Introduction

This paper presents a case study in engineering education teaching practice, with a focus on student-centred learning. The design and implementation of a new research skills course for masters students is presented. The course is structured according to the 'flipped classroom' approach. The paper will communicate the goals of the course design, the methods adopted to implement the design and some analysis of how well the goals were achieved.

Unlike some publications describing course design innovation, this paper is not describing the adaption or improvement of an existing course. On the contrary, the situation of needing to introduce a new research skills course for engineering masters students with relatively high projected class sizes (potentially 200-300 per semester) seemed like the perfect opportunity to deviate from the traditional lecture format and design the course with active learning concepts embedded from the start.

Additionally, the context and requirements of the specific course lend themselves well to active learning approaches. The course is now a core course for almost all disciplines within UNSW's Master of Engineering Science program. The motivation for its introduction was twofold. Firstly, it was necessary to introduce 6 more units of credit via 'enquiry based learning' to fulfil the degree accreditation requirements, hence, the teaching methods needed to prioritise enquiry based learning (therefore, it is a 6 unit of credit subject). Secondly, there was an apparent need to better prepare the students for their two-semester (12 units of credit) research project. The experience of project supervisors in recent years has been that many students are inadequately developed in key 'soft' skills such as writing, literature search, experimental design, etc. Given a tendency for students to view generic compulsory courses as less interesting and less important, and in the current context of dropping attendance at lectures across many types of courses, we were faced with a challenge to succeed in engaging students with this content. These factors all pointed toward focusing on student-centred, active learning, and in particular the flipped classroom approach.

We set out to develop a course that would actively engage students in the practical application of research skills, expose them to some real-world research problems and give them a somewhat realistic experience of working in a research team.

For the university, for the industry and for the students themselves, it is critical that we improve our teaching of skills. While this course is nominally teaching 'research' skills, the content is equally valuable for graduates moving into industry or other roles. At the very least, within the 12-month research project in our masters program, both the students and their supervisors should directly benefit from the skills preparation in this course.

Background

Engineering education literature is increasingly laden with discussion of the outdated nature of the traditional lecturing style. Felder (2012) makes a motivating case for reform and goes so far as to suggest that issues such as the steadily declining interest in engineering among high school students and chronic complaints from employers of graduates about deficiencies in critical thinking, teamwork and communication skills are resulting from outdated teaching methods. He outlines some characteristics of a so-called ‘emerging paradigm’, including curricula focussed on skills as well as content, teaching styles to address a variety of learning styles and teaching dominated by active learning whereby students are actively involved.

Specifically with regard to teaching soft skills, which is relevant for this case study, Woods et el. (2000) states that process skills are “hard to define explicitly, let alone develop and assess”. The article stresses that skills should be developed via practice, that the process must be assessed as well as, or instead of, the product, and that monitoring and reflection of mental processes are key for understanding.

One type of active learning approach is problem-based learning, which is implemented in this case study. From a previous study, a comparison of problem-based learning versus traditional lecturing in an electrical engineering course demonstrated doubled learning gains from the problem-based learning method (Yadov, 2011). Looking at active learning more generally, a comprehensive review of active learning literature defined ‘active learning’ as encompassing also collaborative, cooperative and problem-based learning, and showed consistent improved learning outcomes across all studies of collaborative learning when compared with independent learning (Prince, 2004).

This research background demonstrates that the high level educational concepts followed in this case study are certainly not new, but that the prior work has shown that there are benefits and advantages to be gained by using such approaches. The purpose of this case study is to examine the details of how such concepts can be implemented.

In the list of themes for this conference, student-centred learning is described as aiming to “develop learner autonomy and independence by putting responsibility for the learning path in the hands of students” (AAEE, 2015). This paper will refer to this definition in discussing how student-centred learning was implemented in this case study.

