Increasing student satisfaction with teamwork in project-based engineering units

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Introduction

Teamwork is an important aspect of engineering courses, particularly as many courses move towards a greater focus on project-based and collaborative learning experiences. Effective capabilities in teams is an important competency which students must develop throughout their engineering studies. Despite the importance of teamwork in the engineering profession, students often experience significant challenges in working in teams at university.

Engineering education in the past has focused on the technical skills and knowledge of mathematics and science, however recently has started undergoing a shift to embrace a more comprehensive perspective considering the complex human environments which engineering interacts with (Miller, 2015). This is reflected in the Engineers Australia (EA) Stage 1 competencies, which specifically mention the need to 'appreciate the issues associated with international engineering practice and global operating contexts', consider cultural factors both in design and interactions of systems, and to communicate with and perform as an effective member of multi-cultural teams (Engineers Australia, 2017a).

In a creative discipline like engineering, diversity is a major driver in creative solutions, so managing the challenges of cross-cultural group work is essential to enable students to thrive in their chosen engineering specialisation (Vitto, 2008). Collaborative learning also has the potential to enhance the learning outcomes of a group of collaborative learners which could be useful in facilitating understanding of complex engineering concepts (Göl & Nafalski, 2007; Terenzini, Cabrera, Colbeck, Parente, & Bjorklund, 2001).

There are a variety of different terms used in the literature on group and teamwork with key recurring words being cooperative learning and collaborative learning. Cooperative learning may involve students working individually on tasks then combining the pieces together, while collaborative learning typically requires the group to function together to meet the objective (Agerup & Büsser, 2004). To ensure the success of groups and move them towards the more highly functioning side of the spectrum, careful structuring of the group learning experience needs to be provided (Smith, 1995). Success requires a common goal, cooperation, communication, responsibility, willingness to learn and accountability (Agerup & Büsser, 2004; Chojnacka, Saryusz-Wolski, Macukow, & Andersen, 2009; Göl & Nafalski, 2007; Smith, 1995). Individual performance assessment is also often identified as a key factor to consider (Stump, HilpertI, Husman, Chung, & Kim, 2011), as is providing a reasonable workload, class time and peer evaluations of teamwork performance (Volet & Ang, 2012). Achieving success in collaborative group work experiences requires group participants to be well-trained in how to engage in teamwork activities successfully and in intercultural communication (Agerup & Büsser, 2004; Dunne & Rawlins, 2000; Smith, 1995). Teachers often require additional training in how to teach teamwork skills as evidenced by Dunne and Rawlins (2000) study utilising industry supported resources. Li, Remedios and Clarke (2010) define groups as being heterogeneous or homogenous depending on the cultural and ethnic background of the participants. The learning experiences essential for engineering students to develop cross-cultural competence based on these definitions above, are collaborative learning in heterogeneous groups.

Some research work has shown that Australian and international students prefer to work in homogenous groups primarily for language reasons and due to negative stereotypes (Volet &

Ang, 2012). These same students through Volet & Ang's (2012) study, completed a cross-cultural group assignment where their perceptions were challenged and found to be incorrect, however this did not contribute to a desire for students to engage in future work in heterogeneous groups.

Much of the existing literature suggests that training is required for participants in cross-cultural group work and group work in general and that common goals, communication, responsibility, accountability and expectations around the requirements of project work are essential (Agerup & Büsser, 2004; Chojnacka et al., 2009; Göl & Nafalski, 2007; Smith, 1995).

At the study university a change in course design was introduced from 2018 leading to students undertaking a program with more embedded design opportunities. As part of this students engage with more team-based design projects earlier in their degree and emphasis is placed on the development of teamwork skills. Additionally, the study university has a significant international cohort with which cross-cultural group work experiences are encouraged. The sequence of 4 design units are described below.

Design Unit 1. Teamwork is first introduced through a 5-week design and construction project. The project engages teams of 5 students in designing a balsa wood bridge to a specified span. Final built designs were tested to destruction. In this unit, team management tools were provided. Students were introduced to the concept of a group contract, setting meeting agendas and action lists. Group contributions were identified in the report, and students completed an individual reflection using an e-portfolio.

