Comparing Self-Perceptions of Students from Australia and the USA as they Develop Teamwork Competencies

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CONTEXT

The outcomes of comparing the development of self-reported teamwork competencies in design courses at the University of NSW, Canberra, Australia and the University of Oklahoma, USA are discussed. Both student cohorts were involved in courses with "Warman" and "Warman-like" group design and build projects that provide authentic and immersive "mechanical / mechatronic" design experience. The instrument used to capture student views was a survey. Through better understanding and calibrating student perspectives, it follows that course design can be modified to better achieve course goals – which is a growth in relevant competencies.

PURPOSE

The hypothesis is that students self-realize improvement in their teamwork as they engage in an immersive design experience and to examine the hypothesis three main questions are asked:

- How do students perceive attributes of teamwork while executing a design project?
- How do these perceptions change through the design experience?
- What differences are evident (if any) between the student cohorts from different institutions?

APPROACH

A structured approach using surveys was implemented to track progressively the change in student self-perceptions of teamwork during the immersive design activity at each campus. The courses are similar in that they have their focus on learning the principles of design in the context of a significant project, requiring the realization of functioning hardware. However, differences exist in the actual project scenario and that the Australian students were in their 2nd year while the American students were in their 4th year of their 4 year undergraduate engineering programs.

RESULTS

The results presented aim to document student perceptions of their developing competencies. This activity ties to some parallel work examining student motivation and performance. It is believed that self-evaluation facilitates the development of competencies related to team-work. Having students undertake a design, and then build and test a mechanism under competitive conditions provides a framework for students to experience, recalibrate and reapply team-work competencies. The change in perception depends on the composition of the team and individual characteristics of students in the team and the phase of the project being encountered. The changes in perception are necessary elements of competency development, personal growth and life-long learning attitudes.

CONCLUSIONS

In this paper the focus is on student perceptions of development of their own team-based competencies. Observed is how the teaming competencies are developed in students when they work in courses with design problems. Time-based tracking of student perceptions has been used. The fact that some teams and individuals did not work well together or recognized they could have done some things better does not negate the development of competencies; rather it is natural and normal for learning to take place through failure and mistakes as well as success.

KEYWORDS

student competency, teamwork, self-perception.

Motivation

Industry and employers have frequently pointed to a lack of professional awareness and low levels of communication and teamwork skills in engineering graduates (Bradford School of Technical Management, 1984; Evers, Rush, & Berdrow, 2005; McLaughlin, 1992; Sparkes, 1990). Globalization and rapid change in technology has also led to changes of expected competencies of engineers. One change over the last decade has been the increasing emphasis placed on developing competencies related to innovation and problem-solving, which in turn rely upon domain expertise in applied fields (Feltovich, Prietula, & Ericsson, 2006). One of the competencies for innovation and the engineering profession is the ability to effectively work in a team environment.

According to Bransford and co-authors, students learn best when presented with organized information that relates it in some way to their own experiences, and when they are given the opportunity to test themselves on their own understanding and when working on developing their understanding with other students, (Bransford, Brown, & Cocking, 1999). Thus, they emphasize the value of scaffolded authentic experiences in a group setting.

Subsequently, while the author is engaged in providing such opportunities in an engineering design context, the hypothesis is that students self-realize improvement in their teamwork as they engage in an immersive design experience and to examine the hypothesis three main questions are asked:

- How do students perceive attributes of teamwork while executing a design project?
- How do these perceptions change through the design experience?
- What differences are evident (if any) between the student cohorts from different institutions?

Method and Instrument

In pursuing answers to the motivational questions posed a comparison of student cohorts in an American university (University of Oklahoma) and an Australian university (University of NSW, Canberra) has been made and is reported herein. Logistically, observations by the author at the University of Oklahoma were made possible during a sabbatical in the Fall Semester of 2013. Both cohorts comprised predominantly mechanical and aeronautical engineering students. Both have been studied while they have been undertaking similar design and build experiences, albeit that the UNSW Canberra students were in their 2nd year while the University of Oklahoma students were in their 4th year of their 4 year undergraduate engineering programs respectively.