Course design

The course content obviously consists of research skills, but this is structured around a course theme, which is ‘Engineering Future Challenges’. The assessment task topics and the group problem-based learning tasks are based on this course theme, which provides real-world engineering problems to relate the content to. The Engineering Future Challenges are drawn from a range of disciplines, but using them as a hook onto which to hang the learning of soft skills is useful, because such skills are inherently non-discipline specific.

Teaching activities

An overview of the course design is depicted in Figure 1, including outlines of the teaching activities and the assessment tasks. As shown, the 8 flipped classroom lectures are supplemented by 4 traditional lectures plus tutorials. The specific structure of a flipped classroom lecture as defined in this course is: pre-class lecture snippet videos and readings, followed by a large group Q&A/discussion session (~120 students), followed by small group facilitated workshops (16 students per group). The large group discussion is run by the guest lecturer for that topic, i.e. the same person that the students watched in the pre-class videos. The small group workshops are facilitated by pairs of students from within the group on a rotating basis, hence a different pair each week (see more on this facilitation in the Assessment Tasks section).

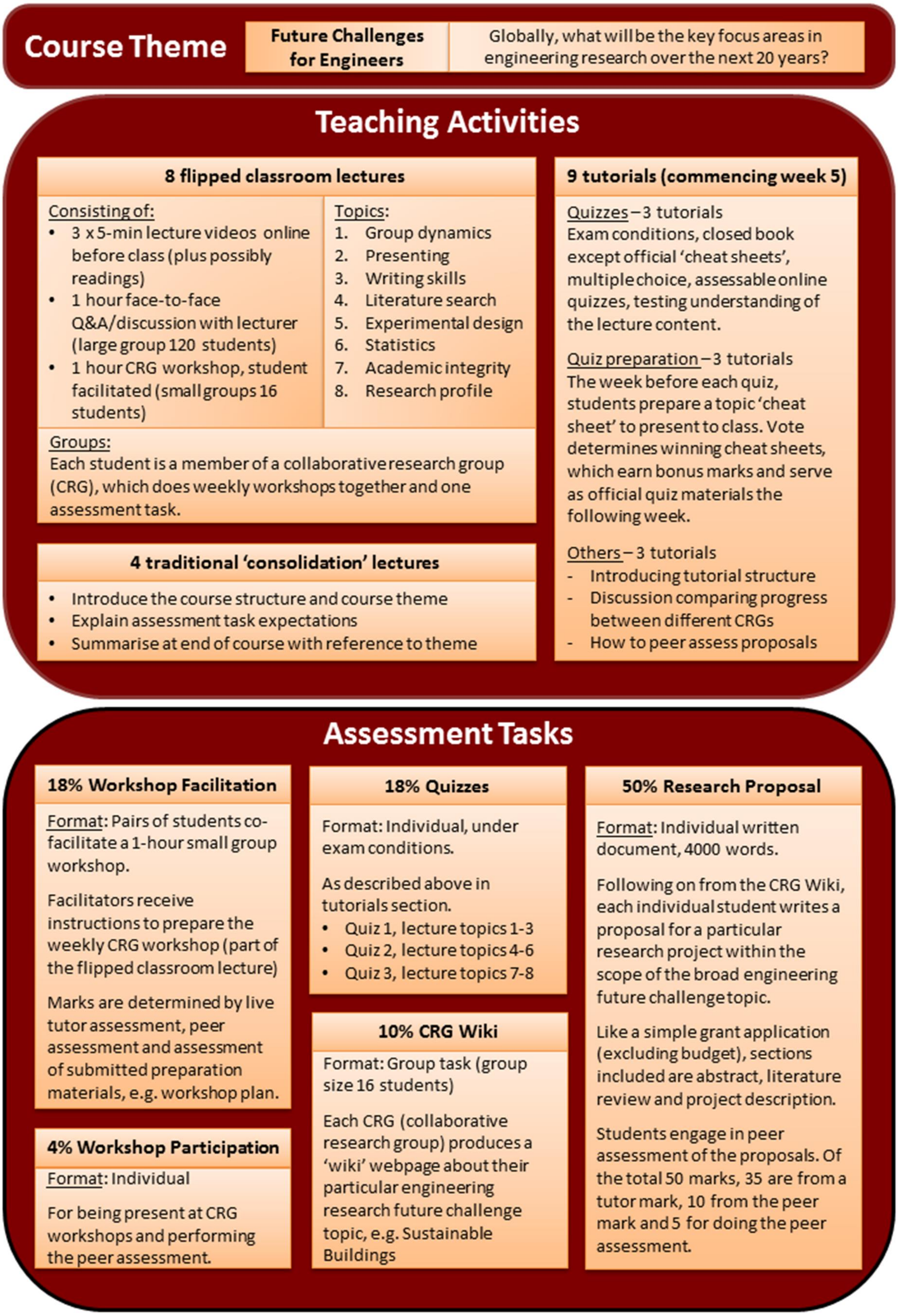

Figure 1 - Overview of course design

The groups of 16 students for the facilitated workshops stay together for the whole course. These groups are called the Collaborative Research Groups (CRGs). In addition to doing the weekly flipped classroom lecture workshops together, these groups also complete a group assessment task to write a wiki about one particular engineering future challenge. The weekly workshops include activities such as discussion, brainstorming and direct practice of skills. The workshop activities are clearly related to that week's lecture topic, but are also designed to assist the CRG to move step by step toward completing the group task.

The rationale for the tutorial plan is that 'traditionally' designed activity-based tutorials are redundant in the flipped classroom structure due to the activity-based group workshops. The concept of the quiz preparation tutorials is to incorporate student-centred learning by giving incentive for the students to take responsibility for their own revision of the topic content.

Assessment Tasks

An overview of the assessment tasks is shown in Figure 1. There are multiple motivations to include the workshop facilitation as an assessment task. Firstly, it enables a flipped classroom structure including small group workshops without being resource intensive in terms of hiring workshop demonstrators. Secondly, referring back to our definition of student-centred learning, empowering the students to facilitate their own workshops definitely hands the responsibility for the learning path to the students. Thirdly, from a group dynamics perspective, rotating the