Redesign of First Year 'Principles of Engineering Design' Course

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STRUCTURED ABSTRACT

CONTEXT
For the past few years, the course 'Principles of Engineering Design' (ENGGEN 115) has received very low approval ratings from the students, *e.g.* 20.2 % in 2nd Semester 2017 and that became a faculty concern. As a result, a working group was setup to review and redesign the course.

PURPOSE
This initial study was undertaken to determine whether the changes on the course had increased student satisfaction, and to identify the aspects of the course that require further improvement.

APPROACH
At first, a team of academic staff, including new lecturers for 2018, distilled the learning outcomes of the course, ensuring they were suitable for the diverse student body including all engineering disciplines. The team then used a holistic approach to address the student feedback, which resulted in the redesign of ENGGEN 115. Major changes were done to improve the quality of the course book, course organisation, tutorials, assessments, design projects, and teaching approach. For the computer aided design (CAD) part of the course, a more suitable software package, Autodesk Inventor, was selected instead of PTC Creo, and a scenario-based approach was used for assessment.

In addition to the compulsory summative course evaluation run by the university, an online survey tool, Qualtrics, was used to collect anonymous feedback from the students after the first four weeks of the semester; i.e. formative feedback. Initially, the students were asked about the course organisation, tutorials, and overall quality of the course using the Likert scale. Then, a Stop-Start-Continue approach was used to gather valuable constructive feedback from the students.

RESULTS
The mid-semester formative feedback survey results indicated a significant improvement in student satisfaction on the course organisation and overall quality of the course, and the summative evaluation results at end of Semester 1 confirmed this. The redesigned ENGGEN 115 was also commended for its well-structured course book, detailed assessment instructions, fun design project using Autodesk Inventor to create accessories compatible with the LEGO® toy system, the pace of the lectures and assessments, and engaging lectures/lecturers. However, the student tutorial satisfaction did not show a significant improvement. The summary of the survey results, including the plan of action to address feedback, were released to the students.

CONCLUSIONS
Overall, the redesigned ENGGEN 115 received a high satisfaction rating and overwhelming feedback from the students. However, there are still aspects of the course that need to be improved such as the tutorials and marking. Key components in the improvements of tutorials will be training of the tutors, forming a positive culture where tutors and lecturers work towards the common goal of student satisfaction, and provide transparent marking guidelines and support to the tutors in the marking of student work.

KEYWORDS
CAD, design project, engineering design, problem-based learning, scenario-based learning.

Introduction

The course 'Principles of Engineering Design" (ENGGEN 115) is a mandatory course for all first year engineering students at the University of Auckland. The student body includes all engineering disciplines, and the course has approximately 550 students in Semester 1 and 500 students in Semester 2. The course is taught in collaboration between the Department of Mechanical Engineering and the Department of Civil and Environmental Engineering.

Despite good efforts by the teaching team in the past few years, the course has received very low approval ratings from the students. For example, in the 2nd Semester 2017 offering, the course received approval rating of 20.2% and that became a faculty concern. This coincided with a natural generation shift in the teaching team, which provided an excellent opportunity to redesign the course and content delivery. Major changes were done to improve the quality of the course book, course outline, tutorials, assessments, design projects, and teaching approach. Furthermore, a new computer-aided design (CAD) software package was implemented and a scenario-based approach was used for the CAD assignments. In this study, Student Evaluation Tool (SET) evaluation results were used to determine if the changes in the course improved the student satisfaction, and to identify the aspects of the course that require further improvement. In addition to SET, and informal online tool, Qualtrics, was used to collect anonymous feedback from the students after the first four weeks of the semester.

Redesign Approach

Top-down approach was used to redesign ENGGEN 115. Initially, all the teaching materials in the course, including results of student evaluation, were given to an expert academic staff who has never taught the course to get a fresh perspective. The staff reviewed these materials and come up with the list of learning outcomes. The intended learning outcomes were discussed and brainstormed with the new teaching team. The redesign of the course focused on three contextual areas that could either improve or impede in achieving the intended learning outcomes namely course organisation, assessments, and teaching and learning activities (Drew, 2001). Course organisation can significantly impact the student learning experience. Based on student feedback from previous years, the aspects of the course that lacked organisation were identified. These include the teaching team, lectures, course book, tutorials, class activities and assessments.