At each university, both courses attempt to orchestrate learning through authentic and immersive experiences using an ill-structured problem in the form of a design, build and test project. Common and salient features of course organisation on both sides of the Pacific include: self-selecting and self-organised teams, scaffolded assignments that lead students through a design process from requirements analysis, to concept identification and development, prototyping, testing and demonstration in a competition based environment. The process is modelled in a design office or studio styled environment with the students being treated as junior engineers.

The primary method of gathering data was through survey and the appropriate ethics approvals were obtained through both institutions for administering the surveys. During the course of a semester in each case, students were surveyed multiple times with effectively the same instrument, five times in the USA and four times in Australia. The questions were focused on competency development which includes teamwork. From survey to survey, students were not provided feedback on how they had previously responded to the questions asked and it was hoped that they would answer in accordance with their current perceptions independently of prior responses.

Each survey response window closed following the submission of a significant piece of assessment as students progressed their design. A comparison of the general course syllabi and the administration sequence of the surveys is shown in Table 1. To aid comparison in interpreting Table 1 and other comparative data provided in the paper, the American perspective is shaded in blue and is on the left while the Australian perspective is in red and on the right.

Table 1 - Generalized Syllabi and Survey Schedules (University of Oklahoma (Blue) and University of NSW, Canberra (Red))

Week	University of Oklahoma Course	University of NSW, Canberra Course
1	Introduction and forming teams Steps in the design processes Meta design, designing and scheduling	Introduction and forming teams Design principles Requirements analysis **SURVEY 1**
2	Building and testing bridges Safety instructions	Electronics Electronics lab
3	Understanding customer needs, Requirements analysis Function structure, Generation of concepts *Assignment: Planning* **SURVEY 1**	CAD refresher, product modelling, drawings Components Concept design Electronics
4	Concept evaluation *Assignment: Needs analysis* **SURVEY 2**	Workshop skills and safety *Assignment: CAD Exam*
5	CAD modelling and simulation Basic animation with SolidWorks Motion	Designing Electronics *Assignment: Requirements and Concept Report* **SURVEY 2**
6	FEA –introduction (structural and heat transfer) *Assignment: Function and Concepts* **SURVEY 3**	Designing Electronics *Assignment: Electronics Design Review*
7	Designing *Assignment: Concept Evaluation* **SURVEY 4**	Designing Electronics *Assignment: System Design Review*
8	CFD – introduction and brief overview *Assignment: CAD Modeling and Analysis*	Build prototype Electronics
9	Build prototype Design for assembly and life-cycle	Build prototype *Assignment: Proof of Concept* **SURVEY 3**
10	Build prototype Ethics	Build and test prototype
11	Build prototype Demonstration *Assignment: Detail Design* **SURVEY 5**	Build and test prototype *Assignment: Competition*
12	Project presentations	*Assignment: Final Jury / Portfolio* **SURVEY 4**

Twelve of the questions focused specifically on teamwork and they are the prime focus for this paper. They are questions numbered 25-36 and were asked in multiple surveys. The students were asked "at this stage of the project and from your perspective, how well did the team work together on …:

25. understanding the requirements,
26. meeting together,
27. listening to everyone's ideas,
28. decision making,
29. written communication,
30. design documentation,
31. how to work in a group,
32. how to carry out a project,
33. importance of organization,
34. skills in organization,
35. skills in problem solving, and
36. estimating time to complete a project."

