Teaching strategies in a level 2, large class design course

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Structured Abstract

BACKGROUND

A change of teaching practice, incorporating a number of new teaching strategies, has been gradually introduced to the Design Practice, a level 2 design course at the School of Mechanical Engineering at the University of Adelaide. As a result, over recent years this design course has been transformed from a course with focus on an individual assessment of embodiment design of power transmission elements to a large class course with a more complex structure involving a blend of teaching methods. The process of change was initialized by incorporating the Warman design and build competition into Design Practice. Since this incorporation a project-based learning approach has steadily evolved to include learning experiences in developing communication skills, problem solving skills and the capacity to work in a team. Assessment criteria were modified to reflect the new course structure and emphasize learning outcomes. The new structure of the course also provided the opportunity to offer students a small group discovery experience, one of the latest initiatives at the Adelaide University. To further increase the effectiveness of these new teaching methods, undergraduate students, with previous experience of the Warman competition, were employed as peer mentors and tutors.

PURPOSE OR GOAL

The main motivation behind the change in teaching practice was to address the evolving requirements of contemporary engineering education programs by exposing students to many professional aspects important for their future career, and thus to achieve the best educational outcomes.

APPROACH

This paper explains the new structure of Design Practice and examines student perceptions of the restructured course. Survey responses of two separate cohorts that have experienced the integrated Design Practice course, the 2011 class and the current 2014 class, are compared. An analysis of the data, both quantitative and qualitative, is discussed. Importantly, this analysis will provide information that will be used to ensure continued improvements to the learning and teaching approach already developed.

RESULTS

Students overwhelmingly agree that the course helped them to develop their analytical and problem solving thinking skills, and, despite large class sizes, exposed them to a small group discovery experience. They are also generally satisfied with the course quality, content and structure, including the peer tutors scheme. Most controversial aspects of the course, with noticeably lower level of students' agreement, are the level of logistic and structured support for the project, the Warman project being biased towards mechatronics, and course assessment, whilst relatively small component is awarded for quality of a competition device and competition score.

CONCLUSIONS

The restructured Design Practice provides students with the opportunity to apply their theoretical knowledge to practical engineering problem, resulting in a creative, integrated theoretical and project based course that involves many challenges related to students' future engineering careers. Based on the survey results, large majority of the students are very enthusiastic about these challenges and they consider Design Practice to be one of 'the best' courses offered in the School of Mechanical Engineering.

KEYWORDS

Student perceptions, curriculum design, PjBL, Small group discovery experience (SGDE), Warman competition, "hands-on" engineering

Introduction

The importance of design courses in engineering education has been widely recognized for a long time, with project-based learning being one of the most popular pedagogical models for teaching design (Dym, Agogino, Eris, Frey and Leifer (2005)). This teaching model allows the use of a blend of teaching methods to increase effectiveness of teaching. The project-based learning includes some form of structured support such as lectures or tutorials, with the level of support depent on the adopted strategy of project-based learning (Kolmos 1996; Mills and Treagust, 2003). The difference between problem- and project based learning is the degree of learning support provided by teaching staff, as discussed by Maier (2008). Such project-based learning approaches can also provide learning experience in communication skills, problem solving skills and the ability to work in a team which is increasingly considered to be an essential part of engineering education programs (Hadgraft, 1998).

The Warman design and build competition is a national competition, which can be readily adopted for project-based learning. It has been run for over twenty five years and has involved around 2000 students from up to 20 universities from Australia and overseas (Smith, 2008). The competition is organised by Engineers Australia for teams of second-year mechanical-engineering students and it is sponsored by Weir Minerals Australia Ltd. A local competition is organized on a university's campus after which the winners attend the finals in Sydney. The competition is used by the National Committee on Engineering Design to provide a problem-based learning (PBL) experience in a competitive environment. The objective is to design, build and prove prototype autonomous devices to perform a number of tasks on a competition track with a scoring system that is generally quite complex, with points awarded for speed and accuracy at which individual tasks are performed.

