Designing Assignments and Rubrics for Multidisciplinary Capstone Projects for Engineering Students as Part of Integration of Curriculum and Programs

Kourosh, Dini [a]; Elizabeth, Levin, and Aaron, Blicblau.
Swinburne University of Technology, Melbourne, Australia
Corresponding Author Email: kdini@swin.edu.au

Introduction

Many universities around the world use the term "Capstone Projects" to describe the final stage of learning process. Through Capstone Projects, students have to demonstrate their final achievements via a project designed to bring together aspects of the undergraduate student's learning experience. This allows students to apply the range of knowledge and professional skills they have learned. In the case of engineering students, skills are including: data interpretation, application of theory, problem solving, innovative design, multi-disciplinary teamwork, communication skills and ethics (Ward, 2013). Through reviewing designs for Capstone Projects in different universities and based on comments from Accreditation Board of Engineering and Technology (ABET), Ward (2013) concluded that Capstone Projects are high impact practices that enhance students' capabilities and performances. These projects also have some characteristics such as: demanding significant time and effort, offering learning environment outside of the classrooms, encouraging interaction with various people within universities and outside, and eventually, delivering regular and essential feedback.

Referring to ABET engineering criteria, Davis et al. (2006) and his research partners pointed out that students must demonstrate an ability to design a system, component, or process to meet desired needs within realistic constraints. These constraints include economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability (Davis, et al. 2006, p. 4). They stated that: students must be prepared for engineering practice through the curriculum and based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints. Davis and his team (2006), also stated that many Capstone units or courses pursue to offer students with learning experiences that simulate professional practice, which proposes an opportunity for an authentic assessment environment that can make assessment results more effective.

Capstones by their nature are multifaceted and complex. Lee and Lorton (2015) define capstones as 'substantial culminating learning experiences that take place in the final stage of an educational course, offering closure and a focus for the sense of achievement that comes with completion' (p. 1). Capstones require careful design and skilful teaching to maximise the outcomes for all stakeholders. There is a growing body of literature on Capstone units much of which is focussed on the objectives (Rasul, et al., 2016), forms (Ku & Goh, 2010), and curriculum design (Lloyd, 2016; Ward, 2013).

In regards to the design of Capstone units, Ward (2013) identified five major elements used by universities in the USA to design Capstone projects. These are: 1) problem-based learning courses, 2) focusing of group and team working, please also see comments in Bruhn & Camp (2004) and in Aller, Lyth and Mallak (2008), 3) design-build-test model approach, 4) involving industries as much as possible, and 5) sequential assignments. An example for sequential assignments includes students' design notebooks (5%), supervisor's evaluation (10%), oral multimedia presentation (8%, 10%, and 17% at final stage), and written reports (18% & 32% for final stage) which is totally 100%.

For students who are studying both Engineering and Business at our institute in Australia, the capstone projects are designed to help students combine, and demonstrate their expertise and

skills in two disciplines – Engineering and Business. Final year students are completing Engineering specialisations in Mechanical, Civil, Robotics & Mechatronics, and Electrical and Electronics, as well as a broad range of Business specialisations including Entrepreneurship and Innovation, Finance, and Management.

Students undertake a year-long capstone project, spread over two semesters as separate but interlinked sequential subjects. They have two supervisors, one from the Faculty of Science, Engineering and Technology (FSET) and one from the Faculty of Business and Law (FBL). This joint Capstone experience has been developed to indistinguishably link both disciplines. In our study (encompassing 4 years), about 100 students per year completed capstone projects, generally in teams of up to 4 students.

These Capstone units have been running since 2015 in our university. As a result of supervisor, examiners, and student feedback, the subject panel and teaching team monitored the unit with the aim of continuous improvement. The teaching team decided to change some parts of the structure of the units, involving changes in assignments and rubrics for assessments and evaluation. There is a pair of Capstone units, which double degree students must complete, and each has four assessment tasks. These assessment tasks were originally designed taking into account the course and unit learning objectives, requirements of Engineers Australia, and compared to the assessment requirements for Capstone units in other universities, as well as engineering literature relating to capstone assessment design.