To achieve the learning outcomes, formative and summative assessments, including appropriate class and teaching activities were carefully selected. Assessments, including an online quiz, homework, test, individual and group design projects, and an examination were systematically aligned with the teaching methods. The teaching methods were envisioned to cater to all the students with diverse learning styles i.e. sensing and intuitive, visual and auditory, inductive and deductive, active and reflective, and sequential and global (Felder, 1988). Although the teaching techniques selected pre-dominantly favoured some of the learning styles, other teaching techniques in a lesser extent in the lectures and/or tutorials were also included to meet the needs of most or all of the students (Felder, 1988). Class activities were chosen to reinforce learning, to motivate student engagement, and to develop or enhance the required soft skills of engineering students. The course was structured based on the active learning principle. The learning activities included box tutorial, engineer-contractor-observer activity using Tangram puzzles, drawing exercises, CAD exercises, brainstorming, and design project testing. The goal was to achieve academic rigour without losing student interest and engagement.

From the student feedback, the teaching team also identified the other aspects of the course that specifically required improvement namely course book content delivery and tutorials. All of these are related to the assessments, and learning and teaching activities. Strategic planning was done to address these problems, and to align with the goal of the redesign, which was to improve student satisfaction with the course, which could also improve student learning.

Significant changes

Course organisation

All the duties, responsibilities and expectations from each teaching team member (lecturers, tutors, and markers) were discussed in the first team meeting to effectively work with each other. The coordinator is in charge of all the administrative work while the lecturers coordinate their lectures to avoid repetition of content and to match the learning outcomes. Course advisors help guide the whole team to avoid committing the similar mistakes in previous offerings. Among all the members of the team, tutors have

the longest interaction time with the students. Tutors reinforce the lecture materials and assist in developing the skills of the students in engineering design. Hence, the team focused on improving its organisation by 1) providing the tutorial materials such as slide presentations and tutor notes in advance and 2) allowing tutors to ask for clarification on any of the instructions during the weekly meeting and offer their suggestions. Tutors were also given formative feedback based on the short visit of the lecturers in the tutorials, and student feedback in the mid-semester online course survey. Markers were given detailed marking guidelines and rubrics and met the lecturer in charge of the assessment to minimise the inconsistency in marking. Lastly, all resources and facilities required for class activities were planned and prepared in advance.

Assessments

The assessment structure is made up of the parts shown Table 1. The main change from previous year was the introduction of a drawing test. Drawing skills were previously assessed through homework assignments, but the poor results in the final exam indicated that the students may have collaborated and many of the students did not learn proper drawing skills. Close to the final exam, it was too late to help the students who were struggling. Therefore, a test was introduced to encourage a larger effort in learning, and to measure students learning under examination conditions. The CAD related assessments were also changed, and these are discussed below.

Table 1: Assessments

Learning outcome	Type of assessment and weight of final mark			
	Semester 2 2017	**Total weight**	**Semester 1 2018**	**Total weight**
Drawing skills	Two drawing homework assignments (6% and 9%)	15%	Drawing test (10%)	10%
CAD	CAD assignment (10%)	10%	Quiz (1%), two homework assignments (2% each), Design Project 1 (10%)	15%
Design Process	Concept project (15%), Truss building project (20%)	25%	Concept project (15%), Truss building project (20%)	25%
Summative assessment of all skills	Final exam (40%)	40%	Final exam (40%)	40%