Peer mentors and tutors can provide valuable assistance in organizing the project based learning in large classes. Peer mentoring and tutoring schemes have been recognised as an effective tool to stimulate enthusiasm of engineering students (see for example Blazewicz, Kestell and Grainger (2009), Crouch & Mazur (2001)). These schemes are often used in first year support initiatives to address the issues of retention rates as discussed by King (2008), but they have proven to be most effective when applied to project based programs such as Formula SAE (Godfrey 2008).

Design Practice, a level 2 mechanical engineering design course at the University of Adelaide

In recent years the Design Practice, a level 2 design course at the School of Mechanical Engineering at the University of Adelaide has been gradually transformed to address the evolving requirements of contemporary engineering education programs and thus to achieve the best educational outcomes. A change of teaching practice, incorporating a number of new teaching strategies, has been introduced shifting a course focus from an individual assessment of embodiment design of common power transmission elements to a large class course with a more complex structure involving a blend of teaching methods. The process of change was initialized by incorporating the Warman design and build competition into Design Practice, which provided students with the opportunity to apply theoretical knowledge acquired in their studies to a practical engineering problem. Since this incorporation a project-based learning approach has steadily evolved to include learning experiences in developing communication skills, problem solving skills and the capacity to work in a team. The project part of the course involves number of specific aspects which are important for student's future engineering career:

- ability to critically analyse complex competition rules and draw a design specification
- application of theoretical knowledge (including steps in design) to a practical design

- ability to effectively work in a team using work breakdown structure
- ability to manufacture a device based on their design
- need to allow for testing and improvements of the device (design iterations) and
- ability to work within a budget.

The new structure of the course aligned well with senior undergraduate level courses in the School and therefore also serves as an ideal preparatory approach to more complex levels of project based (PjBL) and problem based (PBL) learning, in particular the third year Engineering Systems Design and Communication (ESDC) course and the level 4 year-long Design Project course. Interestingly, the nature of this evolved level 2 Design Practice course is also well aligned with a more recent initiative at the University of Adelaide in offering students Small Group Discovery Experiences (SGDE) (see Bebbington (2012)) as part of their learning. Small Group Discovery Experiences require that students directly collaborate with motivational lecturers, and with tutors whose role includes facilitating learning in a small group setting with the goal of instilling life-long learning and research skills, via discovery experiences. In the Warman project, while there is a degree of structured support for the students, they also have to rely on self-learning and ability to work effectively in a small team, of up to five members, to design and manufacture their competition devices with the support of peer tutors.

Course structure

Design Practice in its revised form has a quite complex structure involving many course components and teaching methods. Students are given lectures, synchronised with the Warman competition, on theoretical steps in design, aspects of working in a team and organising a project, written communication skills, power transmission devices and basic microprocessor programming. It should be noted that, due to the nature of the course and to encourage students' self-learning as a part of their small group discovery experience, the structured support for electronics design is limited. The lectures, on average two hours a week, are complemented by two two-hour Design Offices during which students, with assistance from tutors, work on the design of power transmission devices in one session and the Warman project in the other session.

Making the project compulsory to all the students creates a challenge of stimulating students' enthusiasm. For this reason the temptation to allocate students into groups, to mix local and international students and thus to provide more realistic teamwork experience, has been resisted and students are free to work in a team of their choice.

Apart from the lectures and Design Offices, two laboratory sessions provide students with hands on experience. The first laboratory involves disassembly of a four-stroke engine while conducting a function analysis of this relatively simple mechanical system, and the second one is an introduction to basic measurement methods and associated error analysis.

Course assessment

The complex structure of Design Practice is reflected in the course assessment. The project assessment, aimed at emphasizing learning outcomes, is based on two group design reports, a preliminary report, worth 5% of the total course mark, and final report worth 7%, and only to small extent on quality of a produced device (4%) and on the competition score (4%). This assessment scheme aims to focus on the design process rather than final outcomes, which can be strongly affected by students' lack of practical experience and manufacturing limitations. Weekly group reports on design of power transmission devices are 20% in total. A final exam covering design aspects of the course is 50%. Laboratories are worth 5% each.