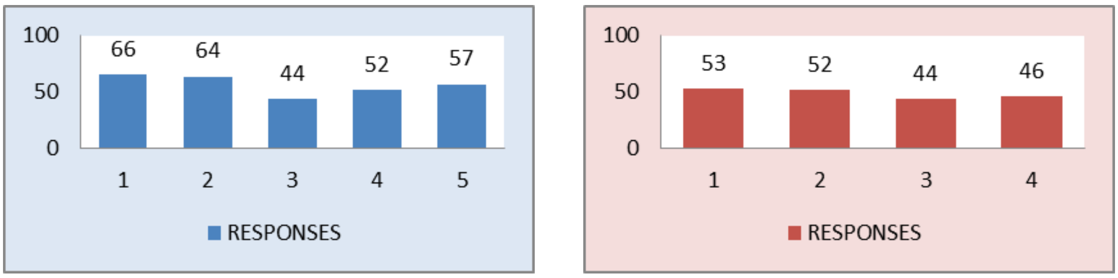
A seven point scale was used to measure student responses, namely: 1) Very Poor, 2) Moderately Poor, 3) Mildly Poor, 4) Neither Poor nor Well, 5) Somewhat Well, 6) Mostly Well and 7) Very Well.

Discussion of Results

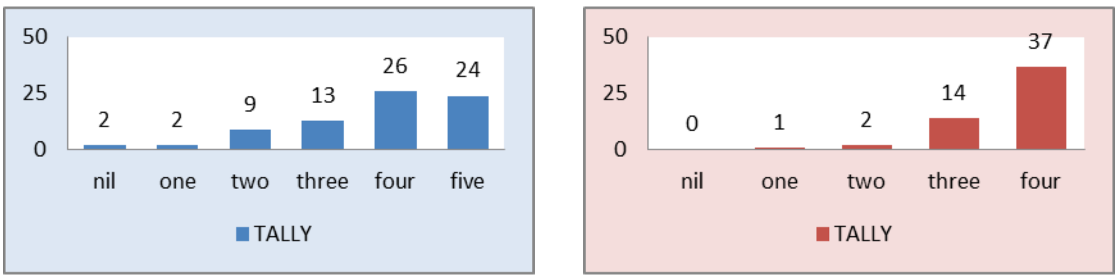
In most cases but not all, when given the chance to work with friends or study partners, students did so. On the other side of this circumstance, a small number of students on both campuses identified in the surveys that they worked with “strangers”.

For the University of Oklahoma (colour coded blue throughout the paper), the subject senior (4th year) class of 2013 comprised 76 students. As shown in Figure 2 (a) (left), of the 76, the most number of students, 66, responded to Survey 1, while the least number of respondents was 44 for Survey 3. A tally of the number of responses made by an individual student is presented in Figure 2 (b) (left). Across the five surveys, 24 of 76 responded to all five surveys and only two students failed to respond to at least one survey. These surveys were conducted on line through the learning management system at the University of Oklahoma.

For the University of NSW, Canberra (colour coded red throughout the paper), the subject 2nd year “Warman” class of 2016 comprised 54 students. As shown in Figure 2 (a) (right), of the 54, the most number of students, 53, responded to Survey 1, while the least number of respondents was 44 for Survey 3. A tally of the number of responses made by an individual student is presented in Figure 2(b) (right). Across the four surveys, 37 of 54 responded to all four surveys. These surveys were conducted on paper.



