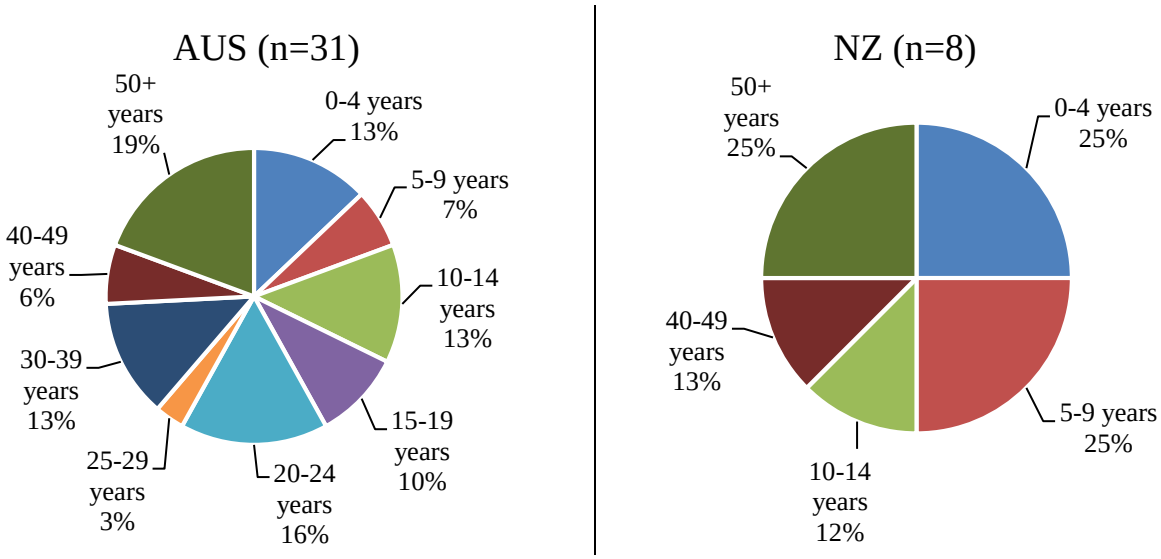

Figure 2 – Age of Capstone Design Courses

3.2 Course Information

Figure 3 shows responses from all three countries surveyed concerning the duration of their capstone design courses. The figure shows only responses related to trimester and semester schedules; an additional ten percent of United States respondents indicated course durations on the quarter system (with durations ranging from 1-4 quarters) but there were no comparable data from either Australia or New Zealand. Semester sequencing was the most common for all respondents and, of those, a sizable majority from all countries had courses that spanned two semesters. There were no major variations across country. Interestingly, the broader capstone survey by Lee and Loton[8] found that for their Engineering/ICT respondents, 46.2% had capstone design courses less than 15 weeks in duration, and 53.8% greater than 15 weeks, suggesting more semester-length capstone design courses across Australia than captured in this survey.

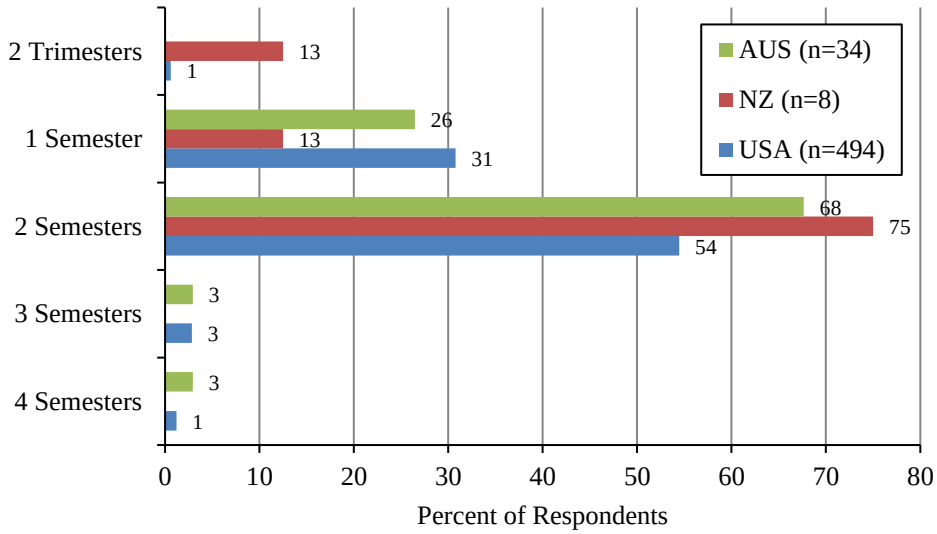

Figure 3 – Duration of Capstone Design Course Sequence

In both Australia and New Zealand, the ratio of credits associated with Capstone Design courses compared to the credits needed to graduate were surprisingly consistent within each country. Every single New Zealand respondent required 480 credits to graduate; one responding institution awarded 60 credits for the capstone design course and the remaining seven respondents gave 30 credits for completing the course. This latter value equates to roughly 6.3% of credits needed to graduate, which was similar to the data from Australia.

Figure 4 displays the sequence in which capstone design courses are administered in Australia, New Zealand, and the United States. While there was a fairly even split between "Class & Project Together" and "Project Only" in Australia, more New Zealand respondents favored a "Project Only" approach in their capstone design courses than something else. These data differ from the 2015USA data in which 68% of respondents ran the class and project together, and only 13% did project only. The two "Other" responses from New Zealand included a project supported by workshop/seminars, and the combination of an individual research project and group design project. The emphasis on project is corroborated by the broader capstone survey in Australia by Lee and Loton[8] who found that 100% of their Engineering/ICT respondents had the presence of project-based and/or problem-based learning in their capstone design courses.

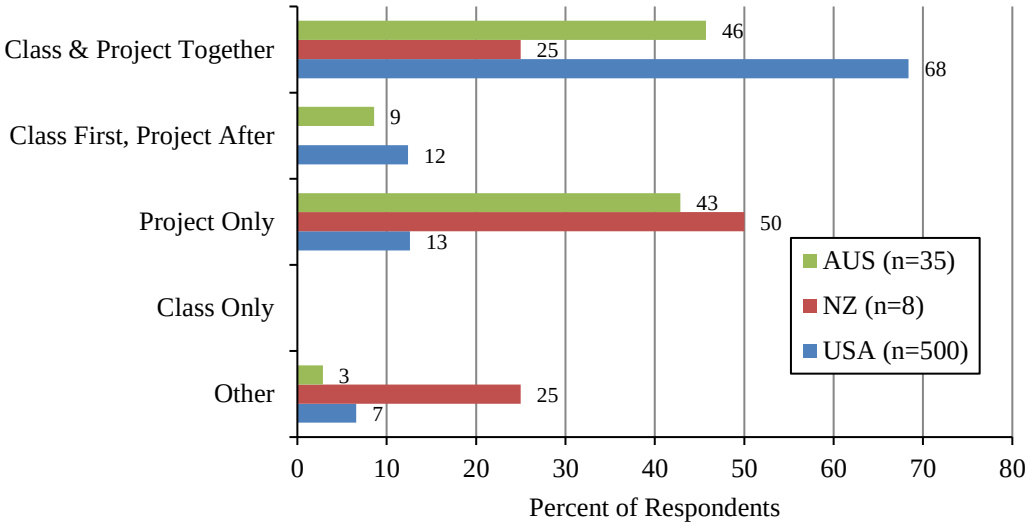

Figure 4 – Course Sequence of Capstone Design Courses

Capstone design courses spanned a wide variety of engineering disciplines, as shown in Table 1. There were similar trends across all three countries surveyed, including involvement of multiple departments within each capstone program. A notable difference can be seen in Electrical Engineering, which was included by over half of Australia's respondents, compared to the United States' and New Zealand's one-third. Also of note is New Zealand's large proportion of responses indicating "Other", which included responses such as Mechatronics, and Product Development. Note: the color-scale shading in the table is in 20% increments, such that values of 0-20% are shaded with the lightest color and values of 81-100% are shaded with the darkest color. This shading approach is used in subsequent tables as well to assist with data visualization.

Table 1 – Departments Involved in Capstone Design

	Percent of Respondents		
	AUS (n=35)	NZ (n=8)	USA (n=500)
Aero/Astro Eng.	17	13	8
Agricultural Eng.	0	13	3
Architectural Eng.	0	0	3
Art/Architecture/Design	0	0	2
Biological Eng.	0	13	5
Biomedical Eng.	29	0	15
Business/Marketing	3	0	4
Chemical Eng.	26	25	11
Civil Eng.	37	13	20
Communication	9	0	1
Computer Eng.	37	38	22
Computer Sci.	6	13	11
Electrical Eng.	54	38	32
Eng. Mechanics	6	13	1
Eng. Sci./General Eng.	9	13	5
Eng. Technology	6	0	5
Environmental Eng.	17	13	11
Health/Medical/Nursing	0	0	2
Humanities	0	0	1
Industrial/Systems Eng.	3	13	11
Materials Sci./Eng.	6	25	7
Mathematics/Statistics	0	0	1
Mechanical Eng.	46	38	36
Natural Sciences	0	0	2
Nuclear Eng.	0	0	2
Ocean Eng.	3	0	1
Other	23	63	12
Social Sciences	0	0	1

3.3 Pedagogy and Evaluation

Capstone Design courses covered many topics, as shown in Table 2: in lecture (L), in an individual assignment (IA), or as part of the team project (TP). In all three countries, team projects were the most common place for topical coverage. United States respondents were most consistent in their coverage of topics in the team project, with many topics covered by 80% or more of the respondents. New Zealand and United States respondents included topics more often in lecture than did respondents from Australia; no topic in Australia was covered in lecture by more than half of the respondents. New Zealand respondents tended not to cover topics through individual assignments, but the large number of "0" responses in the "not covered " (NC) column suggests that some topics were covered by all respondents in at least some aspect of the capstone design experience.