Logistic support

In recent years Design Practice class sizes have grown steadily to reach nearly 280 students in 2014, resulting in over 60 design teams. With so many teams involved organizing the Warman competition created a serious challenge for the School organisers. The student numbers combined with increasingly restrictive safety rules resulted in the School being able to offer only very limited workshop support (technicians are available at assigned times to help with small jobs). Instead each team is given a budget ($120 in 2013) to cover material and manufacturing expenses. Teams with limited access to manufacturing facilities can also hire a toolbox including basic hand tools.

Peer tutors

Historically tutors employed for Design Offices were usually retired engineers, who while possessing vast engineering experience, did not necessarily relate to students and their problems associated with the Warman design (especially mechatronics aspects). These experienced engineers were in time replaced with postgraduate students, who could relate to the competition and undergraduate students more easily but, in some cases, lacked necessary commitment to the job. Most recently undergraduate students, with previous experience of the Warman competition, were employed as peer mentors and tutors for the project Design Offices to stimulate student enthusiasm to the project. The idea of employing undergraduate students, winners of a past Warman competition, as tutors was generated in 2008, after a team of exceptionally committed and skilled students won the national finals. To capitalize on this success to increase students' enthusiasm and involvement in the competition in the years to come, students, who were a driving force behind the 2008 team success, were recruited as Warman tutors for 2009. As discussed in Blazewicz, Kestell and Grainger (2009), the experiment in employing the undergraduate students has proven to be very effective in many respects. The tutors are generally successful in motivating their peers and, while having the experience of past competitions, are able to help in many practical aspects of the design and manufacture. These peer tutors, selected from most promising undergraduate students, also benefit from the process as they are given a valuable learning experience in teaching. However, it should be noted that while the undergraduate tutors, being generally more enthusiastic and committed to their duties than postgraduate students, are very effective in motivating their peers, they can lack in teaching experience and maturity. To compensate for these shortcomings a supervision of a more mature and experienced postgraduate student is usually required. As the peer mentor and tutor scheme has now been operating for several years the post graduate tutors chosen are amongst those who undertook the revised Design Practice course as undergraduates and has included several who were originally peer mentors. Through this mechanism it has been possible to ensure greater continuity of approach as well as to retain and pass on the learning and teaching knowledge that has been developed among the tutor.

Student perceptions of Design Practice course

To gauge student perceptions of the restructured Design Practice course, survey responses of two separate cohorts that have experienced the integrated Design Practice course, the 2011 class and the current 2014 class, have been examined. It should be noted that there have been relatively small changes to the course over this period, including mainly some additional support with the preparation of Warman reports and CAD drawings. Summary of both, 2011and 2014, Student Experience of Learning & Teaching (SELT) – Course Evaluations indicating broad agreement and broad disagreement (combined percentage of students who, to any extend, agree and disagree, with undecided students excluded), are given in Tables 1 and 2 respectively. Two separate tables are used since some survey questions have been changed between 2011 and 2014. In both surveys students used the a

Likert scale from 1 (strongly disagree) to 7 (strongly agree), with 4 corresponding to 'undecided', applied to a list of statements.

The survey results indicate that Design Practice is generally well received by students. There is also a remarkable agreement between similar questions in both surveys despite the different ways the surveys were administered. The 2011 SELT was conducted in a lecture, presumably attended mainly by students satisfied with the course, which was reflected in relatively low response ratio of 20%. The 2014 survey was conducted online, where all students, including ones dissatisfied with the course, could easily participate (35% response ratio).

Table 1. 2011 SELT Course Evaluation

No.	Statement	Agree %	Disagree %
1	Overall, I am satisfied with the quality of this course.	89	2
2	This course stimulates my enthusiasm for further learning.	89	4
3	This course helps me develop my thinking skills (eg. problem solving, analysis).	93	2
4	I am satisfied with the course information provided.	89	9
5	The learning resources are valuable for my understanding of the course.	80	13
6	Overall, the workload in this course is heavy.	82	0
7	The assessment allows me to demonstrate what I understand.	73	9

