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Does an assessment rubric provide a better learning experience for undergraduates in developing transferable skills?

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Does an assessment rubric provide a better learning experience for undergraduates in developing transferable skills?

Abstract

There is ongoing interest in developing rigorous and accurate assessment methods in higher education, particularly in the use of assessment rubrics and in providing more useful feedback to students rather than a simple grade. However, there has been little use of reliable assessment rubrics that provide feedback to individual students on their teamwork participation and skills, and which assist academic staff in assessing teamwork among students. This paper reports on the second phase of a study that aimed to evaluate a rubric to assess skills and processes in teamwork, and whether a rubric facilitated a better learning experience than a simple marking scheme. The second phase focused on the implementation of a revised assessment rubric designed to assist students and staff in understanding what was expected in the assessment process, and in particular the creation of efficient tools and metrics to measure both teamwork and individual performance during collaborative team design projects. Findings from two surveys of students provided the dataset for this second phase of the study. The findings demonstrate that assessment rubrics provide an important adjunct in improving students' teamwork performance and their understanding of their learning activities. This study will also contribute to ongoing discussions on higher education assessment methods.

Practitioner Notes

1. Rubrics are useful in assessing skills and processes in teamwork
2. Students' reflections on team processes can improve their learning experiences
3. Rubrics provide extra support to teaching staff in grading students' works
4. Rubrics improve consistency in grading
5. Effective assessments encourage students' satisfaction and better learning outcome.

Keywords

project-based learning, teamwork, assessment rubric, engineering, design

Introduction

Engineering degrees need to produce graduates who have basic competency in the technical aspects of engineering and the communication and teamwork skills needed to ensure engineering projects are completed and implemented safely. These requirements are indicated by the transferable skill attributes as described in the Engineers Australia Stage 1 Competency Standard for Professional Engineers, and are related to professional and personal qualities such as effective team membership, leadership, communication and creativity (Engineers Australia, 2019). After completing their engineering degrees, each graduate engineer must be able not only to demonstrate the required engineering knowledge and skills to solve complex problems, but also function as an effective team member as well as lead and manage teams toward the timely completion of engineering tasks and projects.

In 2008, the Australian Council of Engineering Deans highlighted a concern that various subjects within engineering curricula were not presented or taught in a way that enabled students to transfer problem solving, critical thinking, teamwork and communication to the workplace. Since 2008, this concern has only grown, even though a focus of research in engineering education has been directed toward how to improve the communication and other transferable skills of students (Chadha, 2015; King, 2008; Rizzo et al., 2013). In providing sufficient skills training, engineering educators develop curricula, instructional materials, teaching and learning strategies, and assessment processes to help students acquire the skills needed.

As a result, the use of interdisciplinary and industry-sponsored engineering design projects that incorporate project-based and/or problem-based learning (PBL) strategies have become more widespread and are frequently regarded as effective approaches for cultivating transferable skills, such as problem solving, teamwork, creativity, and a strong work ethic (Andersen, 2001; Chu et al., 2017; Ditcher, 2001; Jensen et al., 2019; Joo et al., 2019; King, 2008; Laybourn et al., 2001; Ribeiro, 2011). As described by Andersen (2001), a good project is one that involves engineering design activities that require a team effort and the application of theories, to devise creative and innovative solutions for real problems which meet the project specifications, while also managing project constraints. The success of any project depends on the shared responsibility, creativity of, and effective communication between individuals from different disciplines (Charyton, 2013; Charyton et al., 2011; Chu et al., 2017; Joo et al., 2019; Zhou & Krogh, 2019)

Engineering design projects and teamwork

As a result of the need for further transferable skills training, there has been a greater emphasis on engineering design in engineering curricula as success in this technical field is aligned with the development of strong transferable skills (Andersen, 2001; Ditcher, 2001; Dym et al. 2013; Han et al., 2021; Heylen et al. 2007; Joo et al., 2019; King, 2008; Laybourn et al., 2001; Ribeiro, 2011). According to Dym et al. (2013, p7), “engineering design is a systematic, intelligent process in which engineers generate, evaluate and specify solutions for devices, systems and processes whose forms and functions achieve clients’ objectives and fulfil users’ needs while operating within a specified set of constraints. Engineering design may be challenging for many reasons”. As stated by Heylen et al. (2007, p375), “students are required to solve complex open-ended problems in various contexts, mostly in interdisciplinary teams”. Ditcher (2001) and Frank & Barzilai (2004) found that PBL approaches help students by: fostering deep learning in which students apply

concepts to define problems; integrate and apply analytical knowledge to solve problems; and work through to the solution.

Problem solving often needs critical thinking and creativity; these are skills needed to survive in employment and solve everyday problems. In a previous study, Bailey & Szabo (2006) found that design process knowledge is essential in assessing problem-solving skills of students in the design process. Further, a recent study by Han et al. (2021) has highlighted the merits of group work in science, technology, engineering and mathematic design education, where it helped cultivate creative thinking and decision-making abilities that employers sought. However, there was a lack of appropriate assessment tools for these design-based assessments. Ralston & Bays (2015) argued that integrating and evaluating critical thinking assignments into engineering curricula is possible, but there is a major challenge that engineering educators need to be trained in the use and development of valid and appropriate rubrics. Similarly, Guaman-Quintanilla et al. (2020) argued there is a lack of accurate, systematic, assessment and performance-based measures in design education.

A number of research studies have emphasised the importance of collaborative teamwork skills in undergraduate education (Andersen, 2001; Britton et al., 2015; Chan & Ho, 2019; Jensen et al., 2019; Planas-Lladó et al., 2020; Puente & Jansen, 2017), and there has been an increase in use of rubrics in teaching engineering design courses aimed at developing students' teamwork skills. A study carried out by Puente & Jansen (2017) investigated whether rubrics, used as a supervision, feedback and assessment instrument, have any impact on students' progress. Despite an example rubric that assessed students' performance in an engineering design group assignment being provided by the authors, their rubric lacked the assessment criteria related to teamwork processes and participation. A recent study by Rooney & Scott (2021) provided an example of a rubric for assessing teamwork during a four-phase design process. However, their rubric did not provide detailed information on the marking criteria, descriptors and grade levels for students' work to be assessed.

In summary, there has been a lack of focus on reliable assessment rubrics providing detailed feedback to students on their participation in group work and teamwork skills development, which can also assist academic staff in supervising and assessing the students. Provision of feedback on and efficiency in marking are both important issues, because students want detailed feedback. Yet, for the teaching staff, marking a large number of team projects is labour-intensive, and providing each student with feedback on teamwork skills is complex. The issue is, then, to determine how best to provide feedback and assess critical thinking and teamwork in engineering design processes when students are undertaking collaborative team projects (Bailey & Szabo, 2006; Stentoft, 2019). It is the lack of focus on reliable assessment rubrics that the study reported here sought to address.