(a) Responses to each survey

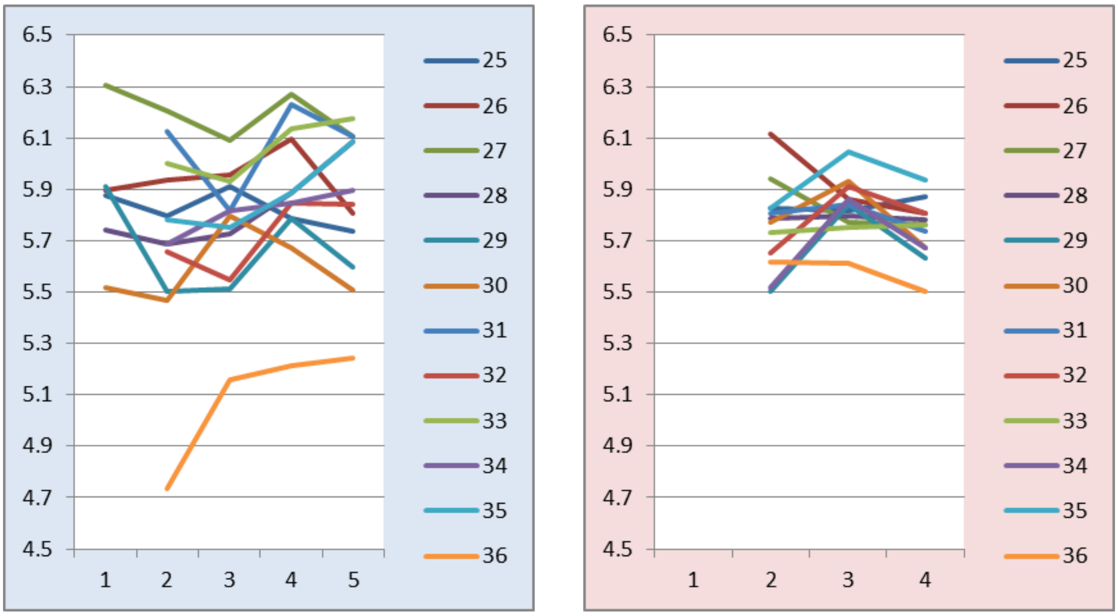


(b) Tally of surveys completed by individuals

Figure 2 – Survey Statistics (University of Oklahoma (Blue) and UNSW, Canberra (Red))

For the 12 questions of interest herein (questions numbered 25-36), the mean responses for each question in each survey are shown comparatively in Figure 3. Some fluctuations are evident in the mean values recorded across the five surveys. It is believed, these changes are due to students readjusting and calibrating their self-perceptions as new challenges, related to working in teams arise and are addressed. These changes are crucial for development of competencies through authentic experiences.

Considering only the first and last time a question was asked, these mean response values are presented in Figure 4. A companion table to the Figure 4 comparison is Table 2. In Table 2, the questions have been ordered based on the differences in mean response from the first time the question was asked to the last time it was asked.



KEY: at this stage of the project and from your perspective, how well did the team work together on:

25. understanding the requirements
26. meeting together
27. listening to everyone's ideas
28. decision making
29. written communication
30. design documentation
31. how to work in a group
32. how to carry out a project
33. importance of organization
34. skills in organization
35. skills in problem solving
36. estimating time to complete a project

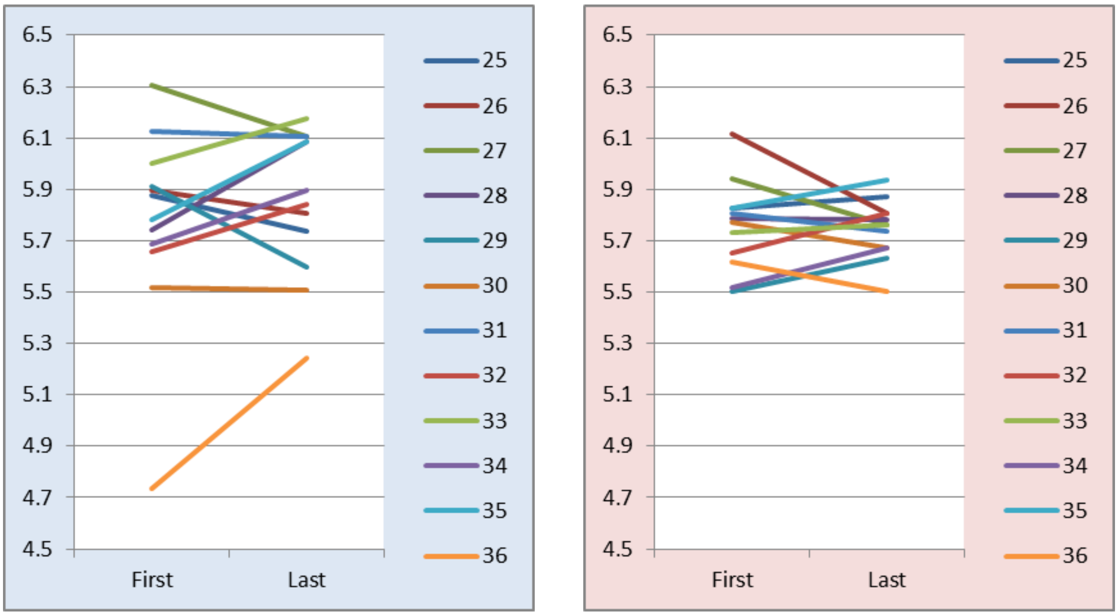
Figure 3 – Mean Responses to Questions from survey to survey (University of Oklahoma (Blue) and UNSW, Canberra (Red))