Table 2. 2014 SELT course evaluation

No.	Statement	Agree %	Disagree %
1	Overall, I am satisfied with the quality of this course.	89	5
2	This course is well organised	89	4
3	This course helps me develop my thinking skills (eg. problem solving, analysis).	93	3
4	The teaching strategies engage me in my learning.	87	5
5	Online resources help me achieve learning outcomes.	78	6
6	The workload is appropriate to achieve learning outcomes	79	11
7	The methods of assessment help me achieve learning outcomes.	85	3

The vast majority of respondents are satisfied with the course quality (Statement 1 in both surveys) and consider the course to be well organized (Statement 2, 2014 SELT). They also acknowledge that the course stimulated their enthusiasm for further learning (Statement 2, 2011 SELT). Encouragingly the highest level of agreement is in Statement 3 (both surveys), where 93% students agree that the course helped them to develop thinking skills such as problem solving and analysis, arguably the most important learning outcome of a design course, and an essential skill to equip students for their future as professional engineers.

Statements 4 and 5 in both surveys indicate that students are generally happy with the level of support in the course. This might be somewhat surprizing, considering the limited logistic support offered for the Warman project. While the majority of the students perceive the course overall workload as heavy or very heavy (Statement 6, 2011 SELT), they believe that the workload is appropriate for the teaching outcomes (Statement 6, 2011 SELT). They also admit, although with lower level of agreement, that the assessment allows them to demonstrate their understanding of the course and help them to achieve required learning outcomes (Statement 7 in both surveys).

It was decided that the standard questions in SELT Course Evaluation are not necessarily best suited for evaluating a design course such as Design Practice. To address this issue and to obtain students' feedback on more specific aspects of the course, a short, anonymous survey was conducted online in 2014. To encourage student participation the survey was short and simple. It was constructed in a similar way to SELT survey but with a simpler scale, from 1 (strongly disagree) to 5 (strongly agree), with 3 corresponding to 'undecided'. Students were asked to rate the statements presented in Table 3 and asked for additional comments. Table 3 gives summary of the survey results, indicating broad agreement and broad disagreement (combined percentage of students who strongly agree and agree, and disagree and strongly disagree).

Table 3. 2014 Short Survey results

No.	Statement	Agree %	Disagree %
1	This course provides an opportunity to practically implement the engineering theory that you have learnt so far.	74	13
2	The learning experiences in this course are more enjoyable to those that are more theoretically focused	66	14
3	This course enabled me to work in a small team in which we discovered, through research and exploration, how to find design solutions for an engineered problem.	80	7
4	The tutors employed in the course were competent and helpful.	73	9
5	Information provided during the lectures was relevant and helpful.	64	14
6	The course assessment is fair.	64	18

At 18% participation ratio, broad agreement levels in this survey are generally lower than in the SELT surveys, which could be explained by the fact that the students were encouraged to be critical to help to improve the course in the future. Statement 1 (This course provides an opportunity to practically implement the engineering theory that you have learnt so far) indicates that the students generally agree with what was the main reason of incorporating Warman project in Design practice. Majority of the students enjoy the experience of more practically oriented course (Statement 2), despite some level of discontent. There is, however, a very high level of agreement for Statement 3, related to a small group discovery. This result correlates well with Statement 5 of the 2011 and 2014 SELT surveys, where overwhelming majority of students agreed that the course helped them to develop thinking skills such as problem solving and analysis. These findings are further confirmed by students' additional comments, many of them very enthusiastic, where the students believe that they have been provided with an insight into the work of an engineer in particular. The comments also stress the importance of a team-work experience as preparation for their future career.

> *This course allowed for me to put into practice a lot of the theory learnt throughout first year, which provided a greater insight into the work of an engineer and this was the best aspect of the course for me. The engine disassembly laboratory and WARMAN project were also enjoyable parts of the course and again provided greater practical learning than any other courses experienced so far. Overall, this has been a challenging and enjoyable course.*

> *I've been enjoying the Warman project. It provided me with a valuable opportunity to get a taste of what it is really like to be a mechanical engineer. The project encouraged me to be working in a team and contributing to the project. It's been very pleasant and educational! Once in a life experience! Great thanks!*

> *This course provides a good introduction on how to approach real life engineering problems whilst encouraging correct documentation of the process, all of which i expect to be important for future courses and into my career. As such the early impartation of this knowledge is welcomed.*

> *This course has allowed me to improve my performance in teamwork and the challenges faced in doing team projects. The experiences from this course will certainly help me prepare and know what to expect for future projects.*

The level of agreement in Statement 4 (The tutors employed in the course were competent and helpful.) confirms finding of Blazewicz, Kestell and Grainger (2009), that the peer mentoring and tutoring scheme employing a mixture of undergraduate and graduate tutors works effectively and is welcomed by students.