Content delivery

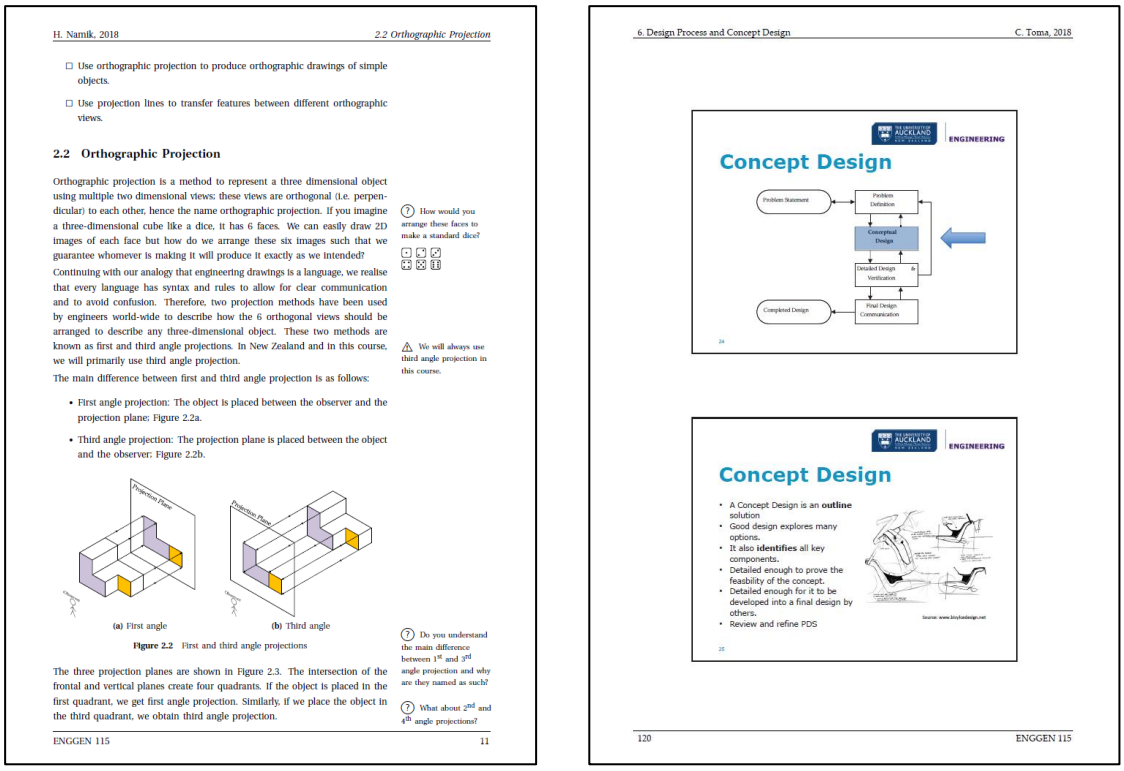
In terms of the content taught, very little was changed since the course focusses on fundamental aspects of engineering design. Therefore, focus was shifted on how the material is delivered to the students. Looking into student feedback from previous offerings, the teaching team identified several areas which can be improved upon; these include restructuring the course book, lectures and how the CAD part of the course is taught.

Course book

A major problem with the previous version of the course book is that it lacked coherent structure, focus, and did not have consistent style. Furthermore, during the lectures presentation slides were used that did not closely resemble the content in the course book. This lead to student confusion and disengagement during the lecture.

The focus of the new course book was set on the design process and all subsequent topic would relate back to the design process to give students a big picture overview and how each topic was being taught. In terms of clarity, the team decided to use following rules of thumb when creating the course book (see Figure 1):

- The lecture notes need to be clear, concise, and to the point. They should also point to relevant textbooks for additional background reading.
- The content that is displayed on the projectors during the lecture must match with what the students have in their course book. This meant that the format of the lecture notes in the course book changed to match the teaching style of each lecturer.
- Each page should have enough white space for students to write their own notes.



H. Namik, 2018 — 2.2 Orthographic Projection

- ☐ Use orthographic projection to produce orthographic drawings of simple objects.
- ☐ Use projection lines to transfer features between different orthographic views.

2.2 Orthographic Projection

Orthographic projection is a method to represent a three dimensional object using multiple two dimensional views; these views are orthogonal (i.e. perpendicular) to each other, hence the name orthographic projection. If you imagine a three-dimensional cube like a dice, it has 6 faces. We can easily draw 2D images of each face but how do we arrange these six images such that we guarantee whomever is making it will produce it exactly as we intended?

Continuing with our analogy that engineering drawings is a language, we realise that every language has syntax and rules to allow for clear communication and to avoid confusion. Therefore, two projection methods have been used by engineers world-wide to describe how the 6 orthogonal views should be arranged to describe any three-dimensional object. These two methods are known as first and third angle projections. In New Zealand and in this course, we will primarily use third angle projection.

The main difference between first and third angle projection is as follows:

- First angle projection: The object is placed between the observer and the projection plane; Figure 2.2a.
- Third angle projection: The projection plane is placed between the object and the observer; Figure 2.2b.