Comparing the two cohorts as evidenced in Figure 3 and Figure 4, the spread of response across the seven point scale is greater for the American cohort in comparison with the Australian. It is also evident that the focal 12 questions were not asked in all surveys. For the American students, questions 31 to 36 were asked for the first time in survey 2 recognising that at the time of survey 1 during week 3, they had had minimal opportunity in respect of these aspects of teamwork. Similarly, for the Australian cohort, given that Survey 1 was undertaken on the 1st day of class during team forming activities, questions 25 to 36 were not posed at all in Survey 1. In hindsight, asking students to predict their future performance in teaming with a slight rewording of the question may have provided data for an interesting starting point. This requesting a forecast as opposed to a reflection will be implemented in a follow on study of the 2017 cohort at UNSW, Canberra.

The slopes of the lines in Figure 4 and the tabulated differences in Table 2 lead to some interesting points of difference and of similarity. The cross comparison of ranking shows 4 of the 12 aspects quite consistent but 4 are ordered relatively up and 4 relatively down (see the connections shown in Table 2).

For the American cohort, written communication shows the greatest negative difference while estimating time to complete a project is the greatest positive. However, it should be noted that estimating time to complete started from a very low base relative to other measures and remained low. Overall, four of the questions (written communication, listening to everyone's ideas, understanding the requirements and meeting together) show a decrease in mean value, two are very flat (slightly negative – how to work in a group and design documentation) while the remaining six exhibit an increase.

For the Australian cohort, meeting together shows the greatest negative difference while "skills in organisation" represents the greatest positive. Overall, five of the questions (meeting together, listening to everyone’s ideas, estimating time to complete a project, design documentation, and how to work in a group) show a decrease in mean value, decision making is very flat (slightly negative) while the remaining six exhibit an increase.



KEY: at this stage of the project and from your perspective, how well did the team work together on:

25. understanding the requirements
26. meeting together
27. listening to everyone's ideas
28. decision making
29. written communication
30. design documentation
31. how to work in a group
32. how to carry out a project
33. importance of organization
34. skills in organization
35. skills in problem solving
36. estimating time to complete a project

Figure 4 – Mean Responses to Questions from first to last time asked (University of Oklahoma (Blue) and UNSW, Canberra (Red))

Table 2 – Questions ordered based on differences in mean responses from to last time asked (University of Oklahoma (Blue) and UNSW, Canberra (Red))

Q#	1st	Last	Diff	Issue
29	5.9	5.6	-0.313	Written communication
27	6.3	6.1	-0.198	Listening to everyone's ideas
25	5.9	5.7	-0.142	Understanding the requirements
26	5.9	5.8	-0.087	Meeting together
31	6.1	6.1	-0.020	How to work in a group
30	5.5	5.5	-0.006	Design documentation
33	6.0	6.2	0.175	Importance of organization
32	5.7	5.8	0.186	How to carry out a project
34	5.7	5.9	0.207	Skills in organization
35	5.8	6.1	0.306	Skills in problem solving
28	5.7	6.1	0.345	Decision making
36	4.7	5.2	0.511	Estimating time to complete a project