Statement 5 (Information provided during the lectures was relevant and helpful.) has noticeably lower level of broad agreement. This is supported by student comments confirming anecdotal evidence that some students find the mechatronics part of the project challenging and believe that there should receive more structured support in the course.

> *The amount of guidance and assistance for the electrical component of the WARMAN project needs to be re-assessed. I understand that a certain amount of work needs to be done by the student but to expect a group of students, who have at most complete an inductory course in electrical engineering and computer programming, to complete the task well is a big ask.*

> *Not enough material has been covered to actually aid in designing and building the Warman machines. I personally have never had any experience with using electronics to this extent or constructing machines.*

The issue of The Warman project being heavily oriented towards mechatronics is reflected in ongoing argument between the Warman campus organizers with one view that the competition should move back to more fundamental mechanical designs. However the currently prevailing view is that mechatronics should be involved in the project as it reflects challenges of current engineering design. This, however, creates a problem for many universities, including Adelaide, where level 2 students do not have mechatronics courses prior to the Warman competition. This situation leads to frustration among some students, who do not have any mechatronics background.

> *I did not find that the Warman contest this year was beneficial to the course. To be more honest I would say that it actually to a far greater degree degraded the course overall, which is quite a shame. None of what I learnt through any of my hobbies or course material, prepared my team nor myself even remotely to deal with the electrical circuitry and microprocessor functionality.*

It should be however noted that while the logistic and structured support for electronics aspects of the project is certainly an issue, there was no specific comments on possibly insufficient support for mechanical aspects of the project or possible inequity issues, with some students having better access to tools and manufacturing materials.

Statement 6 (The course assessment is fair.) has similar levels of broad agreement and disagreement to Statement 5. To achieve the best educational outcomes the assessment criteria focus on the design process rather than final outcomes. This approach also recognizes that the performance of project devices is usually adversely affected by students' lack of practical experience and manufacturing limitations. To reflect these shortcomings the course assessment has relatively low part allocated to a final device, both quality of the device and a competition score, which is perceived by some students, who put a lot of time and effort into building and testing, as unfair.

> *As much as I loved doing Warman, I believe the time and money spent on it for being worth the percentage of the grade is a little unreasonable. I would like to see either smaller scale projects or a larger percentage with more Warman focused help. That would be very helpful in my opinion.*

> *The amount of time focussed on the WARMAN project is completely disproportionate to the amount of marks the project is worth. I feel that, considering such large amount of effort and time are put into completing the project that it should be worth more. The fact that it is worth so little leaves students with little motivation to actually compete in the project.*

Conclusions

The introduction of project-based learning by incorporating the design and build Warman competition in a large class has produced a number of challenges including financial and workshop support. Importantly, however, it has provided the majority of students with their first opportunity to apply their theoretical knowledge to a practical engineering problem with the process exposing them to many aspects necessary for their future career.

Based on the survey results, the majority of the students are very enthusiastic about these challenges and they consider Design Practice to be one of 'the best' courses offered in the School of Mechanical Engineering. The course helps them to understand the reason and the need for many theoretical courses they had to attend in their earlier year. Students overwhelmingly agree that the course helped them to develop their analytical thinking and problem solving skills, and, despite large class sizes, exposed them to the Small Group Discovery Experience (SGDE). Students are also generally satisfied with the course quality, content and structure, including peer tutors who provide helpful support. The most controversial aspects of the course, with noticeably lower level of agreement, are the level of logistic and structured support for the electronic part of the project, the Warman project bias towards mechatronics, and course assessment, with a relatively small component allocated to a final device.

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