(a) First angle (b) Third angle

Figure 2.2 First and third angle projections

The three projection planes are shown in Figure 2.3. The intersection of the frontal and vertical planes create four quadrants. If the object is placed in the first quadrant, we get first angle projection. Similarly, if we place the object in the third quadrant, we obtain third angle projection.

? How would you arrange these faces to make a standard dice?

⚠ We will always use third angle projection in this course.

? Do you understand the main difference between 1st and 3rd angle projection and why are they named as such?

? What about 2nd and 4th angle projections?

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6. Design Process and Concept Design — C. Toma, 2018

Concept Design

Problem Statement → Problem Definition → Conceptual Design → Detailed Design & Verification → Final Design Communication → Completed Design

Concept Design

- A Concept Design is an **outline** solution
- Good design explores many options.
- It also **identifies** all key components.
- Detailed enough to prove the feasibility of the concept.
- Detailed enough for it to be developed into a final design by others.
- Review and refine PDS

Source: www.lovyfondesign.net

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Figure 1: Sample pages from the 2018 course book.

Active lectures

To increase student engagement and improve student learning, active learning methods such as worked examples and demonstrations are utilised during lectures. For the drawings-related part of the course, worked examples are used where students are presented with the object they need to draw and are given several minutes to draw it in their course book. Then, the lecturer would do the example by hand to show the students how to approach the problem and how to use the drawings tools. Worked examples are also used in other parts of the course, such as detailed drawing exercises and truss calculations.

In-class demonstrations, using student participants, are used to illustrate some concepts related to the design projects such as compression member failure due to buckling. Demonstrations that engage student thinking, *e.g.* by asking them to predict the outcome, have been shown to improve student learning (Crouch, Fagen, Callan, and Mazur, 2004, and Sokoloff and Thornton, 1997).

CAD – self-study and scenario-based assessments

Solid modelling and generation of engineering drawings in CAD is a necessary skill for all engineers, regardless of discipline. The CAD section of the course had historically suffered from a very low student satisfaction. The CAD package used was PTC Creo (formerly Pro/Engineer). PTC Creo is a powerful high-end CAD system, but the students consistently commented on its difficult interface, complexity, and steep learning curve. The decision was made in 2017 to change to a software package more suitable for the diverse student body. The selected software was Autodesk Inventor Professional (from here on referred to as Inventor). It is a user-friendly, mainstream software. It also offers free licences for both the university and the students, which was a very strong selling point. The change of CAD software coincided with the change of teaching team.

The approach to teaching CAD was also changed. The CAD sections had previously been taught in a traditional lecture format, but CAD does not lend itself well to this type of teaching. Instead, a self-study approach was chosen. Instead of introducing CAD as an extension of the hand drawing section, CAD was introduced in the first week of the semester. The students were given instructions how to access the software by either installing it on their personal computer, or using it in the engineering computer labs. They were also given a list of the built-in tutorials - featuring both videos and practice exercises - that we suggested they follow to familiarise themselves with the software. A checklist where the students could track their progress was included in the printed course book.

An online quiz in week 2 of the semester, despite only worth 1% of the final mark, encouraged the students to install the software and get started with the tutorials. The quiz covered features and functions such as file types and line types, and basic modelling skills.

The built-in Inventor tutorials cover a selection of both basic and advanced features, but we identified areas where the students would need more practice. To fill these gaps, the homework assignments included step-by-step guidance for certain features and tools that are particularly important. This ensured that all students, regardless of their prior experience of CAD, would have sufficient fundamental skills when Design Project 1 was released in week 4.

Design Project 1 was another large change for the course. Instead of just a CAD assignment, a complete design project was introduced, worth 10% of the final mark. Adopting the strategy used in the modern aviation curriculum to train pilots, Design Project 1 used a 'scenario based' approach (Craig, 2012). This means that instead of practicing isolated manoeuvres (or in the CAD case, isolated tools or commands), the training is placed in a scenario where all the fundamental skills will be used, tested, and improved.

In Design Project 1, the student was hired by a fictitious toy manufacturer. This manufacturer makes toys compatible with the LEGO® system, and needed a new toy kit or accessory for next year's collection that would work with the existing toy figurine. In the scenario, one of the CAD files for the toy figurine had been lost, and the CAD assembly had fallen apart. The students had to reverse engineer the head for the figurine with manual Vernier callipers, and model the head in Inventor. The student then had to assemble the head and the other body parts (files were provided to the students) using step-by-step tutorials, building their skills in assembly, and at the same time building their confidence by seeing the figurine materialise on the screen. The students were not marked on the figurine assembly, but it had to be included in the final design.