The current assessment design which we implemented is given in Table 1, including both the original assessment values as well as the current assessment values. At the end of the first delivery of the Capstone units, management conducted a review which resulted in an update to value of the various assessment tasks, which is shown in Table 1.

Table 1: Capstone assessment tasks

Capstone unit	Task	Structure	Current assessment value	Original assessment value (2015)	Due date
First	Research plan	2500 words*	15%	10%	Sem. 1, week 6.
	Presentation	5-8 minutes*	15%	10%	End of Sem. 1.
	Progress report	8000 words*	50%	40%	End of Sem. 1.
	Workbook	Portfolio#	20%	40%	End of Sem. 1.
Second	Research paper	4 pages*	15%	10%	Sem. 2, week 10.
	Presentation	10-15 minutes*	15%	10%	End of Sem. 2.
	Final report	8000 words*	50%	40%	End of Sem. 2.
	Workbook	Portfolio#	20%	40%	End of Sem. 2.

*group submission   # individual submission

Two of the present authors, who coordinate these units together, one from Engineering and one from Business, have been made aware of issues and problems relating to the assignments and rubrics through feedback from students, supervisors as well as examiners and markers. These issues can be summarised as

➢ Lack of clear instructions for assignments, and
➢ Complexity of rubrics.

This paper investigates issues identified as relevant to the successful implementation of double degree capstone projects in engineering and business. These issues include; type of assignment information; and associated rubrics used in the capstone subjects for double degree students.

Methodology

In the middle 2018, the teaching team, including the authors of this paper developed an educational research project to investigate whether the design of the joint Capstone projects is achieving the intended goal of producing graduates with professional skills through the unique Capstone model which involves a multidisciplinary research project. That is, an engineering project with a link to a business theme, assessed through a series of sequential assignments as depicted in Table 1.

Having said the above, the research aim for this particular paper is to identify: recommendations for improvement of the teaching and learning outcomes in relation to the assessments and associated rubrics.

The research team used students' feedback in the form of written and verbal comments about assignments and rubrics to delve into the problem as well as feedback from supervisors and examiners. For this reason, before presenting findings from interviews, we provide one section for students' feedback later on in this paper.

This research is considered as a qualitative research in our Capstone units in order to improve the teaching and learning outcomes. The first stage was to get the ethic approval from Higher Research Ethics Committee. The research team decided not to seek further feedback from current students, but rather conduct interviews among supervisors from both FSET and FBL. After receiving approval from the Ethics Committee, in early 2019, twenty one interviews were conducted with academic supervisors and examiners, who volunteered to participate in this research; the participants involved 13 academic supervisors/examiners from FSET and 8 supervisors/examiners from FBL.

In the interview, the participants were asked about their opinions with regards to assignments and the rubrics used in the two Capstone units, as follows:

Could you please share your comments in regards to assessment tasks', due dates, rubrics and marking process, while working on research projects with double degree students?

In the following sections, first we review feedback from some students, and then, we present the findings from interviewing academic supervisors/examiners.

Student feedback

Students provided their feedback about the units at the end of each semester. These feedback were anonymous and sometimes students provide written feedback as well rating the unit itself (on a modified 10 point Likert scale). Examples of students' written feedback from different semesters and years relating to assessment tasks and rubrics are presented in the Table 2.

Table 2: Samples of students' written feedback

Year & semester	Feedback and comments from students
2015 – S1	Organisation of assessments and materials required.
2016 – S1	I found the workbook is a waste of time.
2016 – S1	The marking rubric didn't even make sense. They need to be completely re-done.
2017 – S2	Assessments need to be made more clearly and not changed throughout the semester.
2018 – S1	Maybe a clear outline of what exactly is involved for the workbook submission at the start of the semester.
2019 – S1	The rubric was changed in middle of semester and I am confused which one I should consider
2019 – S1	Still need more clear explanation for assessment tasks and we need more examples of assignments submitted previous years

It is worthy to mention that students provided more feedback in relation to the unit such as: collaboration between engineering and business supervisors, project topics, availability of academic supervisors, and the timing of releasing projects' topic into the Learning Management System (LMS). Having said that, these were not relevant to the current study. It can be seen that over the semesters both the assessment tasks and the rubrics were a cause for concern and an identified area that needed improvement.