Assessment and rubrics

In the current literature, there is generally a lack of consensus on how to assess teamwork, and rubrics have less often been used for this purpose in higher education settings (Britton et al., 2015; Delgado & Fonseca-Mora, 2010; Diefes-Dux et al., 2012; Fernandes et al., 2012; Hastie et al., 2014; Menéndez-Varela & Gregori-Giralt, 2018). For example, Britton et al., (2015) stated that teamwork is difficult for educators to quantify and that the development of team performance is hard to measure. They addressed the challenge by developing a practical and re-useable rubric for different cohorts of students to assess individual teamwork skills in an undergraduate drama course on theatre, history and literature. The rubric was only suitable to measure team skills and,

consequently, is limited in its application to assess critical thinking in engineering. Therefore, Diefes-Dux et al. (2012) stated that assessing student performance and providing feedback on opened-ended problem-solving activities is challenging, especially when students are engaged in developing a complex product that involves many possible solutions.

In addition, assessors need to provide reasonable feedback on an individual student's learning process and the approaches that student utilised when solving a problem (Diefes-Dux et al., 2012; Fernandes et al., 2012; OECD, 2013). Assessment encompasses summative and formative purposes. Summative assessment, usually in the form of a grade, is provided after a final piece of assessment has been completed, to help students understand their overall achievements. Formative assessment provides ongoing feedback to inform students how they are learning, what to look out for, and to help educators adjust the teaching and learning approach throughout a course (Diefes-Dux et al., 2012; Looney, 2011; Prins et al., 2017). Students learnt best and understood more when they were aware of the criteria being used to assess their work. In addition, the use of rubrics, distributed before classes began, helped to improve student learning as the students were able to use the rubrics to plan, monitor and assess their own understanding and performance as the course progressed (Chan & Ho, 2019; Curran et al., 2011; Zhang et al., 2018). Ditcher (2001) reported that once students developed a deep appreciation of the learning material and activities, they were likely to build positive relationships with the instructors, peers and the material itself. In addition, The National Research Council (2001) has argued that assessment instruments, such as rubrics, provide valid and reliable inferences on students' conceptual progress, thereby guiding and targeting the instruction and providing a means of evaluating the efficacy of the subject as a whole. Rubrics also assisted academic staff in improving the efficiency of the marking process while still ensuring fairness and transparency (Chan & Ho, 2019; Curran et al., 2011; Menéndez-Varela & Gregori-Giralt, 2018; Panadero et al., 2013). Rubrics therefore can be seen to provide formative and summative feedback to students as well as provide instructors with valuable information relating to the efficacy of the subject as a whole.

Rubrics also offer explicit scoring systems and definitions of each level of student proficiency. In addition, Menéndez-Varela & Gregori-Giralt (2016, p238) argued that "the validity of assessment rubrics was related to: (a) the appropriateness of the inferences made from the representations of the students' learning; (b) the usefulness of these inferences for attaining the learning goals established; and (c) their soundness for demonstrating the existence of these achievements to the various stakeholders". Rubrics can be used for grading a range of assessments and tasks, for example, reports, oral presentations and teamwork. Normally, rubrics comprise criteria for assessing the students' work (e.g. a breakdown of the skills, knowledge and task descriptions) and standards or grades to represent the levels of achievement. There are several methods of employing grades, for example 'Poor', 'Fair', 'Good' 'Excellent', and other methods of scoring known as rating scales that assess students on a sliding scale (e.g. 1-to-5 or 1-to-10) and allow an assessor greater differentiation between students' performances (Chan & Ho, 2019; Tan, 2020).

There is ongoing interest in developing more rigorous and accurate assessment methods in higher education, particularly in the use of online technologies and in providing more useful feedback to students, rather than simply giving them a grade. This study contributes to the discussion on assessments, in this case, in relation to assessing the skills and processes involved with teamwork. There are distinct challenges in the development of an acceptable, and robust rubric for assessing teamwork. These are: (1) ensuring the assessment rubrics are relevant and applicable without sacrificing validity; (2) defining the criteria and levels of assessment; (3) ensuring that the assessment is process-oriented and focused on student learning and team processes while not

sacrificing the quality and outcomes of the students' group projects. Above all, it is important to ensure all aspects of the engineering design learning process are being assessed.

Rationale for this study

Students are normally aware of the learning objectives (outcomes) and the assessment tasks (e.g. quizzes, tests, examinations and team projects) that determine their grades. In this study, we sought to add a third component to the assessment, in which we aimed to inform the students about their comportment in teamwork tasks as they did them. To achieve this, we developed and trialled an appropriate assessment rubric and created efficient tools and metrics to measure both teamwork and individual performance during collaborative team design projects. The performance expectations are detailed in the rubric table (see Appendix A) and students were provided with this rubric at the start of the semester, so that they were aware from the beginning of how their performance would be evaluated. In designing the rubric, we sought new ways of assessing critical thinking, problem-solving and student interactions within teams. We also hoped that the assessment rubric would further improve students' overall satisfaction and learning outcomes for the course.

This paper reports on the second phase of a larger, two-phase study designed to implement a valid assessment rubric in a first-year undergraduate computer-aided design (CAD) course. Results from the first phase, which involved the development of validated content, assessment criteria and grades, and evaluated the students' teamwork, have been reported elsewhere (Pang et al., 2022). In this first phase, we utilised students and staff feedback to design improvements in the rubric, which included: (i) providing definitive and objective measures that avoid vague interpretation; (ii) revision of the performance categories and scoring levels, specifically on team processes and participation; and (iii) adding a comments section for detailed written student feedback on errors and areas for improvement. The revised rubric that resulted from first phase is provided in Appendix A. The purpose of the second phase was to evaluate the use and implementation of the revised rubric in assessing teamwork as it was important to establish if and how the rubric helped the students to learn during the semester. The following research questions drove the second phase:

1. What are the students' perceptions of the assessment rubric?
2. Would students' knowledge of the rubric at the beginning of the course influence their perceptions of their instructors and peers, and their attitudes to learning activities? If so, how?
3. Do students who have a better understanding of the assessment rubric and its use achieve better overall learning outcomes and improve their mastery of teamwork skills?

A total of 186 students were enrolled in a CAD course from aerospace, mechanical, automotive, mechatronics, manufacturing, and sustainable energy engineering degrees. Students took this CAD course as their first core design course in which they were introduced to the principles and methods of engineering design, including the critical role of graphic communication. The associated learning activities were supported by computer-based tutorials during which students used CAD software to generate computer models and technical drawings benchmarked to the Australian Standard (Australian Standard, 1992).

Methodology

This second phase of the study took place in Semester 1, 2019 at a large public university in Melbourne, Australia. The research used a mixed-methods design. There were three central elements to the study: (1) an engineering design team project, assessment and individual or group reflective statements; (2) participant surveys; and (3) a cohort comparison. Quantitative data from the surveys were analysed using descriptive statistics.