Table 2 – Topics Covered in Capstone Design

		Percent of Respondents											
		AUS				NZ				USA			
TOPIC	n*	L	IA	TP	NC	L	IA	TP	NC	L	IA	TP	NC
Analysis tools	28, 7, 450	43	46	68	7	14	0	71	29	45	25	83	9
CAD design and layout	25, 7, 440	16	32	60	20	14	0	57	43	23	18	67	28
Concept generation	28, 7, 453	32	36	68	7	14	0	57	29	62	23	80	7
Concept selection	31, 7, 451	32	39	65	6	0	0	57	43	61	24	81	7
Creativity/problem solving	30, 7, 462	40	47	70	3	43	29	71	0	53	24	80	6
Decision making	30, 7, 458	33	43	70	10	29	14	71	0	58	19	80	7
Developing functional specs	25, 7, 455	40	44	64	20	14	14	43	57	56	24	77	12
Engineering ethics	26, 7, 455	50	38	38	19	29	0	29	43	69	30	45	12
IP/patents	24, 7, 440	33	29	33	42	29	0	29	57	51	12	33	37
Leadership	25, 7, 443	20	28	80	12	29	0	71	14	47	14	64	19
Optimization	25, 7, 430	32	32	68	20	0	14	57	29	36	12	57	32
Oral communication	31, 8, 469	42	58	65	0	63	25	63	0	57	29	89	1
Project planning/scheduling	29, 7, 468	55	38	72	3	57	14	71	0	67	26	89	2
Prototyping and testing	28, 7, 445	11	39	43	36	14	0	43	43	41	16	71	22
Sketching	28, 7, 422	18	25	43	32	0	0	57	43	18	14	46	44
Standards and regulations	28, 7, 448	43	54	68	7	0	14	43	43	59	17	70	10
Sustainability	26, 7, 434	31	31	58	23	29	0	71	14	44	13	53	27
Team building/teamwork	26, 7, 463	42	19	81	8	43	0	71	14	57	21	81	5
Written communication	30, 8, 472	43	60	70	3	63	13	75	0	56	42	91	1

* n in order: Australia, New Zealand, and United States

Regarding deliverables at the end of the capstone design experience, the vast majority of respondents (15 of 20 in AUS, 6 of 7 in NZ) required a final report. Just under half of respondents in both countries required either a presentation of some sort and/or a final product. Other deliverables mentioned included evidence of the design process and design justification.

One open-ended question asked respondents how they balanced "product versus process" in their capstone design courses. Those responses that could be were coded by specific content theme based on numerical value provided (51-74% = "emphasis", 75-94% = "heavy emphasis", 95-100% = "all") or interpretation of the response by the researchers based on wording and adjectives. Figure 5 shows the distribution of results from Australia and New Zealand. Although the sample size is small, responses from New Zealand were evenly distributed between heavy emphasis on either product or process, and equal emphasis on both. In Australia, responses leaned towards emphasis on process, with a sizable percentage also noting the two were equally important. This data pattern matches that reported in the 2015USA survey as well.

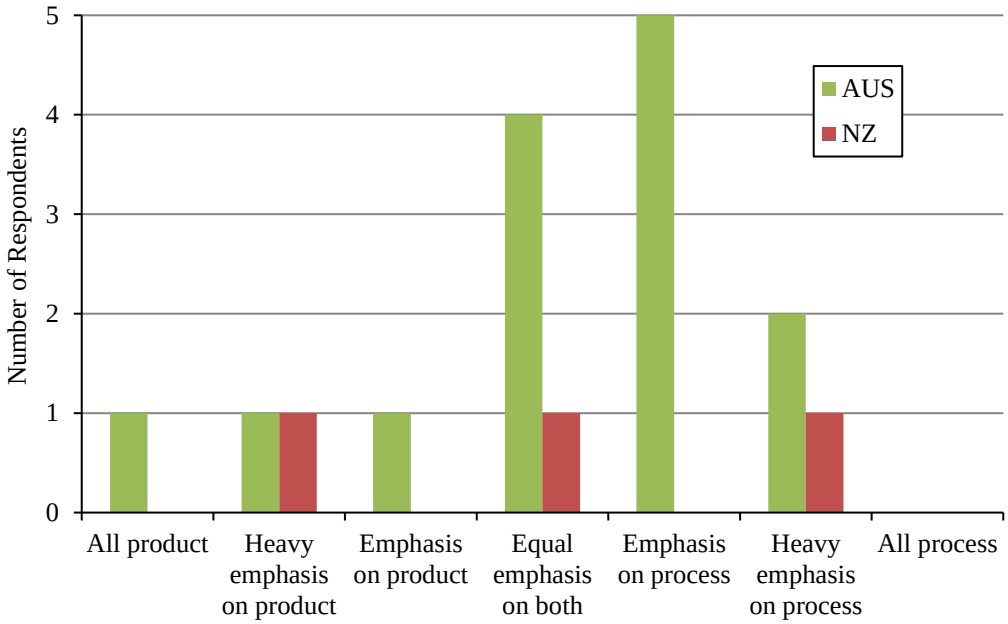

Figure 5 – Product versus Process in Capstone Design

Evaluation of student performance was informed by several groups, as shown in Figure 6. Australia and New Zealand followed similar approaches, with course instructors having the highest input on grades, and national competition judges having the lowest influence. However, more respondents from Australia indicated project advisors and coaches having a high input on course grade than those from New Zealand. Across both countries shown here, as well as in the United States, grades were most commonly assigned individually based on individual and team performance. This result was especially prominent in the United States data.

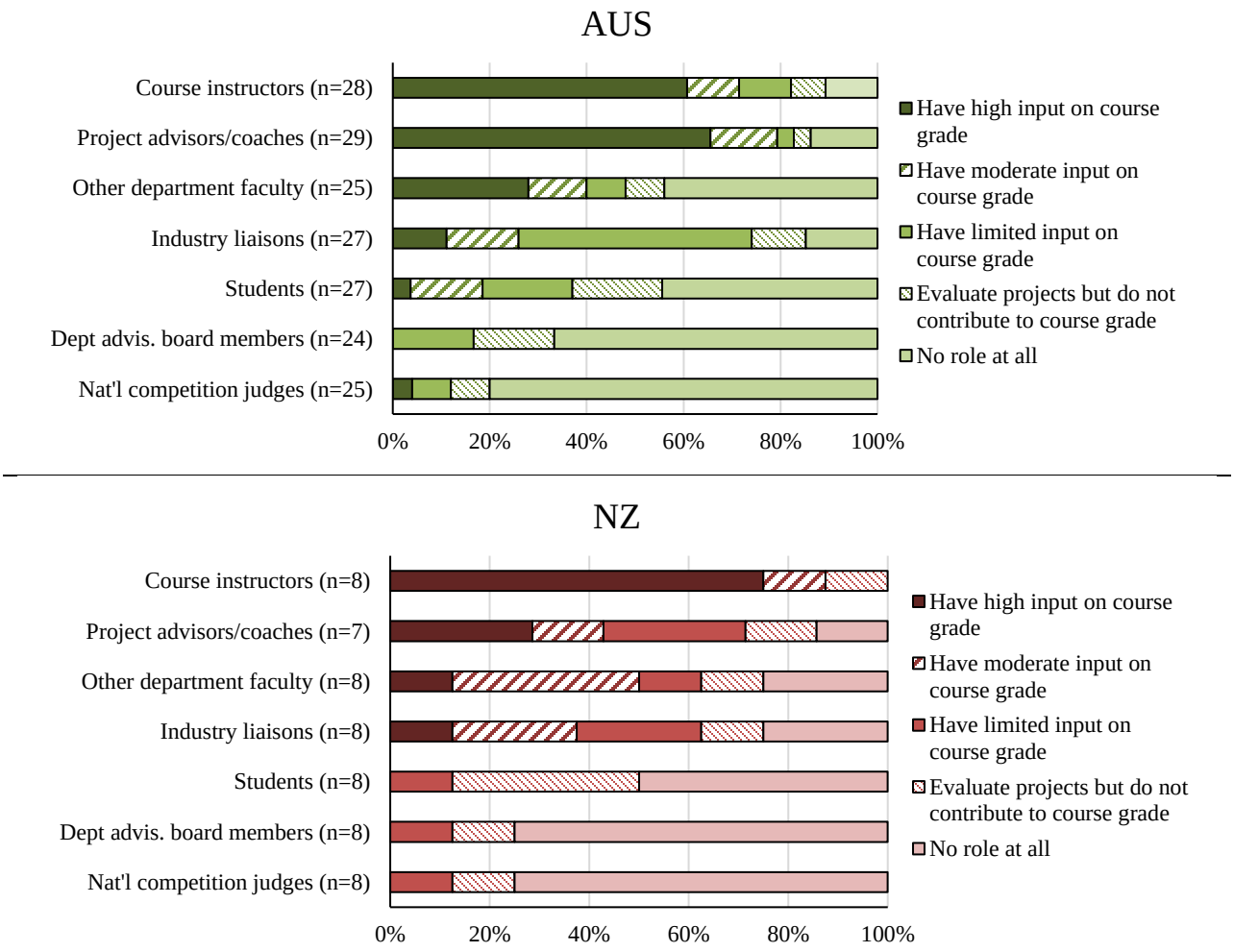

Figure 6 – Groups Responsible for Evaluating Student Work in Capstone Design

3.4 Students and Faculty

Figure 7 shows the average number of students per capstone course cycle, divided into brackets. (Note: both countries lacked responses in at least one bracket.) While a few programs had small numbers of students, the majority of both Australia and New Zealand respondents indicated 50 or more students in their capstone course cycle, and sometimes substantially higher than that; the largest reported number from an Australia respondent was 600 students. These sizable numbers contrast with the 2015USA data, in which less than one-third of respondents reported student numbers greater than 50, and only 12% had more than 100 students per course. In New Zealand, 100% of respondents noted that their students were undergraduates in their final year. Australia respondents were more mixed: of 31 respondents, only 68% reported undergraduates in their final year, and 16% noted a mix of undergraduate and graduate students.