Findings from interviewing supervisors

As mentioned above, there are two groups of participants; one from engineering (FSET) and another from business (FBL). The Engineering supervisors have had previous experience in supervising engineering students in Capstone units, prior 2015 (the year we started to offer the joint Capstone units to double degree students). However, business supervisors were new to this type of Capstone units, although many had previous experience teaching Business Capstone units. In following sections we first summarise some points from engineering supervisors, and then, present the points and comments from business supervisors.

Engineering supervisors

In regards to our question from interviewees about assignments, we received a wide range of comments. One supervisor mentioned '…. In this case, I think it is real fair to have those four assignments'. Another supervisor believed that '… I think the assessment for research plan and final report are fine for me and I can easily follow the rubric'. On the other hand, one supervisor told us that '…..I think there is a problem with final year projects that we have group members, but they sometimes not really collaborate with each other. That is main issue how we can assess students in regards to their report and team performance'.

One supervisor mentioned to us that '… the balance between group assignment and individual assignment is good and also think that the structure of them is fine, although the rubrics could use a little bit of work'. In an interview with another supervisor revealed that, rubrics were not user friendly as some supervisors felt that the rubrics were too specific. The interviewee said that 'the rubrics are very detailed and time wise, it takes a lot of time, especially if you want to do properly'. When we asked about whether supervisors prefer a simplified version of rubrics,

this supervisor stated that 'I will give you an aggregate number and that's what probably works for me.

We received another similar feedback from another supervisor as he mentioned that '…. I think that rubrics are a bit over complicated…' and he added later that '….when you are trying to judge a thing like a complex research project, there are judgements being made that are very hard just to break down into a dot point. In your rubrics you address different evaluation marks by couple of dot points only… and judging the quality of a research project is hard to put in a rubric.'

In brief, we can express that our findings are a mix of pros and cons in regards to assignments and their rubrics from engineering supervisors' points of view. Some had positive views, and at the same time, they pointed out some issues and difficulties in relation to assess the quality of assignments.

Business supervisors

Similar to the feedback from engineering supervisors, business supervisors expressed their opinions in various ways in regards to assessments/assignments and rubrics.

One supervisor stated that the assessments '….are really practitioner oriented sort of assignments ….. Rubrics are great even though we tend to mark towards the higher end of the rubric. Rubrics are really well defined, great criteria to measure …..' Another example came from another supervisor as 'I thought the rubrics were fine and useful ….' Or another example as mentioned by another participant '… I think the rubrics are very well defined, so, they're good.'

Again, on the other side of discussion, we have comments that one of our participants mentioned that in regards to rubrics '… not the rubric, I think it was the marking sheet. The marking sheet can be quite extensive'. This showed a little bit of uncertainty or misunderstanding about the usage of rubrics. Another participant said directly that 'the rubrics were a huge challenge. I didn't understand what was being assessed… Rubrics were very vague …'

In regards to one specific assignment known as workbook, one participants referred to feedback from students and said that '…the feedback I got from students was that the workbook was kind of just a hassle and they had no idea how much they had to put into it'. We also found out that another participant believed that '... I don't see the purpose of workbook to be honest, I think it wastes of time for students. This time can be used more creatively in the actual project'.

A mixed feelings about assignments and rubrics were observed through interviews with business supervisors, we also need to consider that business supervisors since 2015 have helped the teaching team and all participants who were interviewed have had experience supervising projects after 2016.

In the following section, we review some changes that we have implemented since 2015 and then we reach our final discussion and conclusions later on.