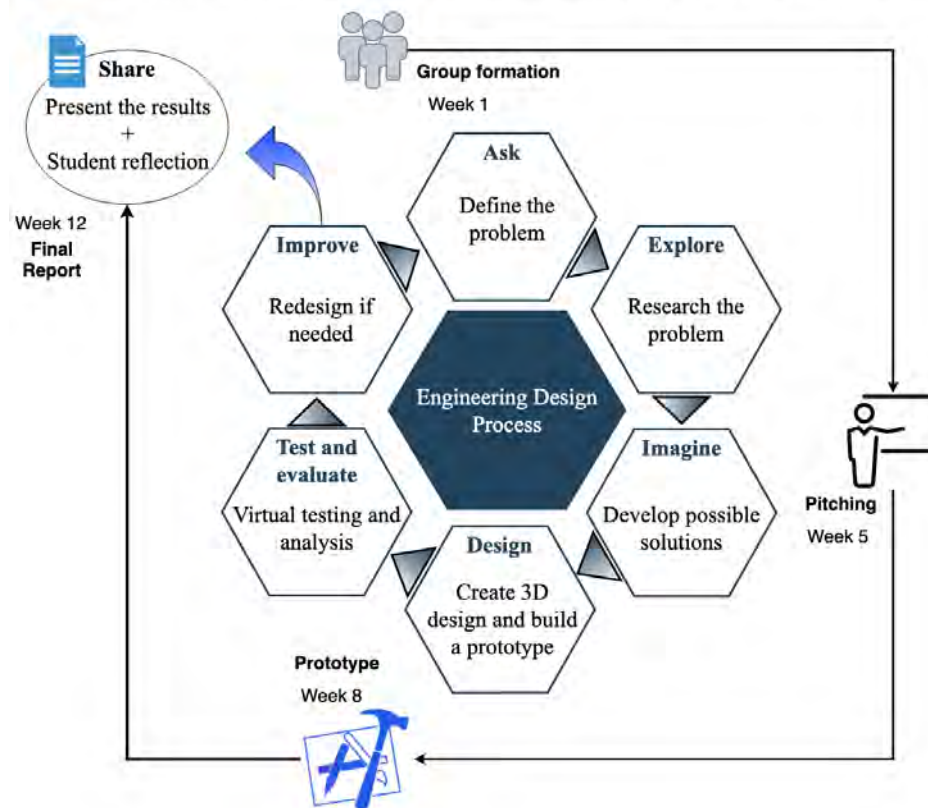
Qualitative data obtained from the students' reflective statements and the surveys were analysed using the NVivo12 software package via the following steps: (1) familiarisation with the data; (2) revisiting the research questions (3) formulating broad phrases and ideas, then assigning codes; and (4) developing themes to address each of the research questions (Anastacia & Kerrin, 2019; Jennifer & Gregory, 2011; Vogt et al., 2014).

Engineering design team project and assessment

In order to create communication, teamwork and collaboration skills, a team design project was developed as part of the assessment, in which students were required to develop an innovative design for a smartphone holder using the engineering design process (Figure 1).

Figure 1

Engineering design process and team activities for the first year undergraduate CAD course



The team project, which was worth 25% of the total grade, started in week 1 of the semester and each team was required to submit a final report in week 12 as part of the assessment. Student teams were asked to ‘pitch’ their design ideas and research to the course coordinator in week 5, and they were then to show how to print their prototypes using 3D printers in week 8. The rubric was used to assess students’ performance in the teams as well as the outcomes of the teams’ projects. Students were encouraged to form their own groups of three to five members from diverse backgrounds. Students were required to have regular team meetings and record team dynamics, roles and responsibilities, project planning, and individual contributions as part of the assessment requirements.

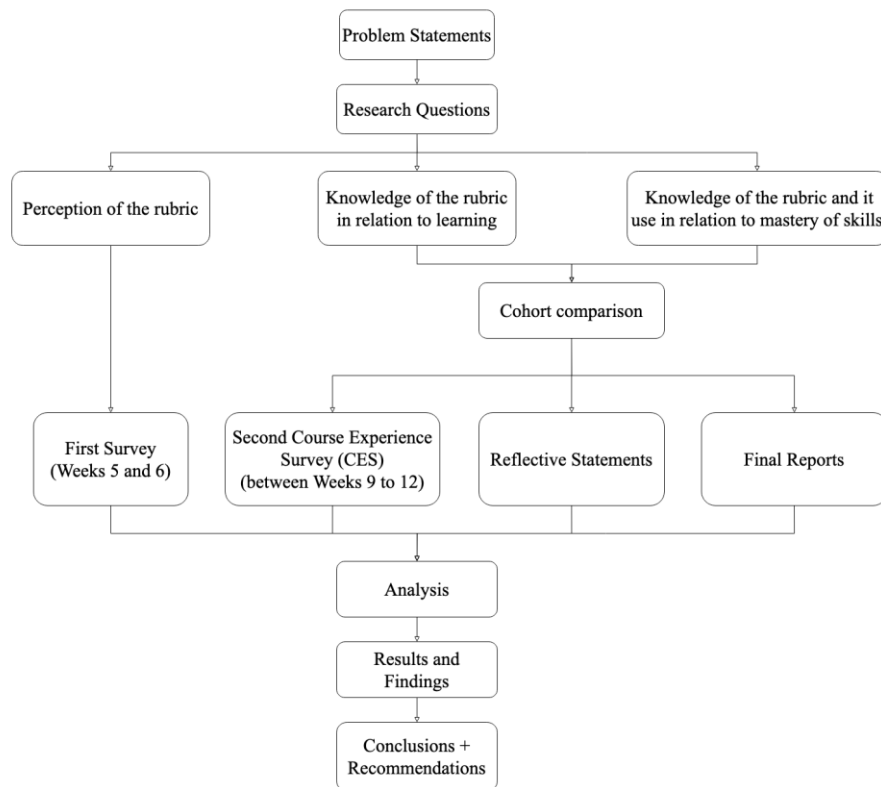
The final outcomes of the design project were written team reports, the pitching presentations, and the physical prototypes. The team report was worth the greatest percent out of these outcomes, so this was the only outcome for which a rubric was provided. Students were provided with the rubric and the template for the final team report, which contained suggested headings and a breakdown on how the final reports would be graded. In the final report, students were asked to provide either individual or group reflective statements about their comportment in the teamwork tasks, and their contribution to the overall project. Reflective writing has become a common practice in higher education. There is evidence suggesting that reflective writing assists students in developing professional knowledge and problem-solving skills. Such reflections on their course activities can also improve their immediate and long-term learning outcomes. Further, reflective writing enables development of creative engineering solutions—this approach students bring to workplace and apply to their professional engineering practice (Badenhorst et al., 2020; Cheng & Chan, 2019; Minnes et al., 2017). The process of reflection employed in our study involved the request for students to consider various group activities and scenarios (listed in Appendix B). As the rubric was designed to assess the teamwork, we anticipated that the reflective writing activity would assist students in understanding the importance of such assessment and improve their learning performance in the course.