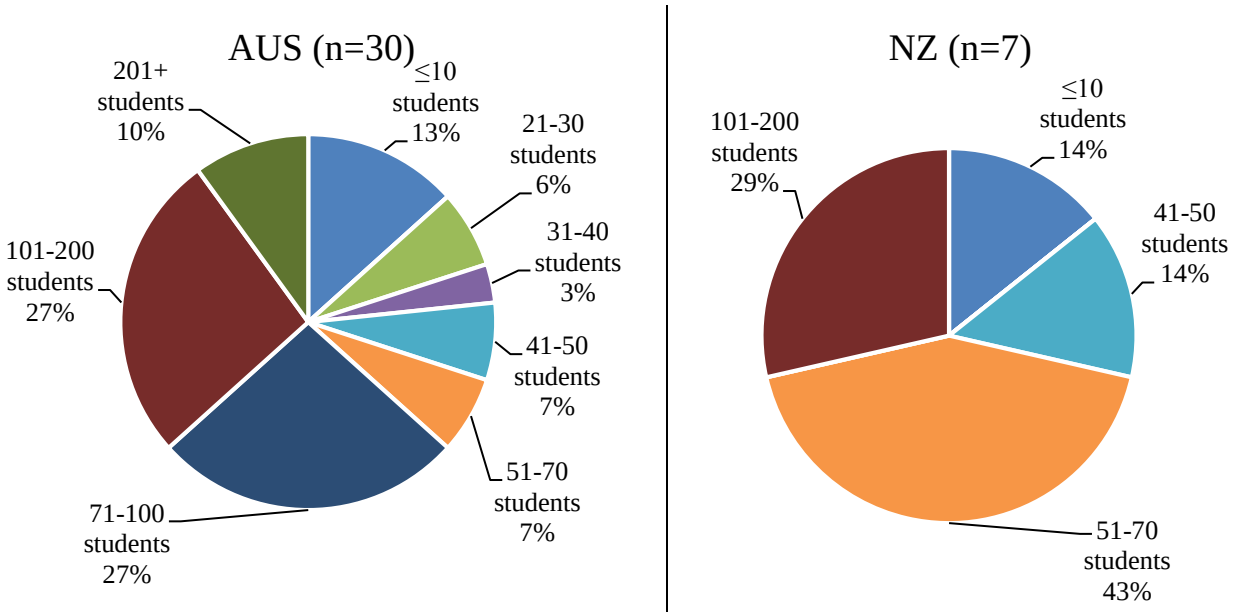

Figure 7 - Average Number of Students per Capstone Course Cycle

Figure 8 shows the average number of hours students were expected to spend on their capstone design course each week. The 10-12 hour bracket was the most common choice for both Australia and New Zealand respondents, as well as for the 2015USA respondents. Worth noting, however, are those AUS and NZ programs that expected students to spend more than 16 or even 20 hours per week; in the 2015USA data, only 4% of respondents selected either of these categories.

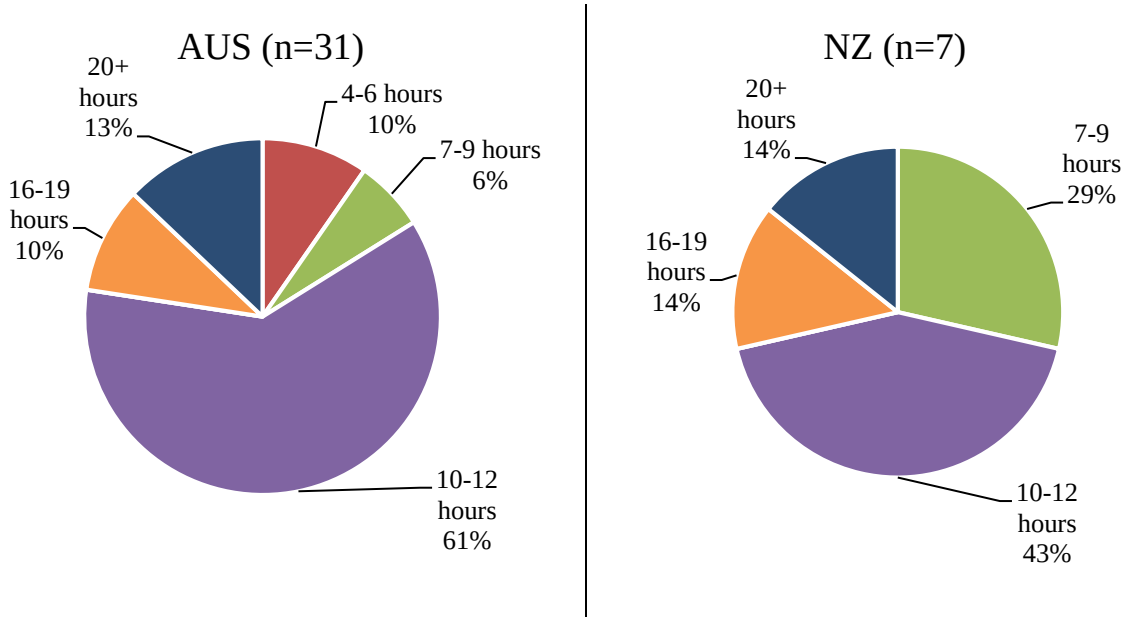

Figure 8 – Expected Student Hours per Week Working on Capstone Design

Respondents reported using various approaches to ensuring student work time. In both Australia (n=30) and New Zealand (n=6), a third of respondents noted that arranging work time was

entirely the students' responsibility. On the flip side, the approach of capstone courses including a lab section or similar time specifically for doing most/all of the project was noted by only 7% of Australia respondents and no New Zealand respondents. The hybrid option of having some of class time set aside for project work but leaving students responsible for finding other times was the most popular choice in Australia (40%) as well as in the 2015USA data (52% of n=461), and was also selected by a third of the New Zealand respondents.

On the faculty side, Figure 9 shows the number of faculty receiving teaching credit for capstone design in Australia, New Zealand, and the United States. It is worth noting that most programs in New Zealand and about 40% of responding programs in Australia gave capstone teaching credit to at least 6 if not more than 20 faculty members. In contrast, in the United States, nearly 40% of responding programs provided capstone teaching credit to only a single faculty member. In all three countries, however, about 90% of respondents (AUS n=31, NZ n=8, USA n=459) reported that capstone design was considered as normal teaching activity – rather than scholarship or service - with regard to promotion and tenure.

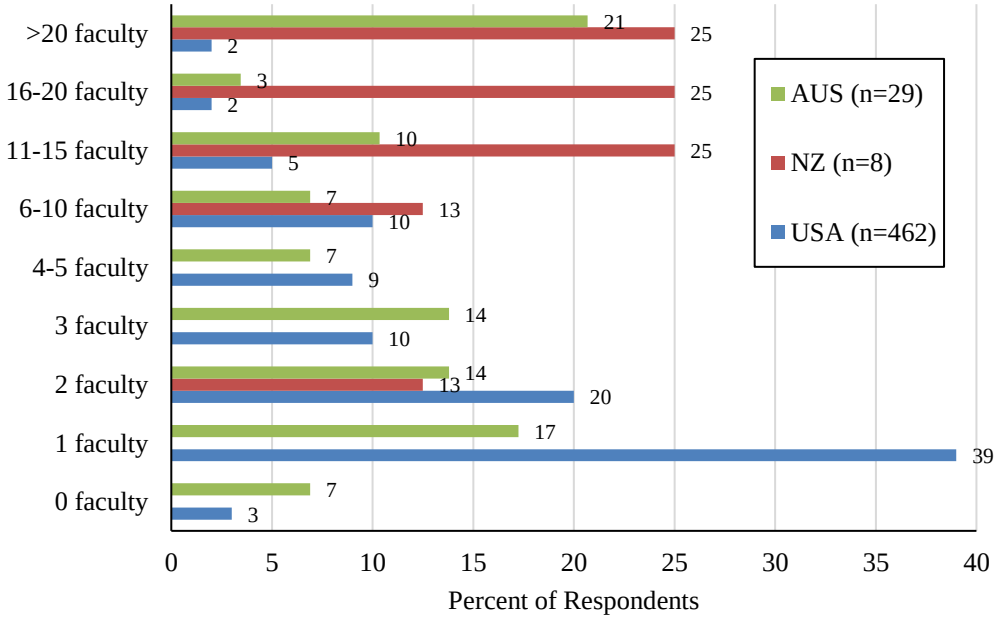

Figure 9 – Number of Faculty Receiving Teaching Credit for Capstone Design

Another way to present these data is as percentage of faculty in a given department who receive teaching credit for capstone design, as shown for Australia and New Zealand in Figure 10. Most striking in these pie charts is that nearly two-thirds of New Zealand respondents provided capstone teaching credit to more than 75% of their faculty, thus indicating the high level of faculty involvement in capstone design. The data are more spread out for Australia respondents, but more than a third of respondents gave teaching credit to at least half of their faculty. In the 2015USA data, on the other hand, only 8% of respondents provided capstone teaching credit to 100% of their faculty, whereas 42% provided such credit to 10% or fewer of their faculty.