Design Unit 2. In the second design unit students complete two design projects including the Engineers without Borders challenge. During the third week of this course, students attend a lecture introducing them to some of the key ideas behind teamwork, team lifecycle and how to work effectively in teams. When forming new teams, they complete the Belbin self-perception inventory and discuss in their teams the implications of their preferred teamwork style. Design studio classes are run in such a way that students have ample in class time to complete facilitated activities to enable them, as a team, to accomplish their project. Additions to the unit in 2019 to monitor team performance include a 'check-in' with the design mentor/tutor each week during the design studio time where team performance and dynamics is recorded.

Design Unit 3. Students participate in a well- known Australian national design challenge known as "The Weir Warman design and Build Competition". This multidisciplinary design challenge aims to engage second year Bachelor of Engineering students. The challenge requires students to develop innovative solutions, then build a working prototype for competition held late in semester. If successful in meeting the challenge, the winning entry may complete in the national final in Sydney. In this unit students receive a series lectures on teamwork and managing team conflict. An important part of the unit is the use of electronically completed Self and Peer-Assessment.

Design Unit 4. In this unit teams of 5-7 students complete a project associated with the "Just like Jack" community, and in this case involves designing a road racing wheelchair frame with intelligent posture monitoring system to evaluate rider's comfort level. The project involves designing and them building of the design in the engineering workshop, liaising the suppliers to source components, managing a budget covering materials, electronic equipment and workshop time. Each team is provided with an Arduino and must design, build and test their electronic systems. Teams complete a peer an electronic based-assessment on three major assessment reports. Teams also present their designs to their peers. Self-assessment of teamwork performance is included.

The role of effective training in the subjective assessment by students of their satisfaction with teamwork experiences is the main topic of study in this paper. Student's subjective assessment of their own teamwork experiences and approaches taken by lecturing staff to

increase students' knowledge and skills in teamwork is explored to determine effective strategies for promoting satisfying and effective teamwork experiences in engineering. The main research question is: 'How can formal training in teamwork be a contributing factor to student satisfaction with teamwork activities?'

Method

A survey featuring quantitative and qualitative elements, and approved by the University's ethics committee, has been distributed to students in the former and revised Engineering degrees in 2017 and 2019, respectively. The survey contains preliminary questions related to year level and international/domestic status which are used as independent variables and asks students to reflect on their teamwork experiences. Survey design incorporates elements found in the literature, including asking students to rank essential skills for teamwork as identified in prior studies (Agerup & Büsser, 2004; Chojnacka et al., 2009; Göl & Nafalski, 2007). Survey design has also considered existing questionnaires designed to understand student experiences of teamwork both generally and in the context of specific assessment tasks (Drury, Kay, & Losberg, 2003; Falls, Bahhouth, Chuang, & Bahhouth, 2014; Johnson, Al-Mahmood, & Maierb, 2010; Pineda, Barger, & Lerner, 2009; Saatcioglu, Asyali, & Cerit, 2005; "Teamwork: Status Memorandum Feasibility Study: Procedure," n.d.; Yongmei Bentley & Shamim Warwick, 2013). The Engineers Australia stage 1 competencies have also been an input into the survey design (Engineers Australia, 2017b). The questions have been designed to elicit students perspectives on teamwork in general, although there is some focus given to teamwork in cross-cultural contexts due to the composition of the cohort at the study university. Throughout the questions there are elements which specifically mention diversity, and cultural background which in conjunction with the open-ended question and international/domestic status question enable these issues to be explored.

Quantitative and Qualitative data has been collected through the surveys, which were offered to students online through SurveyMonkey. The quantitative data (Q1-Q6) has been compiled and simple statistics produced showing student agreement and trends. The qualitative component provides more insight into student experiences and have been analysed by collating the responses to Q7 and identifying themes as discussed in the next section of the paper (Bengtsson, 2016; Kellam, Gerow, & Walther, 2015).

This paper details the results received from providing the survey to students currently enrolled in the Bachelor of Engineering (Hons) and associated combined degrees in 2017, and a follow up survey conducted with students in the new engineering program in 2019.

Results and Discussion

The survey was made available to all engineering students completing the former engineering degree from Monday 2 October, 2017 to Friday 13 October 2017. During this time students (n=21) responded to the survey invitation and their results were compiled. The second round of data collection applied to students studying the revised engineering course and was made available to students from Sunday 11 August to Monday 19 August, 2019. For the second round of data collection (n=16) students responded to the survey invitation. In 2019 an additional incentive for participation was included in the form of the option to enter a draw to receive a food voucher for participation. The survey responses remained anonymous and students registered their interest in entering the draw through a separate link after submission of their survey responses.