Data collections

A qualitative research methodology was adopted to investigate students’ perspectives on the assessment rubric and to understand the implementation of the rubric in the course. For this study, two surveys were used. The first was conducted in class using a questionnaire administered between weeks 5 and 6, where the students were asked about the rubric. The second course-experience survey (CES) was conducted online between weeks 9 and 12 during the semester and was used for cohort comparison (Figure 2). CES focused on students’ perceived teaching quality and their experience in the course. Ethics approval was obtained from the University College of Science, Engineering and Health, Human Ethics Advisory Network (SEHAPP 47-18).

Figure 2

The framework and flow diagram used for the study



First Survey: Questionnaire relating to perception of the rubric

The assessment rubric had clearly defined elements and scores that had been simplified to a smaller sliding scale to provide flexibility for assessor to allocate appropriate points as well as framing written feedback on each rubric cell. A section for overall comments on tasks submitted was also included for teaching staff to provide written feedback.

The rubric was designed for assessing problem-solving and team-collaboration skills in which students needed to demonstrate they were able to work with other team members professionally and communicate effectively to gather and share information. Then, students used such information to identify problems, develop plans and possible solutions to open-ended design problems. The rubric served an essential function in providing the students and academic staff with a clear picture from the start of what assessable standards of performance were. The rubric was also essential in communicating learning expectations to students.

The first survey aimed to capture the opinion of the students on the rubric (see Appendix A) used for their team project, thereby answering the first research question. The questionnaire and the participant information and consent sheet were distributed at the end of a two-hour class. All

students enrolled in the CAD course were invited to participate in the survey and the survey would take five to ten minutes to complete. It was explained that their involvement was voluntary and non-participation would not disadvantage them in their studies. The survey questions related to the assessment rubric were:

- (1) What is your overall opinion of the above rubric?
- (2) How did you understand the key performance indicator at each level (e.g. HD, DI, etc.)?
- (3) How useful do you think the rubric is in providing meaningful and timely feedback in terms of areas needing work or strengthening for improving your performance?

At the end of the questionnaire, students had the opportunity to enter into a draw for an iPad, or book and movie vouchers, by entering their student ID on a separate piece of paper, thereby maintaining the confidentiality of participants' identities. Students' responses to the survey were entered into a spreadsheet for analysis in NVivo 12 software.

Cohort comparison

To evaluate whether providing the rubric before classes began would have any effect on students' perceptions of feedback and overall satisfaction with the course's activities, a cohort comparison method of two student groups was used: (1) Control Group: semester 1, 2018 where the students were provided with a marking scheme (Appendix B), and (2) Comparison Group: Semester 1, 2019, where the students were provided with the marking scheme and the marking rubric. The same CAD course was delivered by the lead author, with the same design project for both student cohorts.

Both cohorts were provided with either a marking scheme or rubric that contained three main assessment criteria: group control, activities, and outcomes, which were developed to assess both process and product related to group work (Pinho-Lopes & Macedo, 2016). For the process components (i.e. group control and activities), students were encouraged to hold each other accountable for their own conduct through weekly journal entries, appropriate distribution of tasks, and effective communication. The product component (i.e. outcomes) emphasised the final report and the design measured against client requirements, including adherence to industry standards, timeliness, and budget.

Descriptive statistics, *t*-test comparisons and correlation analyses were calculated using Excel at the significance level of $p < 0.05$. The cohort comparison focused on two items:

1. Students' perceptions of the helpfulness of staff-provided feedback and time devoted to commenting on their work and their overall performance (answering research Question 2).
2. Students' final report grades for their design projects (addressing Research Question 3).

In order to maintain fairness and consistency in grading, the lead author first showed the course tutor how to grade students' work based on the rubric. In 2018 and 2019, the tutor was asked to select three reports from students' submissions that were ranked at first glance as 'good', 'average' and 'poor'. The tutor then graded those three reports in 2018 using the marking scheme (Appendix B); and in 2019, the selected reports were graded using the rubric. Those grades were then compared with the lead author's final grades for each year. If the tutor produced a different grade (grade difference of no more than $\pm 5\%$ compared with the lead author's grades), the tutor continued to grade the reports, but he was encouraged to contact the lead author at any time for advice or clarification.

There were two items in the second CES. In Item 1, students were asked to select one option from a five-point Likert scale, coded from 1 = ‘strongly disagree’ to 5 = ‘strongly agree’, for the seven opinion-rating questions. In Item 2, two short, open-ended questions were included at the end of the CES for students to give feedback on what worked well and what needed improvement in the course. Item 1 was answered through a Likert scale questions and Item 2 was determined by the lead author and course coordinator of the CAD subject, after the grades had been publicly released.

Results

The first survey: 2019 cohort, using revised rubric

A total of 186 questionnaires were distributed for the survey in week 5 and 6 during the semester and the response rate was 63.4%. This survey gauged students’ familiarity with, and appreciation of the rubric that was to be used to assess their teams’ final report. The first question asked of the students was: ‘What is your overall opinion of the above Rubric?’ The rubric provided in the survey was the same rubric that had been posted on the course learning management system, to be used to grade their final report, which included reporting on teamwork activities. In summary, 38.3% students reported the rubric as ‘good’ in showing the assessment elements, and 24.1% students considered the rubric provided detailed information on teamwork and reflected the key assessment criteria. Some examples of the students’ responses are:

Good indication of other team members’ contribution.

Good. Explains in detail what is required of team members and the whole group.

Helpful with identifying important aspects to be assessed.

The responses implied some appreciation and a clear understanding of the rubric in its assessment of their team projects. Most students also indicated that the rubric provided a clear articulation of the learning objectives of the project. Despite the overall positive comments, there were a few students who suggested that the rubric could be improved by including a separate rubric for self and peer-assessment. The students also suggested an additional section outlining individual group members’ specific contributions.

Students were then asked in the second question: ‘How did you fine the key performance indicator at each level (e.g. HD, DI, etc)?’ A total of 23.3% of the students replied that the rubric contained a good balance of details, levels and key criteria. A further 25.6% of students indicated that the rubric was excellent in promoting positive teamwork, as team members could work together to achieve the same goal based on the rubric’s clear expectations and criteria. Some of their written responses were:

Excellent performance demonstrated through achieving the highest possibility of that category.

Excellent responses, easy to understand yet very detailed and intelligent.

Able to communicate with people and solving the problem rather than avoiding the problem. Good time management.

Almost all students (96.6%) indicated that they thought that the key performance indicators and grade levels in the rubric had helped them achieve their learning goals. Most students also indicated that the rubric gave them a good outline of how to communicate effectively with other team members and how they, as individuals, needed to take on the responsibility to be an active member of their team. However, one participant noted that the descriptions of the key performance indicators were vague, and it would be useful to include some good examples to help them to prepare for their teamwork.

Students were also asked: 'How useful do you think the rubric is in providing meaningful and timely feedback in terms of areas needing work and strengths for improving performance?' A total of 14.8% rated the rubric from 'good' to 'excellent', and 37.5% considered the rubric 'useful' in providing meaningful feedback for their teamwork. Responses included:

Rubric allows one to get constructive feedback on the ability to work as a team.