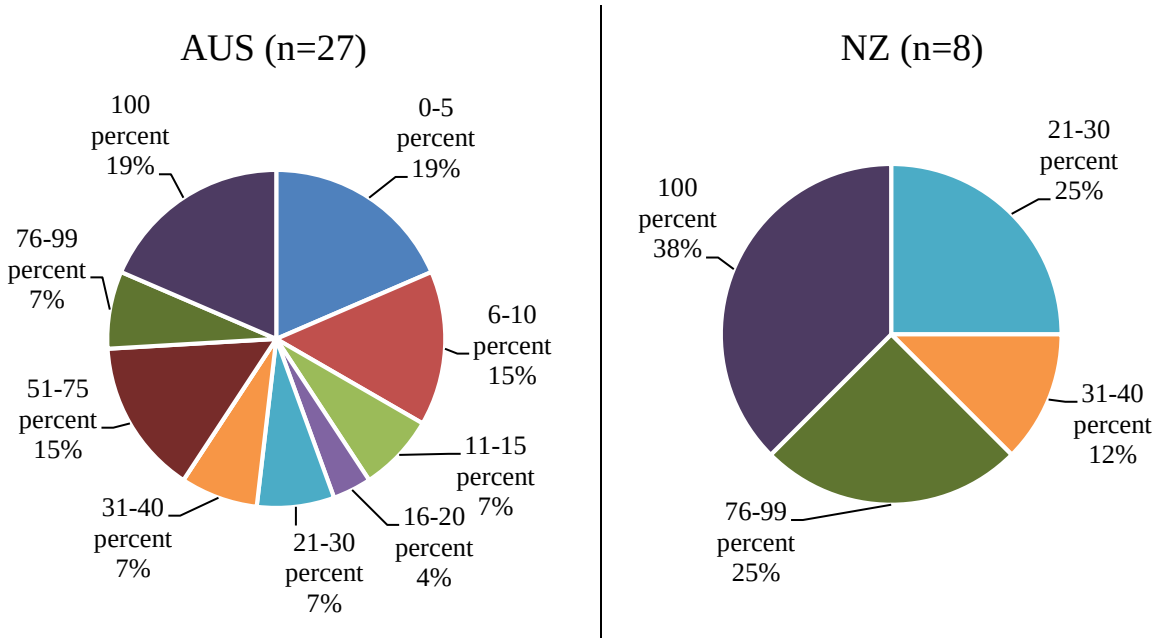

Figure 10 – Percent of Faculty Receiving Teaching Credit for Capstone Design

Combining the student and faculty data, Figure 11 shows the average student/faculty ratio for Australia and New Zealand respondents. Clearly, a student/faculty ratio of 10 or less was the norm for both sets of respondents, and 5 or less was quite common as well. (In the 2015USA data, by contrast, only a third of 440 respondents noted a student/faculty ratio of 10 or less.)

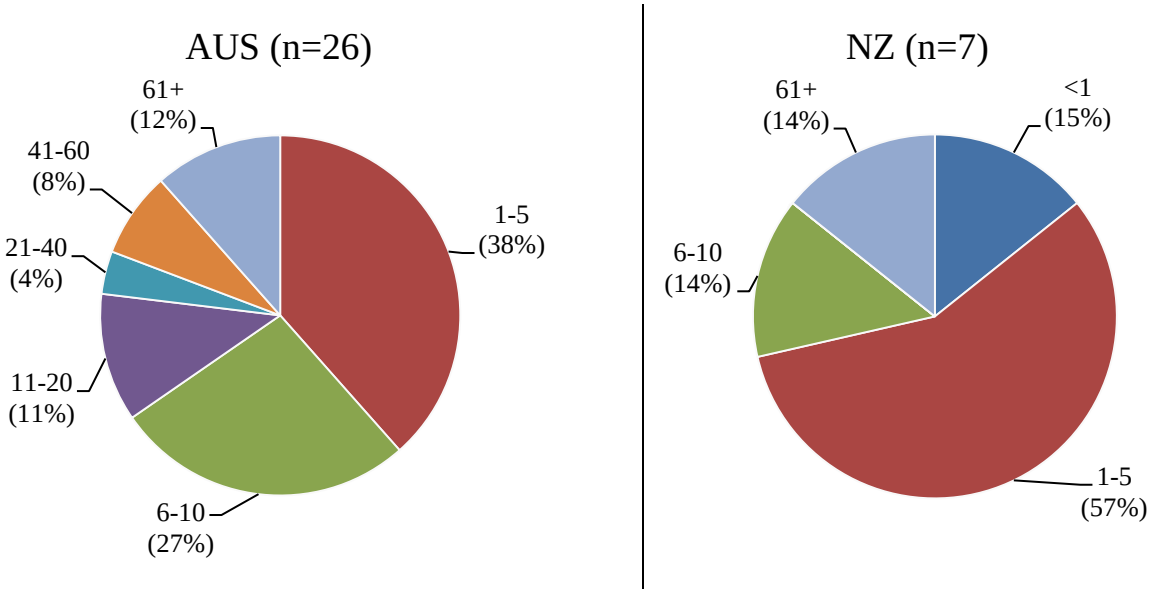

Figure 11 – Student/Faculty Ratio

Respondents were asked "If you involve multiple faculty in your capstone design course, how do you structure and manage their involvement?" Most of the responses indicated either a shared management structure, a focus on faculty/team interaction, or a minimal level of involvement. A few respondents acknowledged that such coordination was difficult. Table 3 shows some

representative responses from Australia and New Zealand; respondent identifiers are noted in brackets after the quotes.

Table 3 – Representative Responses for Coordinating Multiple Faculty

Australia	*"They are simply guest lecturers."* [AUS12]
	"With difficulty!!" [AUS18]
	"Other faculty act as mentors to design problems in their area of expertise. They attend (when I can get them to) student presentations throughout the year. Usually just one if I'm lucky. They are also responsible for assessing the technical merit of the student's final report. The course coordinator moderates this mark." [AUS31]
New Zealand	*"One faculty member runs the course and does the bulk of the assessment. Other faculty members supervise student design groups."* [NZ3]
	"Informally." [NZ8]

3.5 Projects and Teams

Figure 12 displays the range of sources of capstone design projects for Australia, New Zealand, and the United States. Faculty research and industry/government were the two most popular choices. Strikingly, 100% of respondents from New Zealand reported use of faculty research as a project source, compared to Australia's 76%, and the United States' 53%. Additionally, service learning was mentioned by only United States respondents.

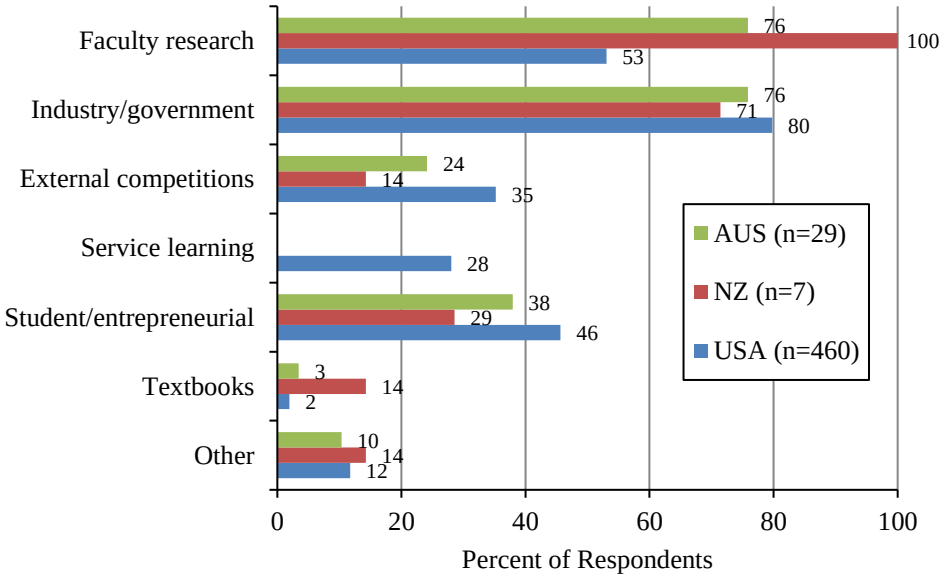

Figure 12 – Sources of Projects in Capstone Design

As shown in Figure 13, the number of projects per capstone course cycle is much larger in Australia and New Zealand compared to the U.S. In New Zealand, 43% of respondents had over 40 projects, as did 36% of Australia's respondents (with a reported maximum of 400 in Australia). This dwarfs the 4% of United States respondents falling in the same category. These data are likely due to the high proportion of individual projects in these countries. Assigning one team per capstone design project was largely favored by all three countries (AUS: 57% of n=28,

NZ: 83% of n=6, USA: 73% of n=458). In Australia, a quarter of the 28 respondents also indicated 10 or more teams per project.