leadership in this way should ideally support students to engage with the tasks and promote group cohesion. Finally, given that presentation and leadership skills are research skills, they are clearly assessable in this course. It could be argued that workshop facilitation would be a justifiable assessment task in any course because the workshop content is the course content. However, in particular in this course, this assessment task aligns very well with expected learning outcomes.

The idea behind the quizzes is to promote consolidation of the concepts covered in the flipped classroom lectures. There is no exam for the course because research skills are difficult to assess via a written examination. In fact, skills are somewhat difficult to assess via any means; note that most of the assessment in this course relies on subjective tutor or lecturer assessment. Hence, the quizzes are the simplest assessment component in this course due to the individual completion and definite marking criteria.

The CRG wiki and the research proposal are designed as problem-based learning tasks, thereby implementing 'assessment as learning'. That is, in completing these tasks the students are demonstrating their learning of the range of research skills. Peer assessment of the research proposals is included because peer review of articles is a realistic part of engineering research. Therefore, similar to the facilitation, while peer assessment could justifiably be included in any course assignment, it is particularly well aligned to learning outcomes in this course.

Evaluation

This course ran for the first time in semester 1, 2015, with 120 enrolled students. It is currently running again in semester 2 with 170 enrolled students. This evaluation section discusses the lessons learnt in the first semester of implementation, i.e. what did/did not work well, and the following section details the improvements that are being implemented in the course this second time around.

The semester 1 evaluation is based on three sources of information: anonymous student feedback surveys; feedback from the 8 tutors about the course structure and how the tutorials ran; and the perceptions of the 2 course coordinators.

Anonymous student feedback

Student feedback was gathered via two anonymous surveys, one conducted early in semester during week 4 and one conducted at the end of semester in week 13. The week 4 survey had 80 respondents (out of 120 enrolled) and the week 13 survey had an even better response rate with 108 respondents. In general, the anonymous student feedback was very positive. Figure 2 shows that a very high fraction of students viewed the flipped classroom format favourably, even by the end of semester. Note that the percentage of students 'strongly agreeing' that they prefer the flipped classroom format over traditional lectures increased from 35% in week 4 to 42% in week 13. At the same time, the percentage of students strongly agreeing that the flipped classroom format makes lectures more engaging and interesting decreased between week 4 and week 13.