Very useful, provides feedback and also direction during project.

Easy to identify areas of weakness to improve performance.

Such responses suggest that students believed the rubric provided constructive feedback that would help them identify areas that need improvement. Another suggestion was for student groups to have a conversation with academic staff to find out their progress in relation to the group project throughout the semester.

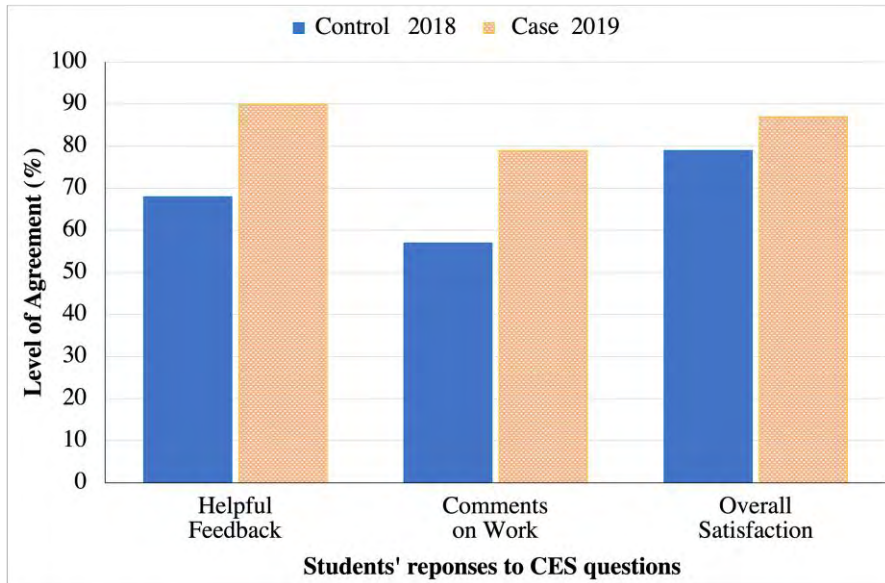
The cohort comparison: CES data

For the cohort comparison, the second CES data (which was conducted between week 9 and 12), final report and student reflections were used to address the abovementioned research questions 2 and 3.

Figure 3 shows that the students who had the rubric perceived that they received more helpful feedback compared to those students who only received the marking scheme. Similarly, those students who had the rubric reported to be more satisfied with the course. This cohort also perceived that the academics spent more time commenting on the students work and providing feedback.

Figure 3

Cohort comparison for students who responded to the questions related to feedback from academic staff and their overall satisfaction with the quality of the course



To investigate students' responses in relation to feedback further, we compared the written text answers to the open-ended questions between the two cohorts. Interestingly, only the first cohort (2018) had raised concerns with the provision and quality of feedback from teaching staff to help them improve their performance:

Better explanations with concepts and better feedback.

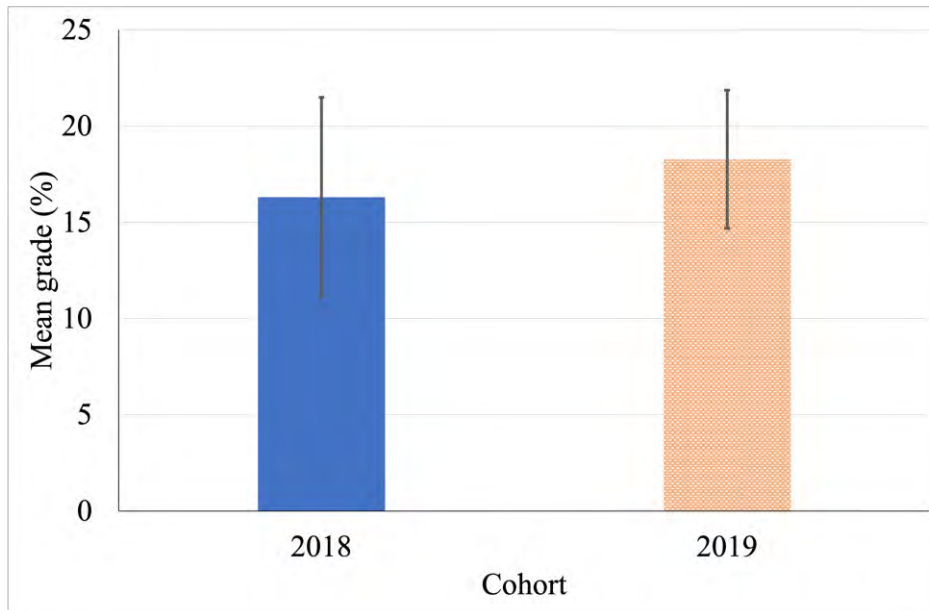
More productive feedback with strategies to improve. Catch up classes or support classes for information that is difficult to grasp or missed.

The results in 2019 indicated that the students understood better and appreciated more the purpose of feedback. They were more aware of the assessment criteria and used the feedback in helping them to improve their learning.

To investigate whether students' knowing the assessment rubric, its key elements and the scoring system beforehand would help them improve their overall report grades, we compared the two cohorts of students for statistically significant differences in the grades for the teams' final reports, (t -test, $t = 1.97$, $df = 261$, $p < 0.001$) (Figure 4). The result indicated that 2019 students who were aware, from the rubric, of the assessment criteria and elements being assessed, achieved higher grades overall. The standard deviation showed a smaller variation in the 2019 cohort compared with the 2018 cohort, which indicates that the rubric was a more consistent instrument for grading student reports.

Figure 4

Comparing students final report grades between two cohorts with and without the use of the assessment rubric.



Student reflections

The clear descriptions of key performance criteria in the rubric, was appreciated by the students as it helped them identify and develop key attributes such as team skills and creative problem-solving that will be important in many workplaces. From the analysis of the students' reflections in their final reports, it can be seen that students felt that they had achieved the course learning outcomes as well as enjoyed the team experience in which they communicated effectively, shared responsibilities, and managed to appreciate the strengths of each individual team member:

Working in this team was a thoroughly enjoyable experience, as we were able to effectively communicate and delegate roles to each other. I was heavily involved throughout the initial stages of market research and problem defining. I also contributed to multiple initial rough sketches, as well as developing [the] final design into a 3D CAD model for the initial prototype. I was also involved with the writing of multiple sections of the report, including the conclusion, the abstract, the introduction and the method. I learnt a lot about leveraging each other's strengths and ensuring all members felt willing to input. I hope to apply what I learnt in this subject (and more specifically this project) into the real work when designing new and exciting products – especially in the field of sustainability.

Other students commented that they enjoyed the team experience and indicated that they had developed an appreciation of the importance of teamwork in engineering design:

This group project was a fun experience, we were responsible to develop a brand-new design from scratch and progress it to its physical stage. I had opportunities to collaborate with good peers, implemented what I learnt from the course into this project and making a step closer to see what engineers do in the industry. Investing more time into making a professional report is what I should have done for this project. Making better use of each members' individual strong point to create a more fluidity group management would be ideal for future group project.