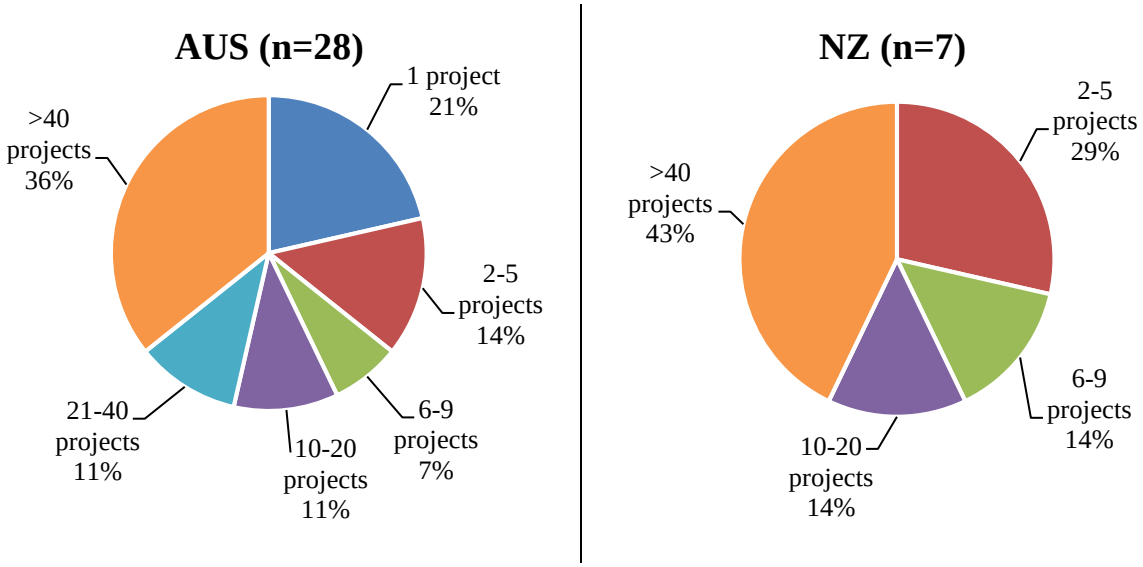

Figure 13 – Number of Projects per Capstone Course Cycle

Respondents noted multiple approaches for finding capstone design projects. Their responses mapped well to the categories identified from the 2015USA survey, especially the following: external contacts, internal sources, marketing, pre-fab, and criteria-based. Table 4 shows some representative responses from both Australia and New Zealand across these categories.

Table 4 – Representative Responses for Finding Capstone Design Projects

Australia	*"Staff involved in supervision will provide project topics based on their research or industrial experience."* [AUS11]
	"Approach academic staff and local industry." [AUS17]
	"Contemporary engineering projects in Australia. Management of residuals from coal seam gas, enhancing value of agribusinesses through waste recovery, second generation biofuels, urban water and waste management." [AUS21]
	"I take examples from things I have done. FSAE provides me with many good examples." [AUS25]
New Zealand	*"Based on faculty members research and/or experience."* [NZ3]
	"A dedicated part-time person is employed to approach industry - they themselves being a company owner and prior project sponsor. Also use of faculty research industrial collaborators." [NZ4]
	"Call for interest to local companies - we also invite industry to the final presentations and utilise local government industry engagement staff." [NZ5]
	"Industry contact / student ideas / or my own ideas" [NZ7]

Having identified sources for potential projects, respondents employed multiple strategies to select projects for their courses. The themes from Australia and New Zealand included educational relevance, scope/depth, resource availability, creativity/design, and professional relevance. Table 5 includes some representative responses across these themes. Many

respondents also provided information about who does the selecting; in all cases the responses indicated either the capstone course instructor or the supervising faculty member or both.

Table 5 – Representative Responses for Selecting/Vetting Capstone Design Projects

Australia	*"Must value add students learning experience and be relevant to functioning as a professional."* [AUS20]
	"Scope, degree of difficulty, availability of appropriate supervisors, resource implications and degree of support and sponsorship offered by industrial partners." [AUS27]
	"Projects must have sufficient depth to distribute the work to 4 reasonably competent final year students. It should have the potential to result in a physical prototype and the client should be willing to support the students in their learning through attending presentations, providing on-site meetings with student teams. The projects should have a creative element to them and not simply be adaptive design problems." [AUS31]
New Zealand	*"Area of specialisation eg. Bioprocessing, energy or classic chemical engineering processes."* [NZ3]
	"Size, complexity, availability of materials and technical support, cost." [NZ8]

A majority of teams in the countries surveyed were departmental or composed of individual students, as shown in Figure 14. Very few capstone design teams in Australia or New Zealand participated in multidepartmental teams, and no respondents from these two countries mentioned teams beyond engineering.

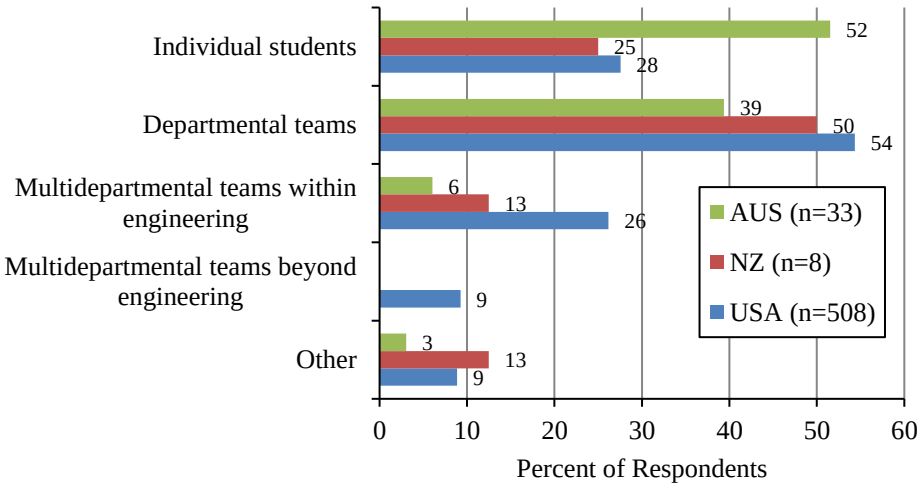

Figure 14 – Types of Teams in Capstone Design

Figure 15 shows the number of students per capstone team from all three countries. It is clear from this chart that teams tend to be smaller in Australia and New Zealand compared to the United States. None of the respondents from New Zealand reported any teams larger than four students, and while the Australia data were more evenly distributed, they showed a much higher percentage of single student teams than did the United States.

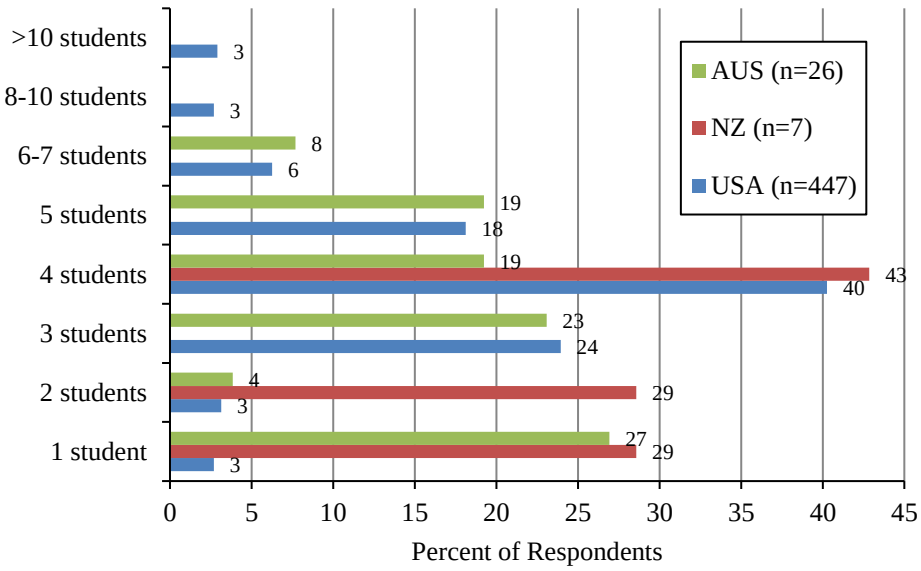

Figure 15 – Average Number of Students per Capstone Team

Respondents were also asked about their method of assigning students to teams. Roughly two-thirds of respondents from each of the three countries surveyed reported student choice, followed closely by instructor choice and matching student skills to the project. Many respondents chose more than one method, suggesting that several factors influence the formation of teams.

3.6 Expenses and Funding

Table 6 shows the types of capstone design expenses reported by respondents from Australia, New Zealand, and the United States. Hardware and project supplies were common in all three countries, and software was common in Australia and the United States Faculty time was the most frequently reported expense type in Australia. The "Other" response from New Zealand was fabrication costs.

Table 6 – Types of Expenses

	Percent of Respondents		
	AUS (n=29)	NZ (n=7)	US (n=465)
Hardware	62	86	71
Software	69	43	68
Travel	14	14	46
Project Supplies	62	86	75
Course Supplies	10	0	28
Faculty Time	79	29	47
External Consultants	21	0	9
Institutional Overhead	38	14	20
Development Support	28	0	14
Other	0	14	10

Figure 16 show the average breakeven cost per capstone project for both Australia and New Zealand. For ease of comparison, the values were converted from their original format (AUS$ and NZ$) to equivalent US$ based on the exchange rate in November 2015. Although there were a few outliers with higher average breakeven costs, the vast majority of Australia respondents had average breakeven costs less than $2000US, and all but one of the New Zealand respondents had average breakeven costs less than $1000US. Similarly, 250 of the 325 respondents in the 2015USA survey had breakeven costs less than $2000, and 200 of those reported costs less than $1000.