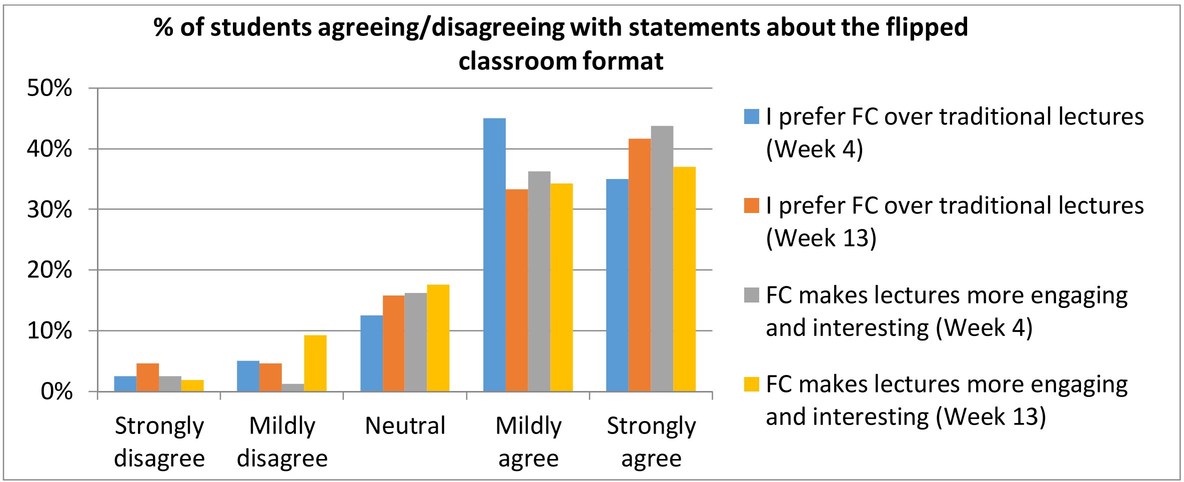

Figure 2 - Results of anonymous student survey questions regarding the flipped classroom lecture format.

When asked which part or parts of the teaching provided the most useful learning experience, 56 of 104 students selected the CRG workshops, 52 selected the pre-class videos and 33 selected the Q&A/discussion with the lecturer. This confirms that it is beneficial to teach via a range of styles to accommodate a range of learning styles.

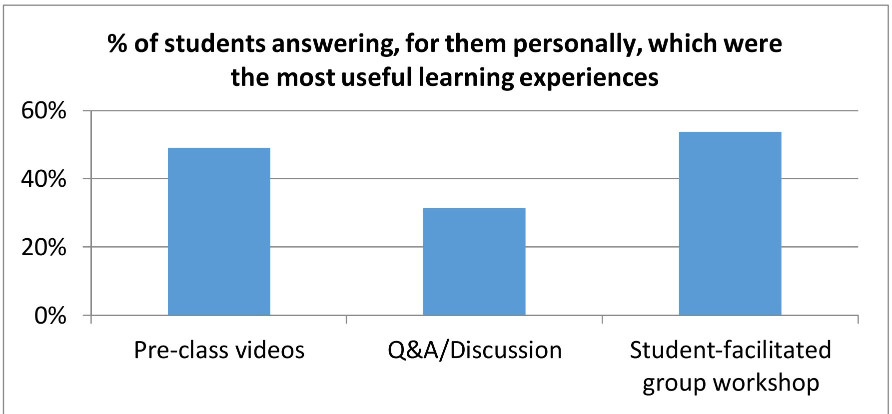

Figure 3 - Results of anonymous student survey questions regarding the parts of the flipped classroom lecture structure. Note that respondents were allowed to make multiple selections, hence the sum of components is > 100%.