The general trend in the reflection statements was positive and pointed to the students' real enjoyment of teamwork. They clearly found teamwork to be very practical as it allowed them to collaborate with peers and apply their knowledge and skills to creating new solutions for real-world problems. As a result, most students were motivated (89%) to perform their best in the course.

Despite the rubric providing the outline of a team process that assessed the professionalism and work ethic of team members, some students were concerned that it did not motivate all students or discourage the 'free-rider' in a strong group:

I always ask my groupmates to hold group meetings and find the suitable time for us. It is my job to kept track on the time of each group meeting. However, some group mate doesn't participate very well even stop presenting at group meeting. In the final report I did my job. But I still think I should spend more time to discuss with my groupmates about the final report. I saw our effort put in this project. Some of us really dedicate a lot and spend a lot of time in the final report.

Some students were able to show leadership skills in organising weekly team meetings and motivating team members to contribute toward shared goals. They also showed proficient project and time-management skills to deliver high-quality outcomes:

For this project I was the Project lead. This involved organising meetings, taking minutes, and providing motivation for my team members. Additionally, I worked on many sections of the project. For the research and conceptualisation stage I assisted with the idea generation, as well as contributing three conceptual sketches. My sketches for the male and female connectors made it to the final design. For the project review, I produced the Gantt chart, and put together the PowerPoint using work that my team had provided. For the design and rapid prototyping stage, I produced CATIA sketches of the male and female connectors, as well as iterations 1 and 2 of the phone case, based on group analysis of iteration 1. For the report, I produced the discussion, as well as completing the final edit. All in all, I am very satisfied with how our team performed in a largely dynamic environment. I

acknowledge that the final report is to the best standard that we can produce and is submitted on time.

Another student indicated that they thought they had developed technical skills to a standard which was similar to that required in the professional workplace.

From this project, I learned how to transfer knowledge from class to actual projects. Such as using CATIA out of the class and learned how to use 3D printer to print what we designed. More importantly, this project gave me experiences with team working in a way of professional engineer, this gave me a taste of future works as a proper engineer.

Despite this generally positive outcome, a few students pointed to challenges they faced in the team projects. They sometimes had difficulty distributing tasks equally between team members, and some team members lost motivation as the project progressed and keen team members had to pick up the workload:

Reflecting on the project, initial stages seemed to be good with the workload being spread out evenly amongst group members. However, as the project went on, it was evident that some members more than others were doing majority of the work in order to get the best results possible for the project and report.

Another student in the same group admitted his lack of contribution to the team:

Reflecting on the project, I try attending as many group meetings as possible however, I did not put as much effort in helping other group members to share the workload as I wanted to.

The students' reflections revealed that the ideas in the rubric helped them understand their learning processes better, and they were generally more able to make better sense of their experiences. We found that a rubric for assessing teamwork was beneficial for healthy team dynamics and encouraging contributions from each team member.

Discussion

This study examined the value and validity of introducing an assessment rubric in terms of: (1) students' perceptions of the rubric and its intent; (2) their understanding of the rubric and the relevant perceptions and attitudes towards instructors, peers and the learning activities of the

course; and (3) student feedback received on their level of satisfaction and learning achievements in order to demonstrate mastery of key transferable skills.

Research Question 1: Perceptions of the rubric

Students' qualitative responses to the first survey in 2019 suggested broad acceptance of the rubric and a belief that the rubric helped them focus their efforts to achieve the best scores. The emerging themes from the survey about the rubric identified the following commonly perceived attributes:

1. the rubric was good as it contained the key elements and criteria to be assessed;
2. the grades and level of indicators were well balanced; and
3. it was useful in providing constructive feedback to students to identify strengths and weaknesses and target areas that needed improvement.

The results are consistent with research on rubrics used to measure student performance (Chan & Ho, 2019; Fernandes et al., 2012) indicating that well-structured rubrics are valid means of providing students with performance expectations for transferable skill development. In addition, rubrics can also be used to provide timely feedback so that students can improve their team skills as a project progresses.

However, to improve the assessment of team processes and to ensure that every student actively participated in the group activities, and to avoid a strong group having to 'carry' a free-rider, some students suggested the incorporation of peer assessment in the rubric to address this limitation on peer feedback.

Research Question 2: Knowledge of the rubric in relation to learning

Learning is considered as the acquisition of knowledge, skills and experience. We evaluated how the students' attitudes to the assessment rubric influenced their skills development and their learning experiences. The students' reflection statements and cohort comparison results have demonstrated that the rubric helped them understand their learning processes better, and they were able to develop the ability to work as effective team members and collaborate with others on agreed tasks to achieve common goals. They also recognised the time and effort the academic staff devoted to commenting on students' work to help them improve. Similar findings were evident in a previous study (Ditcher, 2001) in that student who had developed a deep appreciation of the learning material and activities were more likely to build positive relationships with the instructors, peers and the material itself.

In addition, the rubric had a positive impact on student learning activities, especially in helping students set appropriate learning goals, plan their learning and improve their learning performance. The mean of the final report grades is in agreement with this, showing a better result for the 2019 cohort.

Previous studies (Britton et al., 2015; Charyton, 2013; Diefes-Dux et al., 2012; Planas-Lladó et al., 2020; Zhang et al., 2018) highlighted the challenges associated with assessing and tracking team performance. The rubric discussed in this paper focused on clear task descriptions that reflected how the students made connections with the assessment tasks and the rubric stressed the quality of the transferable skills rather than the appearance of the end design solution and prototype.

Research Question 3: Knowledge of the rubric and its use in relation to mastery of skills

Skills are challenging to evaluate (Bailey & Szabo, 2006; Britton et al., 2015), and we addressed the challenges by developing metrics for assessing students' abilities to work in a team, communicate, solve problems and innovate. In this study, we also included a marking rubric to grade and direct the students in their teamwork activities. The rubric was a tool to inform the students about their comportment in the teamwork tasks, and to explain explicitly how their performance in teamwork comportment would be assessed.

We also surveyed the students to seek their opinions on whether rubric was important to help them develop transferable skills through the design project. As noted from the open-ended responses in the questionnaire and their reflective statements, students' responses were generally positive. With a clear rubric, they were able to identify key performance indicators and achieve a good balance between the acquisition of knowledge and the development of both teamwork and problem-solving skills which allowed them to produce useful and innovative solutions to their problems, and ultimately an overall better grade. Through the PBL approach, which started from problem formulation the complex strategies needed to help students learn the course content and transferable skills were supported.