Interestingly in 2017, 100% of the students who responded to the survey invitation were self-identified as local students and in 2019 only 23% of respondents identified as international students. Possible reasons for the low participation of international students in the survey is that they have limited experience working in teams such as was identified by Wong (2004), that they are reluctant to participate in surveys, or that a different strategy is needed to encourage international student participation in research projects. The potential issues that

international students face in working in cross-cultural teams may be quite complex and difficult to capture in a survey instrument leading to these students being reluctant to participate.

In Question 3, students were asked to rank some common attributes of teamwork (derived from the literature – see (Agerup & Büsser, 2004; Chojnacka et al., 2009; Göl & Nafalski, 2007)) based on a scale from 1 (least important) to 5 (most important). Generally, these results showed that in both years the survey was conducted students thought that communication was the most important attribute, followed by responsibility, accountability, common goals and then expectations. There were however a number of students (n=6) in the 2017 survey who rated expectations as the most important which ties in with some of the open-ended responses given surrounding being placed in groups with students who had expectations or aims of a different level of work.

In Question 4 students were asked to identify where they have been taught how to work in a team where multiple options could be selected. Of the four most commonly selected options of school, university, sporting team and workplace; university ranked the lowest with only 62% identifying that they believe they have been taught to work in a team at university compared with 81% for school, sporting teams and workplaces. Very similar results for the 2019 data collection were received with 81% of participants identifying school as the where they have been taught to work in a team, sporting team followed close behind with 75% and workplace and university with 63%. These results suggest that more work needs to be done in providing instruction on how to work effectively in teams at the university stage.

Questions 5 and 6 utilised a Likert scale and asked students multiple questions regarding their experiences and attitudes towards teamwork. The answers to Question 5 are summarised in Table 1 and for Question 6 are summarised in Table 2. Broadly these questions can be classified as being based on personal point of view, different cultures, engineering specific, process/training related, definition related, and teamwork styles related.

The definition related questions received high agreement from students in acknowledging that “A team is a group of individuals working together towards common goals” (100% agreement 2017, 81% agreement 2019), “Team members share responsibility for team outcomes” (95% agreement 2017, 88% agreement 2019), and “A team can accomplish more than individuals working alone” (71% agreement 2017, 75% agreement 2019). However, 57% of students thought that the product of teamwork was not as good or better than what they could produce individually in the 2017 survey. This reduced for the participants in the 2019 survey with 50% of students agreeing that the product of teamwork could be better than or equivalent to what they could produce individually. In terms of training and process related questions, students typically agreed that teamwork training is necessary (71% agreement 2017, 69% agreement 2019) and that the lecturer needs to provide guidance to students on how to work in teams (52% agreement 2017, 69% agreement 2019). This was further supported by student comments made in the 2017 survey to the open-ended question (Question 7) including “more advice would be good” and “lack of teamwork training is a problem”. No comments of this type were received in the 2019 survey. These results are consistent with other studies in the literature indicating that students need to be well training to engage in teamwork competently (Agerup & Büsser, 2004; Dunne & Rawlins, 2000; Smith, 1995).

With respect to engineering specific questions 100% agreement was achieved in both 2017 and 2019 that “engineers need to work effectively in teams”, however only 57% in 2017 of respondents thought that teams benefited from diversity in coming up with creative solutions. The 2019 survey respondents indicated more favourable responses regarding the benefit of diversity in developing creative solutions with 63% expressing agreement and 31% neutral.

Most respondents were positive about working in teams with people from different backgrounds with 57% of 2017 respondents agreeing that this enables them to learn new things, and 76% agreeing that they know how to work with people from different

backgrounds. The 2019 survey produced similar results with 56% of students indicating that working with others from different backgrounds enables them to learn new things, however these students also expressed that they aren't as confident that they know how to work with people from different backgrounds. This may in part be due to the 2019 survey population being made up of year 1 and 2 students, where the 2017 survey population included all years of the course. As students are exposed to more cross-cultural teamwork opportunities they may become more confident in their abilities to contribute in these teams. When asked if they prefer to work with people from the same background 40% indicated yes, while 45% of respondents gave a neutral response in 2017. The 2019 results on these questions provide similar trends with 44% indicating they would prefer to work with people from the same background and 31% having a neutral response. These results are interesting as of the 33 students who answered the open-ended question in both surveys, 11 made specific reference to teamwork experiences involving both local and international students and the key challenges. Many of the comments related to cross-cultural teamwork experiences belong to the theme of pre-allocated groups. In many cases students expressed negative views about being placed in allocated groups where diversity was a driving factor rather than the outcome the students were aiming for. Other responses and factors related to working in cross-cultural teams mentioned gaps in knowledge when coming from different educational systems, communication ability, and shyness stemming from speaking in a second language. One participant commented:

> *"Adding a peer review section worth a decent amount of the marks will encourage people to work hard and cooperate otherwise they will suffer in marks. This also encourages people to work hard individually on their own sections".*

Table 1: Answers to Question 5 – In the context of your experiences working in a team in a university setting, rate the following statements from strongly agree to strongly disagree. Data presented for both years of survey delivery in the with separate lines given for each.