When asked which assessment tasks had clear expectation, which were useful to meet the course learning outcomes and which were challenging and interesting, the highest ranking task was the workshop facilitation, with close to 80% of students answering yes for all questions. This indicates that the focus on active learning via the CRG workshops was well received, by the facilitators as well as the participants (see Figure 3). The quizzes were the least well reviewed of the assessment tasks, and will be discussed more in the following sections.

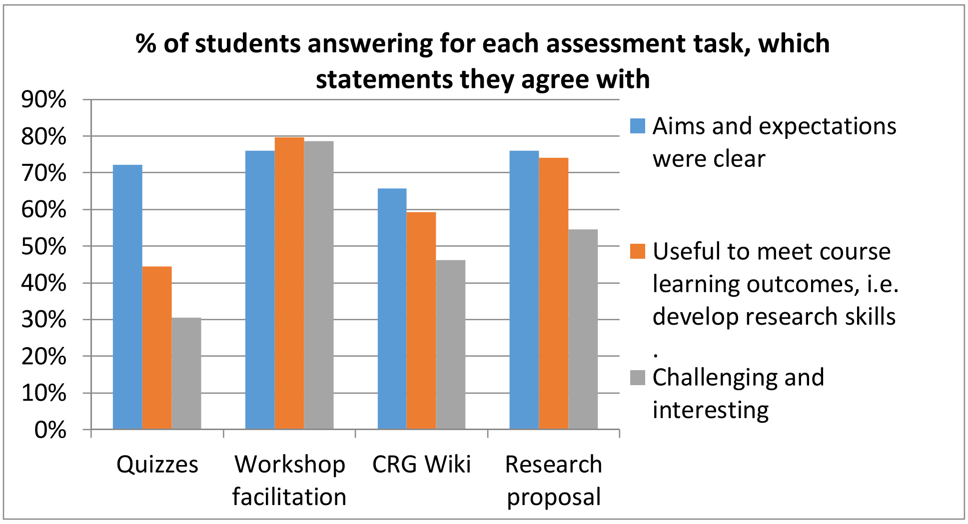

Figure 4 - Results of anonymous student survey questions regarding the course assessment tasks

Tutor feedback

This course benefitted from quite an experienced tutor group of senior PhD students and post-doctoral researchers, who communicated routinely about issues that arose in their classes. As well as issues with the tutorials themselves, the tutors also relayed more general feedback from students on the course structure. For example, many students told their tutors they were struggling to understand the lecture videos and one student suggested introducing complementary quizzes to check understanding. Almost all the tutors received feedback from students that their CRGs were confused about aims and responsibilities, not functioning well and not making any progress on the task for most of the semester. Students and tutors both suggested that the tutorial class groups should be the same as the CRG groups.

As for the tutorials themselves, the assumption that structured tutorials are redundant in a flipped classroom course was proven wrong, as the intended structure was highly unsuccessful. The cheat sheet process did not work as anticipated. Students did not interact, ask questions, give feedback, discuss or debate understanding of concepts, even with much tutor encouragement. Students clearly did not see a benefit from the process because attendance dropped markedly at the second and third cheat sheet tutorials, to around 10% in some cases. The ownership of the learning process was apparently not enticing and the bonus marks were not enough incentive. The one week of tutorials that functioned particularly well involved a structured activity practicing assessment of research proposals, based on critiquing a very poor sample document. Students were engaged, interacting and apparently found the activity useful. This suggests that our original assumption that traditional activity-based tutorials are redundant in a flipped classroom course, was not correct.