Implications for practice

This study reports the findings from the assessment process implemented in the first-year undergraduate engineering design course using the rubric developed to clarify what is expected from students as they learn, individually and along each other within a team, to achieve the specified outcomes. Rubrics provide students with guidance to appropriate effective behaviour in activities within a team environment. As noted earlier, there has been to date a limited use of rubrics in assessing students' teamwork in higher education settings. The focus has been more on individual student assessment, and there is a lack of consensus on how to assess teamwork. This study contributes to the potential use of rubrics in structuring the assessment of group learning processes, thereby making explicit the interactions that take place within student groups and placing those interactions inside a rubric as benchmarks. This, in turn, enhanced the assessment process and provided extra support to teaching staff in grading students work, as well as providing a better (more detailed and specific) feedback to students.

The study revealed several meaningful findings with implications for practice when the researchers conducted further analyses. First, in the CAD course, we introduced the undergraduate engineering students to PBL and to the notion of how it cultivates the transferable skills through teamwork. Assessing transferable skills and students' performance requires a robust tool, and a rubric that provides detailed descriptions of specific criteria for assessment and achievement levels is a common example of a marking tool (Menéndez-Varela & Gregori-Giralt, 2016). In the first survey on the rubric, students demonstrated that they understood what was required of each team member and the whole group, and they provided positive answers to the questions. From a practical perspective, each performance task and its associated rubric entry should be linked to the specific learning outcome it is designed to assess. Once students have a clear understanding of the criteria for assessment and know what the expectations of the assessors were and what it is that they need to accomplish, this not only provide them with guidance to achieve better outcomes, but also motivated them continually to perform at their best.

Secondly, the use of the assessment rubric provided evidence of the improved consistency in grading. These findings confirm the previous studies (Chan & Ho, 2019; Menéndez-Varela & Gregori-Giralt, 2018; Prins et al., 2017; Zhang et al., 2018) reported that rubrics reduce inaccurate scoring and biases of assessors' interpretations when grading students' work because the assessors can more readily select an accurate criterion and the levels of performance described in the rubric. Even though this study revealed a smaller variation in grading the final report, these findings were limited to the development and trial of the rubric, and only the course tutor was trained to use the rubric, as mentioned above. Improving consistency in inter-rater reliability to assist future assessors in applying the rubric to similar courses would require a larger cohort of students and team of assessors.

Thirdly, to realise the full potential of the current rubric for assessing teamwork, we complemented the rubric with students' reflective statements, which is not a widespread practice for engineering students. The reflective statement activity was devised for students to: (i) reflect on how they learnt from their own experience while collaborating with others, and (ii) model professional practice that parallels industry expectations, such as communication, ability to work in team, self- and professional responsibility, and lifelong learning (Minnes et al., 2017; Engineers Australia, 2019). Students provided their subjective opinions on the teamwork process, which contained their personal feelings, revealing an openness and willingness to communicate their thoughts. We acknowledged that the instruction provided in the marking scheme clearly asked students to reflect on the teamwork process, rather than on the specific criteria listed in the rubric. Indeed, most of the reflective statements did focus on teamwork process. This has implications on the importance for teaching staff to ensure they engage students with questions or tasks in real-world context.

Limitations and future research

The findings reported here are drawn from a relatively small sample size, that is, a single undergraduate course, and the final grades for that course were assessed by a single academic staff member. As each student team submitted its final written report at the end of semester, we were not able to determine how each team utilised the feedback for future learning. This is because we did not conduct a follow up study to evaluate how students reflected on the feedback. This warrants further investigation.

The mixed responses from students in comments on group member contributions highlighted the importance of adding self- and peer-assessment. Future research could consider complementing the current assessment rubric with peer-assessment. Fernandes et al., (2012) argued that peer-assessment can overcome some issues related to teamwork and enhance motivation and deepen student learning. However, further thinking on how to improve the assessment rubric to address group dynamics is also needed. In addition, the assessment of team performance needs to be tied to individual student self-assessment. If self-assessment is performed, then the rubric could be used for formative assessment throughout the semester and/or as a framework for the students to reflect on their teamwork skills, thereby providing an opportunity for deeper learning.

The assessment rubric was also intended for use in other engineering design courses and projects, as well as in a broad undergraduate population from diverse faculties and departments, however it has not yet been implemented in a such a broader cohort.

Conclusions

In this, the second phase of the two-phase study, the rubric revised as a result of the first phase of the study, was found by most students to provide better and more detailed information on teamwork and reflected the assessment criteria. Twenty-three percent of the students found that the description of each grade level was useful and another 25% reported that the rubric enhanced their teamwork experience. Seventy percent of students noted that the rubric helped them to help each other and enhanced their team experience. Almost all students (96%) found the rubric helped them achieve their learning goals and more than 52% of students found it to be useful in providing constructive feedback. The students also had a positive relationship with the subject matter and the staff, and they found it easier to appreciate the time staff dedicated to providing feedback when the rubric was used.

Comparing the 2018 and 2019 survey results, the students who were graded using the rubric in 2019 reported that they were receiving more feedback than those students who were graded without the rubric in 2018 and that the later cohort with the rubric available to them also demonstrated a higher satisfaction with the subject overall. The initial data suggested that students do benefit from a rubric that aimed to guide them in preparing a higher quality of the final report. We acknowledged that when comparing final reports of two different cohorts of students (student group using the rubric vs. student group without the rubric), there are various factors that can contribute to a student group's performance. Therefore, it remains to be seen as to whether the patterns observed in the collected data are replicated in future cohorts of students doing the course to ascertain if the improvements seen in this study are sustained over time.

We observed a better consistency in grading, with a smaller variation in the standard deviation of the overall final grades when the rubric was used. However, these findings are limited to selected "sample" reports in which the course tutor's and the lead author's grades were compared. To demonstrate a stronger interrater agreement in grading using the rubric, future studies using a larger cohort of students and other courses are strongly recommended.

This study has demonstrated the use of an assessment rubric, complemented by students' own or group reflection on the team process, can improve students' learning experience and assist in building essential transferable skills. Regarding the extent to which the rubric and students' reflections might influence their learning process and its quality long term, requires a further study. We believe the findings from our study contribute to ongoing discussions focused on assessment methods applied in higher education environment.