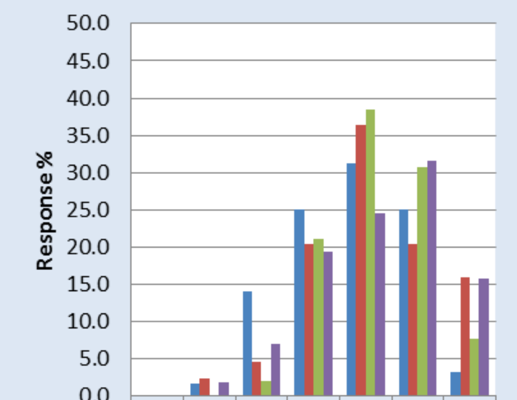
Q#	1st	Last	Diff	Issue
26	6.1	5.8	-0.311	Meeting together
27	5.9	5.8	-0.181	Listening to everyone's ideas
36	5.6	5.5	-0.115	Estimating time to complete a project
30	5.8	5.7	-0.095	Design documentation
31	5.8	5.7	-0.069	How to work in a group
28	5.8	5.8	-0.006	Decision making
33	5.7	5.8	0.030	Importance of organization
25	5.8	5.9	0.043	Understanding the requirements
35	5.8	5.9	0.108	Skills in problem solving
29	5.5	5.6	0.130	Written communication
32	5.7	5.8	0.151	How to carry out a project
34	5.5	5.7	0.155	Skills in organization

The distributions of responses to contrasting questions are shown in Figure 5, one from each cohort. Noting that answers to these questions exhibit the greatest increase in mean value for the Americans and the greatest decrease in mean value for the Australians, by examination it can be seen that the mean of each survey distribution is shifting to the right for the Americans and to the left for the Australians by visualizing and comparing the curve associated with each progressive survey. A shift in mean to the right indicates that students in the class have perceived they are improving these aspects of team competencies as they progress through the semester and engage with the authentic experiential activities. But are these perception differences statistically significant? Statistical significance is the probability that a difference in data samples is not due to random variation.

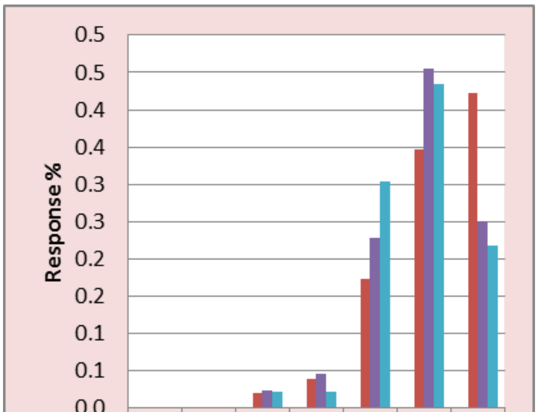
While the 7 point scale has been used some of the data sets are naturally skewed (having asymmetry in the distribution of responses). However, for the American cohort, all data sets associated with Questions 32, 34 and 36 satisfy the symmetry criterion based on a skew test. Similarly, all data sets associated with Questions 32, 33 and 35 satisfy the normal distribution criterion based on kurtosis.

Assuming for a given question the samples for the “first” and “last” are normally distributed, the confidence interval for claiming that the course experience had a “significant” influence in “treating” the students can be tested using a *t*-test. It follows that the results of questions 27, 29 and 36 are significant (<0.05) with one-tailed *t*-test values of 0.031, 0.029 and 0.019 respectively. A weaker case can be made for questions 28 and 35 with one-tailed *t*-test values of 0.078 and 0.861.

Repeating the analysis for the Australian cohort, only for Question 35 data sets are symmetry via the skew test and normality based on kurtosis shown. Again, if the “first” and “last” are assumed to be normally distributed, only question 26 exhibits significance (<0.05) with a one-tailed *t*-test values of 0.007. A weaker case can be made for questions 27 with one-tailed *t*-test value of 0.057.