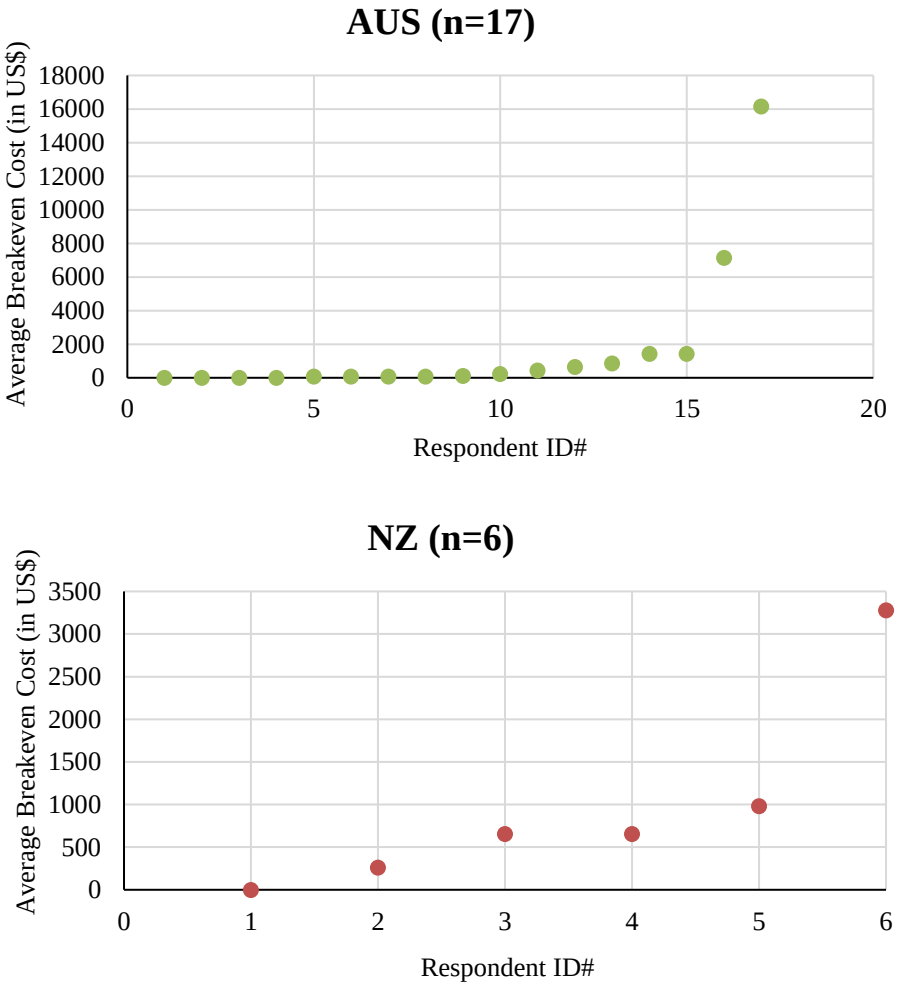

Figure 16 – Average Breakeven Cost (in US$) per Capstone Project

Respondents from all three countries reported a variety of different sources for project funding, as shown in Figure 17. In all cases, 70% or more of respondents received departmental funding for at least some capstone design projects. Nearly 60% of New Zealand and United States respondents reported funding from industry, but only 28% of Australia respondents did. Institution-level funding was also a prominent source for respondents from all three countries.

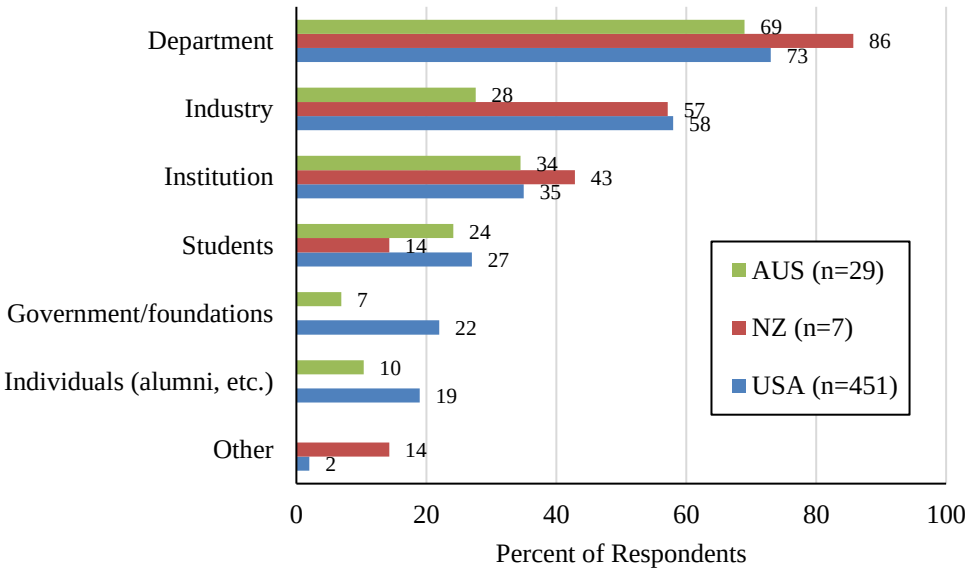

Figure 17 – Funding Sources

A subsequent question on the survey asked respondents to note the average, minimum, and maximum funding that external sponsors provided. As shown in Figure 18, only one-third of Australia respondents received any funding from external sponsors. Comparatively, New Zealand respondents often received between $4,000 and $5,000 from external sponsors, and only 20% of respondents received $0. In the 2015USA data, nearly 10% of responses exceeded the $12,000 maximum seen in Figure 18 below, and only 16% indicated no external funding. Values from all countries are reported in United States dollars for the sake of comparison.

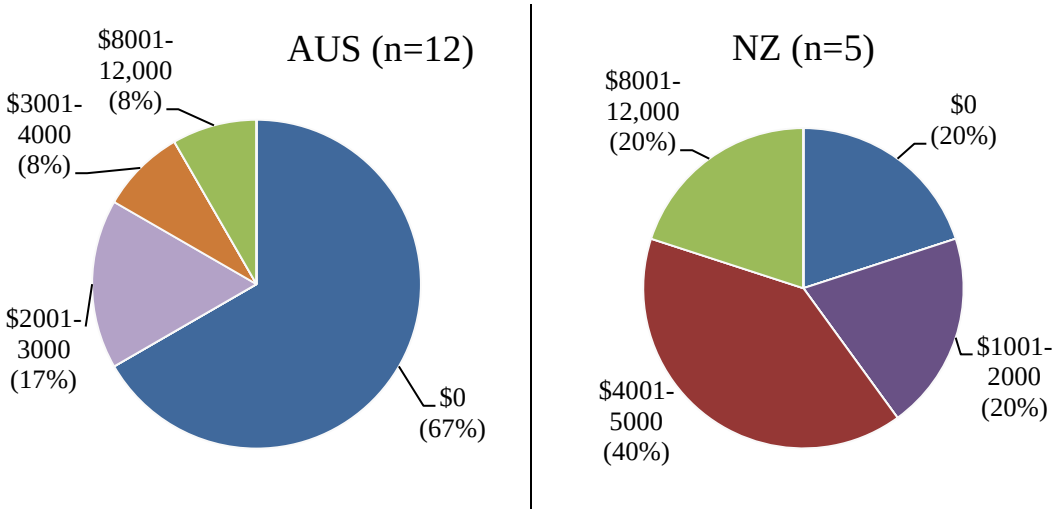

Figure 18 – Average Financial Support from External Sponsors in Capstone Design

Figure 19 shows the forms of funds provided for capstone design programs. Data across countries followed similar trends, although the U.S. respondents had a much higher proportion of funds received in the form of gifts, whereas reimbursement for expenses was the predominant funding form in Australia and New Zealand. The "Other" responses from Australia and New

Zealand, which were often in addition to one of the other options, included contract research, facilities/hardware/access to equipment, and scholarships.

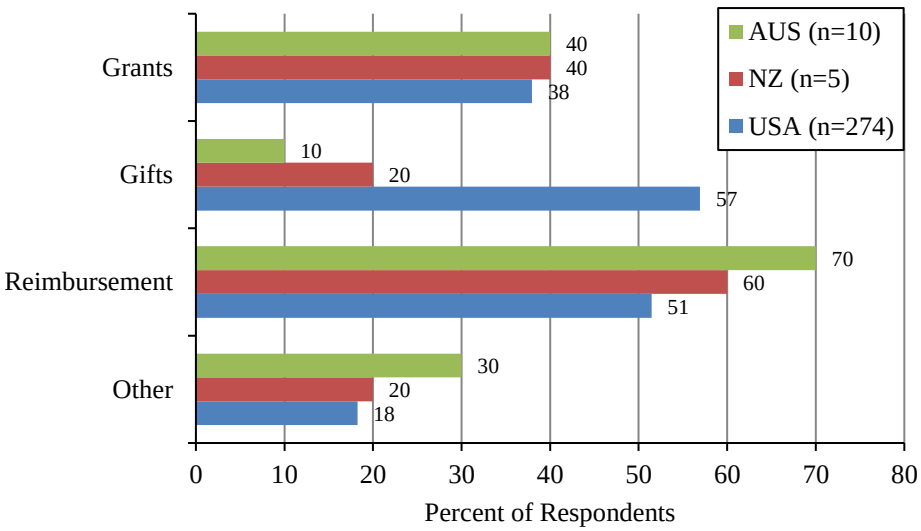

Figure 19 – Form of Funds in Capstone Design

3.7 Sponsors

Roughly two-thirds of respondents from Australia, New Zealand, and the United States reported including externally sponsored projects; the results are shown in Table 7. Because relative distances differ for smaller countries, the response choices for the 2015USA survey were "Local (<20 miles)", "Regional (20-100 miles)", and "National (>100 miles)", whereas the corresponding choices for the 2015AUS and 2015NZ surveys were and "Local (<20 kilometers)", "Regional (20-100 kilometers)", and "National (>100 kilometers)". Local sponsors were most common for all countries, while international ones were the least common. New Zealand had a notably higher percentage of nationally located sponsors, as well as more located internationally.