Course coordinator perceptions

Firstly, some analysis of the flipped classroom structure lectures, including the pre-class videos, the discussion and the group workshops. Throughout semester, it became clear that a high percentage of the students, perhaps more than half, were not watching the pre-class videos. Partially for this reason, the Q&A/discussion forums were not very interactive. It was almost impossible to get more than a couple of students asking questions, and this situation did not loosen up later in semester. There were less than 5 native English speaking students in the course and a very high fraction of international students, so the cultural breakdown also contributed to the situation. The small group workshops mostly ran smoothly and effectively. One remaining question about the workshop facilitation is whether the workshop atmosphere would be more relaxed and friendly without the live assessment of the facilitators by tutors. However, a tradeoff exists because the facilitators would be much less likely to prepare well without the incentive of marks, and the peer assessment alone might not be sufficient because the facilitation peer assessment marks were generally quite high.

The most important evaluation criteria for any course design or teaching method is how well (i.e. how much and how deeply) the students learn. This course was not explicitly designed to enable quantitative evaluation for the purpose of this paper, or to enable comparison of the flipped classroom structure with a traditional structure. However, the course coordinators perceptions of the quality of the submitted tasks are useful in this case. Generally speaking, for both the CRG wikis (group task) and the research proposals (individual task), the quality of the work was significantly lower than expected. Many cases of blatant plagiarism were encountered as well as issues of significant misunderstanding of task goals or marking criteria, both of which were very clearly stated in the assessment documentation. Despite providing a detailed specification for the peer assessment, and the tutorial exercise on assessment, the peer assessment of the proposals generated such wide ranging and seemingly random marks that it did not seem fair to apply them.

The speculated reasons for the low performance are specific to each task. For the CRG wiki, the 10% weighting was probably too low to cause students to take the project seriously. As the tutor feedback indicated, the groups functioned quite poorly, which surely directly impacted on the quality of the work that the group produced. A possible explanation is that the group size of 16 is simply too large to be workable. For the research proposal, it was a problem that students were forced to work on a topic outside their area of expertise, which would be appropriate for a literature review task but not when students are expected to propose a plausible research project. They were told they could 'borrow' ideas as long as they were referenced and still written as a proposal, but this was too confusing and led to increased plagiarism. Overall, it seemed that the course was too complicated with too many components so that students were overwhelmed and missed many of the important details in the task descriptions.

A final comment relates to a misunderstanding about the status of students required to take the course. It was anticipated that students would take this course to learn skills to then be applied in the 12-credit masters research project. However, feedback revealed that around 30% of students had been exempt from the project based on prior research experience, and were nonetheless required to take this research skills course. It is a greater challenge to engage these students and convince them that the content is useful. The inclusion of these potentially disengaged students should be taken into account when interpreting the survey data.

Given the wealth of feedback received, and the alignment of feedback from different sources, we felt obliged to take action and implement immediate changes in the following semester, rather than waiting to test the initial course design again with a second cohort of students.