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Appendix A: Assessment rubric

Criteria	Level of Achievement				Pts
Professionalism Attitude and Responsiveness to task. Hardworking person who always stays true to task and helps in times of need.	10.0 to >8.0 pts Exemplary Stays on task all of the time without reminders. A true team member who works hard and helps others in the group.	8.0 to >6.0 pts Proficient Stays on task most of the time. Group members can count on this person. A strong group member who tries hard.	6.0 to >3.0 pts Marginal Stays on task some of the time. Group members must sometimes remind this person to do the work Moderate group member who needs to try harder	3.0 to >0 pts Unacceptable Hardly ever stays on task. Lets others do their work. Sometimes chooses not to help out and does not complete tasks	10.0 pts
Work Ethics Take ownership for their personal actions when they are involved in an assessment Remembers and understands expectations and then assists others to do the same	10.0 to >8.0 pts Exemplary Is on time for meetings, turns in all work when it is due. Completes assigned tasks and does not depend on others to do the work.	8.0 to >6.0 pts Proficient Usually on time for meetings, turns in most work when it is due. Completes most assigned tasks.	6.0 to >3.0 pts Marginal Sometimes late for meetings, often turns in work late. Does not follow through on most tasks and sometimes counts on others to do the work	3.0 to >0 pts Unacceptable Late for all or most meetings, and late turning in work. Does not complete tasks. Depends on others to do all of the work.	10.0 pts
Communication Engage effectively in verbal, non-verbal, written, listening and/or symbolic communication	10.0 to >8.0 pts Exemplary Respectfully listens, discusses, asks questions and helps direct the group in solving problems.	8.0 to >6.0 pts Proficient Respectfully listens, discusses and asks questions.	6.0 to >3.0 pts Marginal Has trouble listening with respect, and takes over discussions without letting other people have a turn.	3.0 to >0 pts Unacceptable Does not listen with respect, argues with teammates, and does not consider other ideas. Hinders group from reaching agreement.	10.0 pts
Research and Information sharing Exceptional research task on behalf of the group.	20.0 to >15.0 pts Exemplary Gathers information and shares useful ideas for discussions. All information fits the group's goals	15.0 to >10.0 pts Proficient Usually provides useful information and ideas for discussion	10.0 to >5.0 pts Marginal Sometimes provides useful information and ideas for discussion.	5.0 to >0 pts Unacceptable Almost never provides useful information or ideas for discussion.	20.0 pts

Criteria	Level of Achievement						Pts
Problem-Solving Evaluating and implementing strategies to achieve a desired goal. Measures the quality of a process, rather than the quality of an end product.	20.0 to >15.0 pts Exemplary Actively seeks and suggests solutions to problems.	15.0 to >10.0 pts Proficient Improves on solutions suggested by other group members	10.0 to >5.0 pts Marginal Does not offer solutions but is willing to try solutions suggested by other group members.	5.0 to >0 pts Unacceptable Does not try to solve problems or help others solve problems.			20.0 pts
Group/Teamwork The ability to participate actively and cooperatively in a group to advance a common goal	30.0 to >22.0 pts Exemplary Always has a positive attitude about the task(s) and the work of others. All team members contributed equally to the finished project. Performed all duties of assigned team role and contributed knowledge, opinions, and skills to share with the team. Always did the assigned work.	22.0 to >16.0 pts Proficient Works to complete all group goals. Performed nearly all duties of assigned team role and contributed knowledge, opinions, and skills to share with the team. Completed most of the assigned work.	16.0 to >10.0 pts Marginal Usually helps to complete group goals. Usually has a positive attitude about the task(s) and the work of others. Assisted group/partner in the finished project.	10.0 to >6.0 pts Basic Occasionally helps to complete group goals. Sometimes makes fun of the task(s) or the work of other group members. Finished individual task but did not assist group/partner during the project.	6.0 to >3.0 pts Novice Contributed little to the group effort during the project. Relied on others to do the work., Performed a few duties of assigned team role and contributed a small amount of knowledge, opinions, and skills to share with the team. Completed some of the assigned work.	3.0 to >0 pts Unacceptable Does not work well with others and shows no interest in completing group goals. Often makes fun of others' work and has a negative attitude. Did not perform any duties of assigned team role and did not contribute knowledge, opinions or skills to share with the team	30.0 pts
Total Points: 100.0							

Comments:

Appendix B

Marking Scheme for Group Project

Each student is allocated a group mark and an individual mark for the project. The overall mark for a student is normally an unweighted average between the group mark and the individual mark.

This arrangement ensures that every student *must* actively participate in the group activities, and therefore it is not possible for a strong group to ‘carry’ a passenger and allow them to get the same mark.

Each component (i.e. individual and group) is subdivided into three categories: process, achievement and report. Each component has different weightings for each category, reflecting their differing importance.

	Group (90%)*	Individual (10%)*
Group Processes	30%	
Achievement	40%	
Report	30%	
Total	100%	10%

* These two components are weighted 90% and 10% and *the final mark for the coursework is normally obtained by averaging these two marks.*

The following information gives an idea of what will be assessed in each category—however, the guidelines are deliberately not meant to be prescriptive as projects will be so diverse in nature.

Group processes: 30%

The group is expected to attend regular meetings both with and without the supervisor. The group meetings should be minuted. Students should conduct themselves in a professional manner by being fully prepared; and take initiative in planning and conducting the meetings and meeting deadlines set. The marks should reflect:

- Regular meetings are formally minuted and fully attended. For the first four weeks, group members should (15%):
 - Make the right framework on the design opportunity
 - Have brainstorming sessions to develop a pool of innovative ideas (10-20 sketches).
 - Analyse and make critical design decisions to move forward in the design process
- Project is planned using techniques such as Gantt charts.
- There is a sensible allocation of tasks across the group.
- Project is monitored against plans and the group has the ability to modify its plans in the light of unexpected problems.
- Appropriate standards are established and adhered to.
- Deadlines are met.

Group achievement: 40%

The group is expected to produce a smartphone holder (tablet holder) design based the measurement of a physical smartphone/tablets of your choice. This mark should reflect the technical difficulty of the project undertaken by the group and should also take into account whether:

- Getting the right framework on the design opportunity the group is working on (5%)
- An appropriate methodology is applied to the design of the smartphone holder
- Common standards are adhered to.
- An integrated piece of work is produced.
- The final product meets the specification.

Group report: 30%

The group is expected to produce a single unified report describing the analysis, design, implementation, testing and evaluation of the smartphone holder. Marks should reflect:

- Did the group write the report to common standards, producing a seamless manuscript?
- Whether the report is properly structured.
- Whether the aims of the project are clearly stated.
- Whether the project is clearly specified.
- Are diagrams and graphics used appropriately, is it uncluttered and easy to read?
- Whether a critical appraisal of the project is given, in terms of both the process *and* the outcome of the project. The report should clearly show what testing and analysis was performed on the final 'product' and provide a clear analysis and interpretation of that testing.
- Does the report convey to the reader the main points of the project such as: the aims of the project, what was achieved, how was it achieved, future work, etc.

Individual Assessment

Students are assessed by their peers on the quality of the process and achievement of the group, and the report. Individuals are expected to:

1. plan and monitor their contributions to the project and not to impede the progress of the group
2. deliver their agreed elements on time and to specification.

Students were asked to reflect on whether they:

- Were prepared at the meetings.
- Were realistic about their objectives.
- Met their individual deadlines.

- Supported other team members
- Took part in general discussion about the project
- Demonstrated resourcefulness and problem solving ability.
- Were proficient in the chosen implementation.
- Achieved their agreed component.
- Demonstrated command over their problem domain.

Declaration and verification

The report should include a statement in the Appendix from each member detailing his/her individual contributions to the project (both the report and the application) and some reflection on the team process. It should be clear from the student's individual statements of his/her work, i.e. which sections of the report he/she has written or to which they have contributed.

Every student needs to sign this declaration form.