Evaluation, Results and Discussion

The formal evaluation of the course was done through the SET online designed to facilitate student feedback on learning and teaching. The evaluation is administered using a standard questionnaire where students can strongly agree, agree, neutral, disagree or strongly disagree with a statement. In addition, there are opportunities for unique feedback focused on what they felt most helped their learning, and what improvements in the course they would like to see. As the SET results are used to identify courses requiring attention, these results are what we have chosen to gauge the success of the changes implemented.

In addition to the SET, an online survey tool, Qualtrics, was used to receive formative feedback anonymously on the course after the first four weeks of the semester. Similar to the SET, the students were asked about the course organisation, tutorials, and overall quality of the course using the Likert scale. Then, a Stop-Start-Continue approach was used to gather valuable constructive feedback from the students. The preliminary survey results indicated a significant improvement in student satisfaction on the course organisation and overall quality of the course, and the SET evaluation results at the end of Semester 1 confirmed this, which is discussed below.

Three main areas where the general agreement (agree plus strongly agree) score for the previous two year (four teaching semesters) were identified as areas that the teaching team wanted to focus on. These encompassed the organisation of the course content, the appropriateness of the course resources and the quality of the small group teaching. Although the satisfaction score for the small group teaching had previously been consistently in the 50% range, the unique feedback comments highlighted the importance of the tutorial sessions to their learning, and therefore the need to improve the satisfaction in this area. By targeting these three areas we hoped to improve the quality of the course overall.

Course Content Organisation

A considerable amount of the student feedback from 2016 and 2017 focused on the organisation of the course content. This was reflected in the SET evaluation results with an average general agreement rating of 26.3% over 2016 and 2017 for the statement 'The course content was well organised', and 33.8% for the statement 'The resources (including digital) in the course helped me learn'.

The student comments indicated a high level of dissatisfaction with the quality, format and content of the course book. In addition, the teaching of the CAD through a traditional lecture format was heavily criticised. To address these fundamental issues, the course book was restructured as discussed above, and the CAD section of the course was restructured introducing learning by self-study, and scenario-

based projects as also discussed above. The implementation of these initiatives were validated by the marked improvement in the SET evaluations for 2018; the statement 'The course content was well organised' received 79.6% approval rating, and the statement 'The resources (including digital) in the course helped me learn' received a 78.1% approval rating. Figure 2 illustrates the improvement in approval ratings for the organisation of the course, and more importantly the significant reduction in students who thought the course was disorganised. In addition, the response ratio has significantly increased which may imply a higher student engagement in the redesigned course.