	Year of survey	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	N/A
Working in a team is more satisfying to me than working alone	2017	0	2	12	4	3	0
	2019	2	4	6	3	1	0
The product of a team assignment has been as good or better than I could produce as an individual	2017	0	4	5	8	**4**	0
	2019	1	7	1	4	3	0
Working with people who come from different backgrounds in teamwork enables me to learn new things	2017	0	12	3	4	2	0
	2019	2	7	5	2	0	0
My experiences with teams makes me want to work in teams again	2017	0	2	7	7	5	0
	2019	2	2	7	2	3	0
Working in a team improves my ability to work in teams in the future	2017	0	19	1	0	1	0
	2019	4	8	2	0	2	0
Teamwork activities help me to find out about my own strengths and weaknesses	2017	1	10	6	3	1	0
	2019	5	4	5	0	2	0
I prefer to work in teams where team members perform their own tasks independently rather than working together	2017	5	7	5	4	0	0
	2019	3	4	4	4	1	0
I prefer to work with people who come from the same background	2017	2	6	9	2	1	0
	2019	1	6	5	2	1	1
The lecturer should provide groups with guidance on how to work together effectively	2017	0	11	8	2	0	0
	2019	3	8	2	0	2	1
I prefer to be rewarded for my team's performance rather than my individual performance	2017	0	3	7	8	3	0
	2019	2	3	3	4	3	1
I understand how to work with people who have different cultural backgrounds	2017	3	13	3	1	1	0
	2019	2	7	5	1	1	0

In terms of personal point of view related questions, most respondents gave neutral responses regarding teamwork being more satisfying than individual work (57% neutral 2017, 38% neutral 2019), many responded that their experiences of teamwork make them not want to work in teams again (57% negative responses in 2017, while only 31% in 2019), while 90% of 2017 respondents and 75% of 2019 respondents agreed that teamwork experiences improve their abilities to work in teams in the future. Of the respondents. 52% in 2017 and 56% in 2019 identified that teamwork enables them to learn about their own strengths and weaknesses, while 57% of 2017 respondents and 44% of 2019 respondents identified that they prefer to work in teams where members complete their owns tasks independently rather than collaboratively. Very few students in 2017 (n=3) agreed that they would prefer to be rewarded for their teams performance than their individual performance, however this increased to 31% of respondents in 2019. This suggests that teamwork assessment should incorporate an individual element or peer assessment and evaluation.

Table 2: Answers to Question 6 – Rate the following statements related to the role of teamwork

	Year of survey	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	N/A
A team is a group of individuals working together towards common goals	2017	5	16	0	0	0	0
	2019	4	9	1	2	0	0
Team members share responsibility for team outcomes	2017	9	11	0	1	0	0
	2019	7	7	2	0	0	0
A team can accomplish more than individuals working alone	2017	4	11	6	0	0	0
	2019	5	7	3	0	1	0
Engineers need to work effectively in teams	2017	14	7	0	0	0	0
	2019	12	4	0	0	0	0
Everyone in the team should get the same mark for an assignment	2017	1	2	8	5	4	1
	2019	0	2	2	6	6	0
Diverse groups can develop more creative solutions	2017	3	9	3	3	2	1
	2019	1	9	5	0	1	0
Training on how to work effectively in groups is important	2017	5	10	6	0	0	0
	2019	5	6	3	0	2	0

Conclusions

The results from this study show a stronger focus on design and project-based learning in the early years of an Engineering Bachelor degree was linked with students having a more positive view about working in teams in later units. Team related issues involving communication, managing expectations, accountability and assessment did not seem to be influenced by a greater emphasis on teamwork training and need further study. The results suggest that for this study, formal teamwork training was not strongly linked to improved student outcomes, suggesting that a more efficient and integrated approach of delivering this across a program is needed.

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