Table 7 – Sponsor Location in Capstone Design

	AUS (n=16)	NZ (n=5)	USA (n=293)
Local	100	80	71
Regional	50	40	65
National	31	60	37
International	13	20	13

Figure 20 shows the frequency of student contact with external sponsors. While none of the respondents from New Zealand had weekly contact with sponsors, the rest were evenly divided between the remaining four categories. Australia had a high percentage of "Other" responses, the comments for which suggested variability across project, sponsor, and faculty advisor.

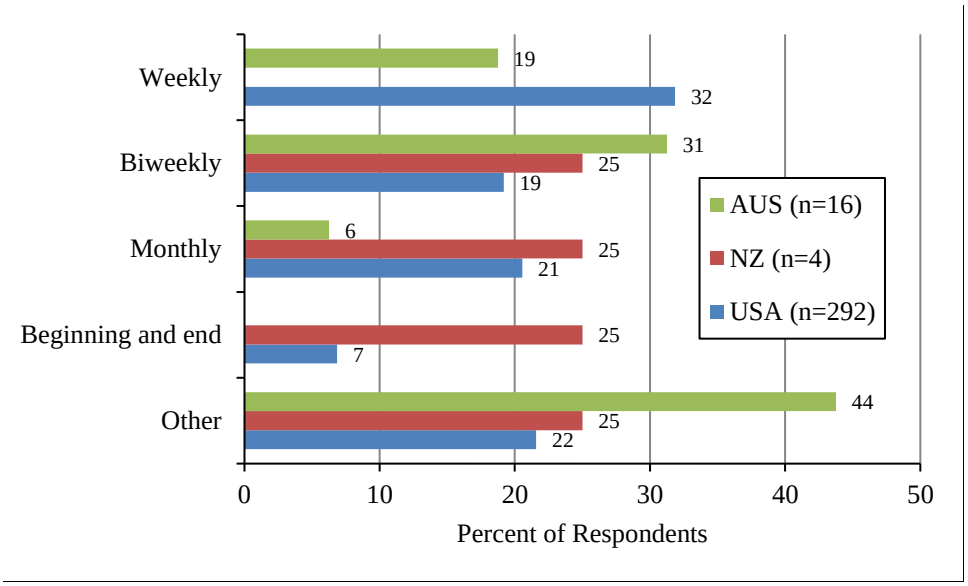

Figure 20 – Student Contact with External Sponsors in Capstone Design

The number of trips to the sponsor organization can be seen in Figure 21. Responses were divided fairly evenly, with Australia respondents slightly favoring 2 trips. However, there was a gap between ≤5 and >10 trips for both Australia and New Zealand, and neither country indicated a frequency of only one trip per course sequence.

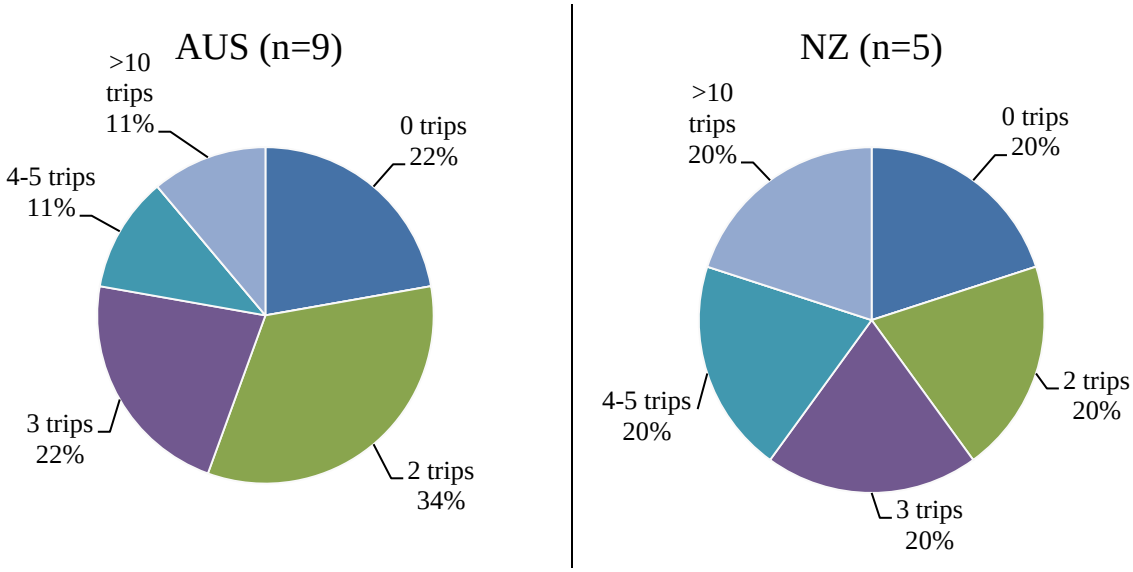

Figure 21 – Frequency of Travel to Sponsor Organization in Capstone Design

Survey respondents were also asked about the percentage of sponsors who have sponsored projects in more than one instance of the capstone design course. The percentage of repeat clients in New Zealand was very high, with over two-thirds of respondents indicating 61-80% of clients had worked with them before. Repeat sponsors were also common in Australia, with nearly two-thirds of respondents noting that more than 40% of their sponsors were repeat clients.

Responses from all three countries related to intellectual property ownership are shown in Figure 22. Many respondents indicated a combination of sponsor, institution, and student ownership, with 100% of New Zealand respondents noting sponsor ownership for at least some of their projects in every capstone design sequence.

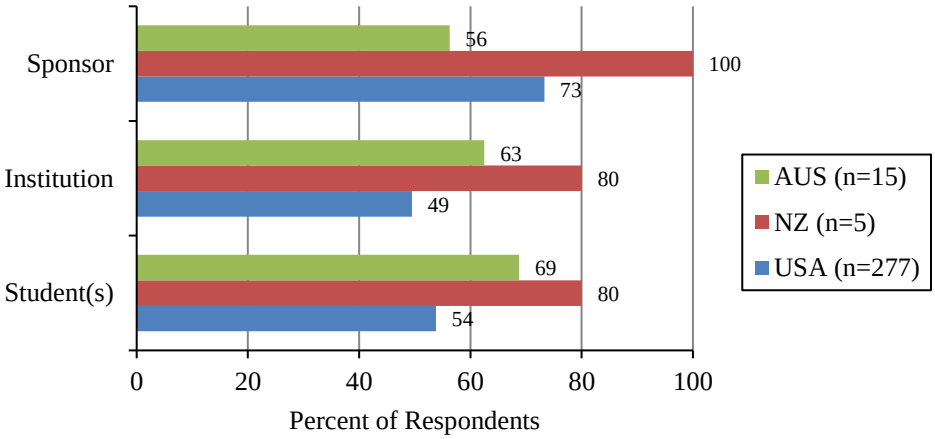

Figure 22 – Intellectual Property Ownership in Capstone Design

3.8 Personal Experience and Opinion

Respondents were also asked about their personal experience. Figure 23 shows the type of faculty position held by respondents from Australia, New Zealand, and the United States. Interestingly, 100% of the New Zealand respondents were tenured faculty members. Tenured positions were also the most common for Australia respondents, though a few held untenured or non-tenure-track positions. The "Other" responses from Australia included a "sessional lecturer" employed specifically for capstone, a permanent employee without tenure, and a semi-retired faculty member hired part-time.

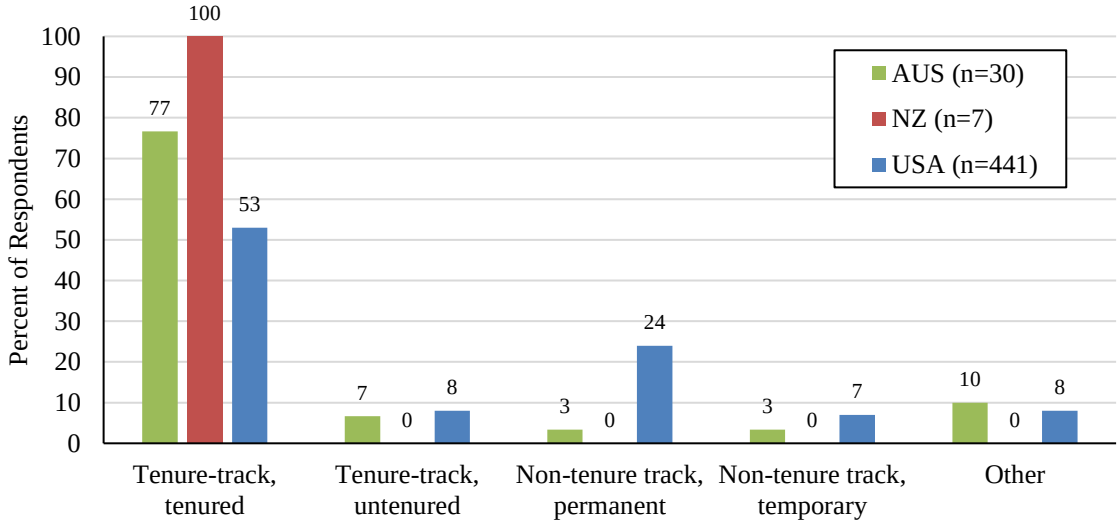

Figure 23 – Faculty Position Type Held by Respondents

Figure 24 shows the years of work experience outside academia for Australia and New Zealand respondents. While both countries have respondents who had little or no work experience outside academia, the majority of both sets of respondents had at least some. The 2015USA data are similar to those from Australia, with just over half of the respondents having worked in industry for 6 or more years. Furthermore, the vast majority of respondents' non-academic work involved design: 80% of 25 Australia respondents, 85% of 410 U.S. respondents, and 100% of 7 New Zealand respondents.