	1	2	3	4	5	6	7
2	0.0	1.6	14.1	25.0	31.3	25.0	3.1
3	0.0	2.3	4.5	20.5	36.4	20.5	15.9
4	0.0	0.0	1.9	21.2	38.5	30.8	7.7
5	0.0	1.8	7.0	19.3	24.6	31.6	15.8



	1	2	3	4	5	6	7
1							
2	0%	0%	2%	4%	17%	35%	42%
3	0%	0%	2%	5%	23%	45%	25%
4	0%	0%	2%	2%	30%	43%	22%

Figure 5 – Distribution of Response to Most Change Questions (Question 36 for University of Oklahoma (Blue), estimating time to complete a project (positive); and Question 26 for University of NSW, Canberra (Red), meeting together (negative))

Concluding Remarks

In this paper the focus is on student perception of development of their own team-based competencies. Observed is how the team-based competencies are developed in students when they work in courses with design problems.

This investigation ties to some parallel work examining student motivation and performance (Warren F. Smith, Siddique, & Mistree, 2014). Also, the twelve teamwork survey questions correlate with and were adapted from those of an ongoing longitudinal study of the outcomes of the Warman competition (Churches & Magin, 1998, 2003, 2005; W.F. Smith, 2008, 2013).

The results presented herein represent some indicative findings aimed at documenting student perceptions of their developing competencies, and in this case, teamwork.

The answers to three questions were sought.

How do students perceive attributes of teamwork while executing a design project?

It is believed that self-evaluation facilitates the development process of competencies related to team-work. Using design projects in courses, with specific steps provides a framework to experience, recalibrate and reapply team-work competencies.

How do these perceptions change through the process?

The change in perception depends on the composition of the team and individual characteristics of students in the team. The drops and increases in student's perception are necessary elements of competency development.

What differences are evident (if any) between the student cohorts from different institutions?

There are obvious differences in the responses from both cohorts as highlighted in Table 2. Clearly there is a fundamental difference that could highlight why in that the Australian students at UNSW Canberra are in year 2 and the American students at the University of Oklahoma are "seniors" in year 4. This may reflect some differences in professional and technical maturity between the cohorts and differences in group dynamics. However, having been involved with teaching both groups, my observation is that on the surface, the engagement and teaming of both was similar.

A significant point of difference in the cohorts is that students at UNSW Canberra are predominantly midshipmen and officer cadets who have been selected to be tomorrow's leaders of the Australian Defence Force. From the point of their selection boards to join the ADF and through the military training processes they follow in parallel with their academic work, they are being trained to be leaders and effective team members.

Opportunities for further work include mining the data collected for further insights, particularly through correlation with assessment and demonstration of true competence. A lot more can be gleaned from all the questions asked but that goes beyond the scope of this conference paper. Repeating the study with following cohorts of students to further validate and confirm would also be a natural extension to the work and is planned for 2017.

To conclude, the lessons learned in conducting the subject classes can be generalized with a view to improving aspects of the engineering education delivered. With appropriate scaffolding, ill structured (design, build and test) problems are highly recommended to provide an opportunity for students to internalize design principles. They provide valuable authentic, immersive experiences. Such activities can be utilized by students to explore and learn the principles of design and teamwork generally, going beyond the specific task at hand. They are useful to teach lessons about such things as design solution fixation and the need to think broadly and holistically. Teams do latch onto specific solutions and through the process, perhaps learn the hard way, that they should have discarded it and started again. Others lose sight of key issues or criteria when building a prototype. Classic examples include failing to consider the effects of friction or the influence of the centre of gravity on stability. Overall, my learning and teaching philosophy is that engineering design involves complex technical and problem solving skills that are best acquired through activities that involve students in authentic, immersive and team based engineering tasks and environments, such as the one described in this paper.

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