Improving the course design

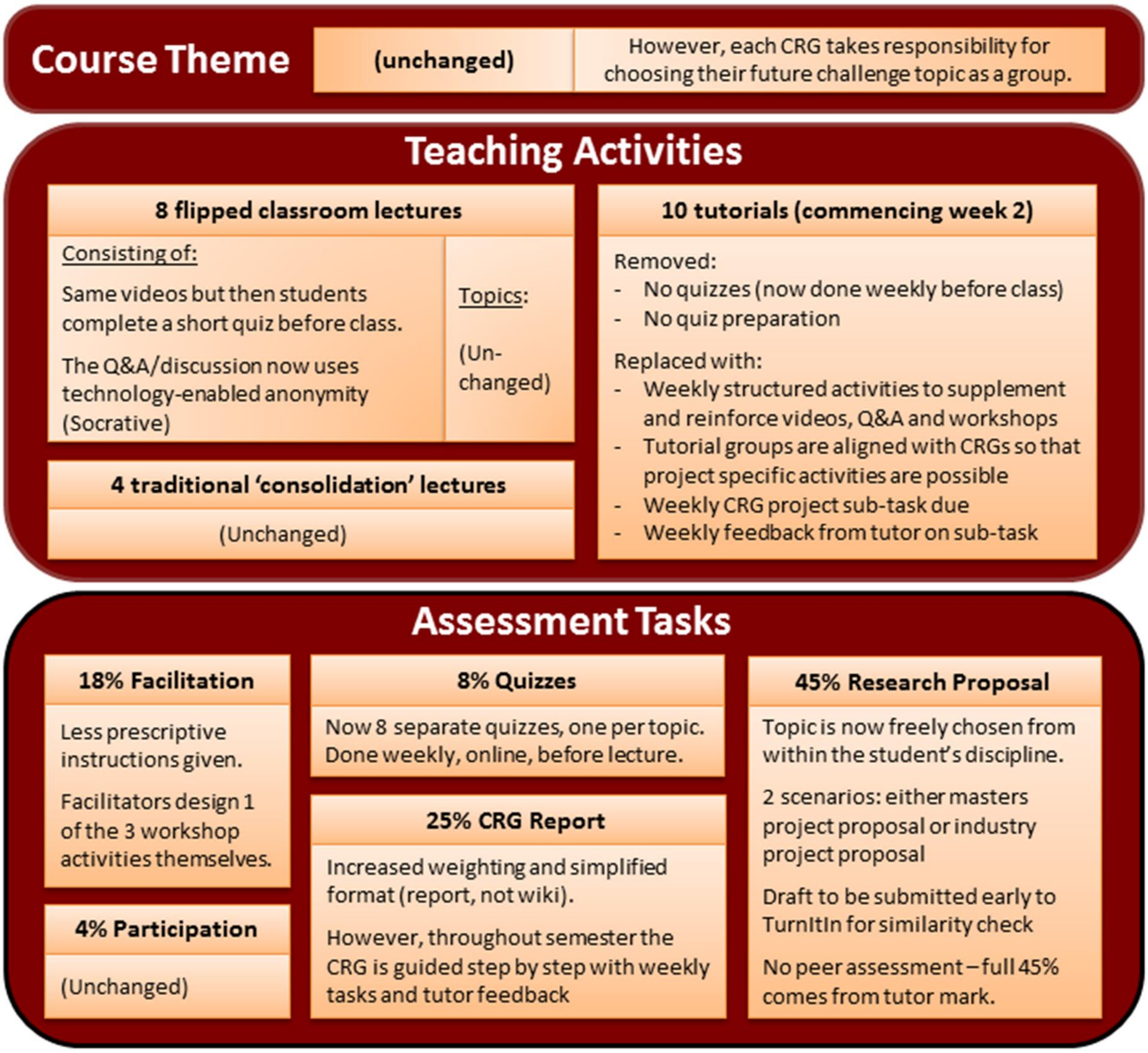

Figure 5 – Overview of modifications made to the course design for the second semester of implementation.

The course structure has been simplified as much as possible (see Figure 5). Tutorials now include structured activities and aim is to supplement the flipped classroom structure and support the problem-based learning undertaken by the CRGs. The tutorial groups are now the CRG groups so tutors can collect and give feedback on weekly sub-tasks to monitor group progress. The quizzes are now used as a pre-lecture tool to increase the fraction of students watching the videos. The Q&A/discussion forum is technology assisted so students can anonymously submit live questions using a computer or smart phone. The increase in the volume of questions is astounding, whereby now the issue is managing to answer them all within the hour.

In the assessment tasks, the key changes affect the CRG wiki and the proposal. The CRG task is now worth much more but simpler and more structured and guided. The research proposal is now written on a topic of the student's choosing, including an optional scenario to write the proposal for an industry setting or for the student's own masters research project. The peer assessment has been abandoned and a greater focus is placed on avoiding plagiarism, with requirements for early draft uploads to TurnItIn.

Conclusion

This paper presents an implementation of a flipped classroom research skills course for engineering science masters students. The most important lesson learnt in this new course was that the flipped classroom structure needs to be as simple as possible. Nonetheless, the increased fraction of active learning components was largely well received by the students. On this basis, and given the prior work demonstrating improved learning outcomes from active learning, we recommend increased use of active learning methods across a range of courses within engineering education.

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