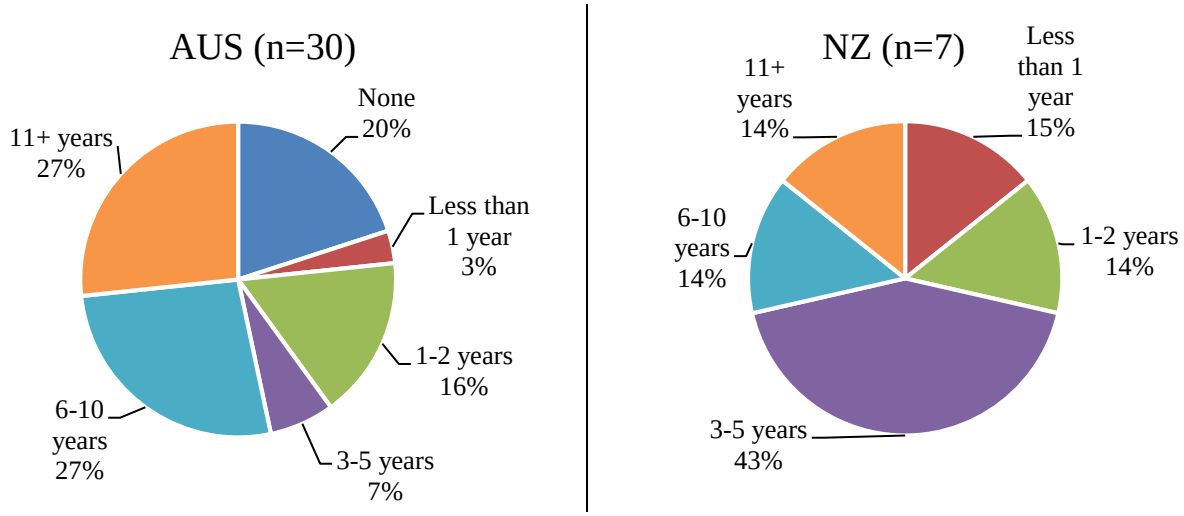

Figure 24 – Years of Experience in Engineering Professional Work outside Academia

When asked what they enjoyed most about being involved with capstone design, respondents from Australia and New Zealand offered many different ideas spanning student growth, interactions/mentoring, projects/real-world, pedagogy, and faculty growth. Table 8 includes selected responses from both countries that map to these themes.

Table 8 – Representative Responses Regarding Enjoyment from Capstone Design

Australia	*"Integrating many courses which are previously covered in their program. Application of knowledge to a real world project."* [AUS10]
	"Achieving tangible/useful and practical applications." [AUS19]
	"Working with bright and enthusiastic young people, helping them realise their potential." [AUS24]
	"I enjoy the opportunity to prepare students for the workforce and to maintain currency and relationships with my colleagues in industry. I also value the opportunity that it gives me in gauging the level of student preparedness." [AUS31]
New Zealand	*"Involves small group teaching rather than lecturing which I find more satisfying."* [NZ3]
	"Contributing to substantial student development and interacting with industry." [NZ4]
	"Working with students to become more independent learners." [NZ6]

Respondents also noted many things that were their biggest challenges regarding capstone design; themes included administration, assessment, design/process, faculty/staff, projects/sponsors, student abilities, student commitment, supporting students, teams/teamwork, and workload/time. Table 9 highlights some representative quotes from both Australia and New Zealand respondents.

Table 9 – Representative Responses for Biggest Challenges Regarding Capstone Design

Australia	*"Ensuring that 222 students are engaged and challenged while learning practical applications of the theory they have learnt to date. Reinforcing that there is no single correct answer."* [AUS2]
	"Managing a large cohort (120 students) while ensuring the students are assessed on individual and group contribution." [AUS21]
	"Troubleshooting in all its guises - technical issues, team issues, coordinating staff etc." [AUS28]
	"As usual, lack of time. There are enormous calls on our time with regard to generating publications, funding and developing research programs, supervising thesis students, sitting on multiple committees and teaching into other courses that truthfully, inhibits our ability to deliver the level of quality that would otherwise be possible. There also seems to be an ongoing arm wrestle between our research science colleagues that feel we should go deeper into technical areas of study and the minority (but thankfully senior professoriate) that believe that we need to strengthen student's application and employability skills. Couple this with the constraints on hiring new faculty with sufficient industry experience and you have the storyline for almost all of us who deliver senior capstone design courses in higher education." [AUS31]
New Zealand	*"Finding new and relevant projects. Assessing individual students fairly in a group work environment. Getting other faculty to agree to involvement in design group supervision."* [NZ3]
	"Individual supervisors are of variable quality. It is difficult to ensure all students have an equally good supportive experience." [NZ5]
	"Getting students to put in the time in the first semester when the deadlines are not until the end of the academic year." [NZ6]
	"Finding enough projects as our class size increases (8 in 2002; 82 in 2005)" [NZ8]

Respondents also recognized a variety of teaching strengths that they bring to capstone design, including overarching themes of assessment, skills/content, professional development, industry experience/connection, pedagogy, project-related, and administration. Table 10 features some representative responses across these themes.

Table 10 – Representative Responses for Teaching Strengths in Capstone Design

Australia	*"Aim to be flexible with regard to assessment and supervision requirements. Genuine desire to improve the process for both academics and students. Desire to exploit 'modern'/online technologies for project planning, document writing, etc. Desire to not waste people's time with excessive/unnecessary assessment."* [AUS15]
	"My extensive work experience allows the projects to be as realistic as possible. Also I am able to make students aware that technical requirements are only a small part of good design." [AUS18]
	"My focus on communication, strategy, planning, teamwork, decision making and conflict resolution. Using modern collaboration, computer aided design and analysis tools." [AUS25]
New Zealand	*"Close relationship with Industry sponsors. High component of individual assessment (75%)."* [NZ4]
	"Individual projects give the students an opportunity to deeply explore an area they find particularly interesting. In some ways it is a mini research project, 1/4 of an ME." [NZ5]
	"Integrated projects; simulate real-world situation; prepares students for their first job." [NZ8]

4. Conclusions and Future Work

The 2015 Capstone Design Survey was extended to both Australia and New Zealand to capture capstone design practices outside the United States and compare data across countries. The 2015 Australia and New Zealand surveys were nearly identical to the 2015USA survey and included a wide range of questions on capstone course information, pedagogy, evaluation, faculty, students, projects and teams, expenses and funding, sponsors, and respondent experience and opinion. This paper reports data for 31 respondents at 20 institutions within Australia and 8 respondents at 5 institutions within New Zealand, making connections where relevant with the 2015USA survey data (522 respondents at 256 institutions).

Overall, the essence of capstone design courses in the three countries was similar in many respects. Courses were most commonly two semesters in length, deliverables included a final report and presentation, course emphasis was most often on both product and process, and course instructors had the largest role in student evaluation. Projects were most often sourced from faculty research and industry based on faculty connections and expertise, and chosen to ensure a rich educational experience. Primary expenses were hardware and project supplies, but breakeven costs were typically less than US$1000 per project and funding was commonly received from the department and/or industry sponsors. Capstone design courses from all three countries included a mix of sponsor location from local to international, with higher likelihood of closer locations, as well as a mix of intellectual property ownership (sponsors, institution, students). Capstone design instructors were most commonly tenured faculty members who had at least some work experience in design outside academia. Respondents noted similar enjoyment, challenges, and teaching strengths with capstone design.

Although the variation in implementation was often greater across programs or institutions than across nations, there were some notable differences across countries as well. For example, both Australia and New Zealand commonly implemented standalone projects, whereas in the United States a parallel course + project experience was most common. Respondents in all three countries covered a range of topics in their capstone courses, but such coverage was less structured and by a lower percentage of respondents in Australia and New Zealand than in the United States. The majority of Australia and New Zealand respondents had 50+ students in their capstone courses and many had 40+ projects per course, much higher than the average in the United States. In New Zealand, institutions commonly provided teaching credit to many/all (often more than 75%) of their departmental faculty; Australia had more variation, but the average number still exceeded that of the United States, where in many cases only a single person received teaching credit for capstone design. Team sizes varied in all three countries, but individual projects were particularly common in Australia. The majority of sponsors in Australia provided no funding at all; funding that was provided was typically either a grant or reimbursement in Australia and New Zealand in contrast to grants in the United States.

It would be interesting to extend this survey to additional countries or world regions to explore other approaches to capstone design courses. The questions could be similar, so as to enable comparisons across countries, though with translation as needed and a confirmation from local educators regarding specific terminology (such as "capstone design"). Capstone design educators interested in partnering in such research are encouraged to contact the authors.

The data in these national surveys represent current practices from the survey respondents and, as such, reflect the breadth of capstone design practices in several countries. They do not necessarily represent *best* practices for they are not tied to programmatic outcomes or student achievement. Given the emphasis on continuous improvement in engineering education as part of accreditation, however, one could infer that capstone practices that are common over location and/or time are *effective* practices, and, as such, are worthwhile for capstone design instructors and administrators to consider. This paper is intended as a resource for capstone design educators and a contribution to the larger goal of understanding and improving capstone design education globally.

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