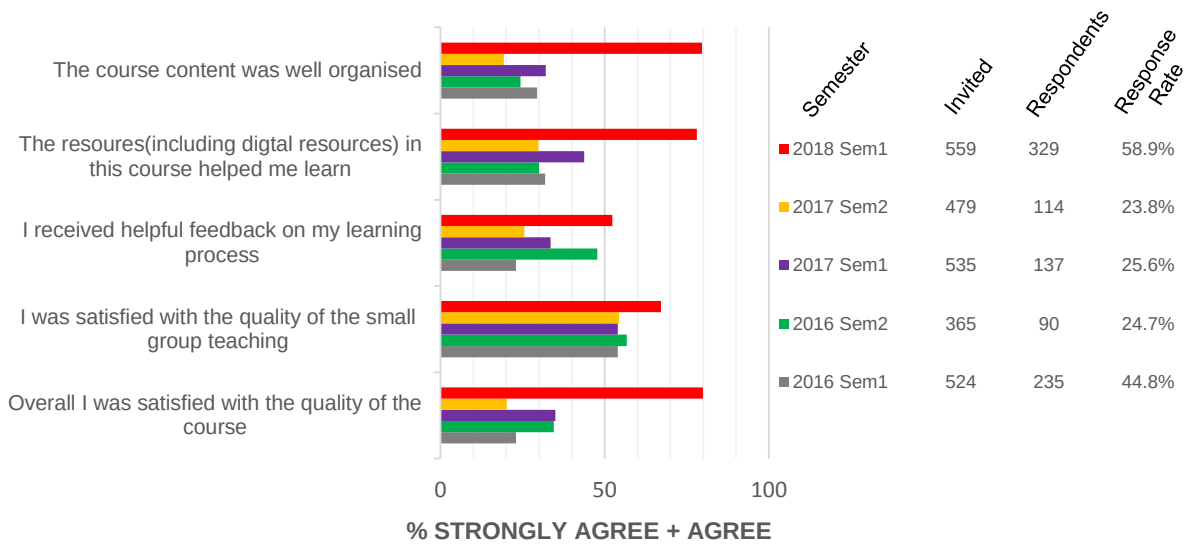

Figure 2: SET evaluation results for the areas of targeted course review

The commonly noted areas students would like improvement on from the 2018 course centred around the communication of the conceptual design projects. Although the statement 'Assessment supported the aims of the course' was well agreed with – 87.8%, student feedback picked up the need for the communication of the assignment to be clearer – in particular the deliverables of the parts of the assignment, a narrower scope, and more detailed expectations for written reports.

Small Group Teaching

The design course has two large class lectures and one two-hour tutorial per week. With the mix of drawing, CAD practice and conceptual design projects, the small group contact time is fundamental to the success of the course. The SET results for the small group teaching from the 2016 and 2017 semesters showed a general agreement rating of 55% on average with a neutral/generally disagree split of 22%/23%. Tutorials were identified as main points of specific feedback in both the 'What was most helpful for your learning' and 'What improvements would you like to see' questionnaire questions. Analysis of the feedback concluded that students felt that the tutorials were where they learnt the most, valuing peer learning and small group interaction, but were critical of the tutors' level of understanding of the course and the lack of consistency across the tutorial streams.

To improve the tutorial experience for the students, significant effort was put into tutor preparation each week, including tutorial plans, tutor meetings, worked examples, encouraging new tutors to attend more experienced tutors tutorials, and working to build the confidence of the tutors in front of the class. More tutor training on the assessments and clear tutorial plans were targeted at ensuring the tutors are giving all the students the same information. Collaborative tutor meetings, where the tutor and lecturing team work together to plan the tutorials sessions so that best communicate the objectives and engage the students, taking into account what has and hasn't worked in the past.

Consistency across tutorial streams in marking and support for assignments was also a concern raised by students - *"More streamlined marking for assessments. There is very much a lack of coordination between tutorial groups."* – SET comment from 2017 Semester 2. Pre-marking meetings were held in 2018 to help guide the marking, in addition the lecturers cross-marked two assignments from each tutor to help with moderation. With the number of tutors for the course, consistency is always going to be an issue, especially with written report assignments.

The general satisfaction with the quality of small group teaching in the 2018 Semester 1 course was slightly improved receiving a SET generally agree score of 67.2%, compared with an average of 54% for 2017.

Overall Quality

The overall satisfaction with the quality of the course was greatly improved. At the end of 2017 the course had a general agreement rating of 20.2% for the SET evaluation statement 'Overall I was satisfied with the quality of this course'. The results at the end of Semester One 2018 showed fantastic progress with the general agreement rating lifted to 79.9%. Figure 2 depicts the results from the SET for 2016-2018, and highlights the significant reduction in students who are dissatisfied with the quality of the course.

The student feedback from 2018 was much more positive about the quality and value of the course overall. The highest ranked (based on occurrence) affirmative comments identified the practice problems/course book exercises, lecturers, tutorials and design projects as most influential on their learning. Analysing the constructive feedback identified a number of areas for improvement; time split across the three design projects, tutor communication, consistency in marking across tutorials, and lectures on design process to be more engaging.

As the course delivered in Semester 2 has to be in line with the Semester 1 course in terms of assessment and content, the changes that have been planned for Semester 2 focus on the teaching methods, tutor training, and clarity in the communication of the conceptual design project. Bigger changes to the course structure are planned for next year in accordance with the feedback obtained from the offerings this year.

Conclusions

Overall, the redesigned ENGGEN 115 received a high satisfaction rating and overwhelming feedback from the students. However, there are still aspects of the course that need to be improved such as the tutorials and marking. Key components in the improvements of tutorials will be training of the tutors (mostly PhD students), forming a positive culture where tutors and lecturers work towards the common goal of student satisfaction, and provide transparent marking guidelines and support to the tutors in the marking of student work.

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