Changes to assessment values and rubrics resulting from feedback and interviews

Initially the present authors reviewed comments from the Student Feedback Survey (SFS), and incorporated them with the supervisor comments to improve the assessment values and the rubrics' structures.

These changes involved: changing the value of each assignment from the first year of running these subjects in 2015 (evidence can be seen in Table 1). Also, we changed the rubrics to provide greater clarity as well as improve the ease of grading.

After discussion with academic supervisors, we decided to change again the contents of rubrics and we did it in three different rounds. The first round was slightly adding different criteria in couple of assignments such as in rubrics for presentation and final report in second Capstone unit to differentiate them from the first Capstone unit's rubrics. Also, we changed some part of rubrics for research plan and progress report for the first Capstone unit to check how students use referencing in their reports. In both rubrics we also assess whether students can capture attentions of proper audience in an appropriate and professional manner.

In the next round of updating the rubrics for both units, we sought advice from the "Learning Transformation Team" and the "Academic Learning Adviser" (two separate departments in our university). As a result we updated the whole structure of rubrics in 2018, prior to conducting the interviews.

The third round was in early stages of 2019 and one of our present authors decided to simplify the workbook rubric and slightly change the research plan rubric. Table 3 summarises the changes in rubrics.

Table 3: Summarising the changes on rubrics

Stage	Rubric for tasks	Changes
One – 2016/17	Research plan and Progress report	Adding the criteria relating to proper in-text referencing
One – 2016/17	Presentation & Final report	Adding the criteria relating to findings and discussion
One – 2016/17	All tasks	Adding the criteria relating to considerations of the audience or reader type/background
Two - 2018	All tasks	Revising the rubrics and identification of the main differentiators of quality of students work in each criteria
Three - 2019	Workbook	Simplifying the assessment rubric to avoid any confusion by assessors
Three - 2019	Research plan	Adding clearer explanations within criteria, so students clearly understand what is expected in the research plan

Discussion

As can be seen from findings in this paper, we have received a very wide variety of opinions from student's points of view as well as from both engineering and business supervisors. It is worthy to consider that we interviewed only 13 engineering supervisors, despite having more than 50 engineering supervisors. In regards to business supervisors, we interviewed eight supervisors, but we have had more who helped us during 5 years running these Capstone units who did not wish to be interviewed.

The teaching team has faced many challenges with this multidisciplinary joint Capstone approach for the double degree students. Although many reviews were completed in terms of design of units and the structure of assignments and rubrics, the evidence from interviews shows that we have not yet achieved the outcomes of reaching all the unit learning objectives, from the academic or student point of view.

We also would like to help students to have a very good and pleasurable learning experience; however, many factors and limitations caused problems for us to reach our goals. The outcomes of students' survey still shows that students have not been satisfied with these units.

The authors suggest that continuous improvement in these Capstone units (double degree) is a long journey with many barriers and challenges. It is more challenging when you want to improve the process or in this case, learning and teaching experience or performance (depended upon from which point of view you would like to focus, either from academic staff or students), as many people are involved with many different perspectives. It is difficult to reach an optimum outcome, which we understand. Notwithstanding that, we will be persistence in our goal for continuous improvement.

Conclusions and recommendations

Capstone Projects are almost universal components of engineering degree programs in universities around the world. In fact the purpose of the Capstone units in engineering is to provide students authentic engineering experience in which team of students design a project or research to meet specific needs while complying with technical, professional and societal constraints. Students must be assessed based on their performance and the results of evaluations must have consistency and be rational.

In our university, for a first time, we offered unique Capstone units for double degree students who study engineering and business courses. Since 2015, we have tried to improve our Capstone units and we have gathered different opinions, however, we received mixed messages and still students have not been satisfied. The current authors will continue to seek further advice on subject implementation improvement.

It seems to us that there are several issues such as "rubrics were not user friendly" or "rubric didn't even make sense" and "rubrics are a bit over complicated" that required attention in relation to assessments. Mixed feelings from both group of supervisors and students (via their end of semester feedback); making it difficult to satisfy all stakeholders in these subjects.

Acknowledges:

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