Rubric-based scoring for engineering senior design course assessment and grading

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ABSTRACT: A senior design project is the learning culmination of all courses for engineering students. It summarises student technical and behavioural skills gained from previous courses needed to succeed in the engineering profession. One of the challenges in the senior design course delivery is assessment, including assigning fair and impartial final grades over different types of project topics and under different types of supervisions. The main objective of this article is to develop a rubric-based assessment system derived from the recent one to seven ABET (Accreditation Board for Engineering and Technology) student outcomes. The assessment system proposed here is unique, since it can produce letter-grading criteria and, at the same time, can quantify the overall learning outcome achievement. Examples of the rubric scoring measure are given here using data extracted from a senior design course offered during the last two semesters in the Civil Engineering Programme at Prince Mohammad Bin Fahd University (CE-PMU). Also, the learning outcomes achieved in the senior design course are compared with the overall programme student outcomes during the same period.

INTRODUCTION

A senior design project or a capstone design project is arguably the most important course in engineering programmes. It is the culmination of student learning and design experiences gained from previous courses including those of non-technical skills, such as communication, teamwork, professionalism, ethics and continuous learning [1]. A majority of engineering schools offer senior design courses in one or two semesters near the students' graduation time [2][3].

The course is normally taught by an instructor who is responsible for coordinating project design activities, and is typically supported by faculty members who act as technical advisors to a group of two to four students. Experts or engineers from related industry are sometimes invited to be technical advisors or evaluators along with the academic advisors to simulate the actual processes in project engineering design [1][4][5].

One of the challenges in conducting senior design courses is assigning a fair and impartial final grade to students over different types of student project topics and under different types of supervisions by advisors and evaluators/examiners. The challenge is also coupled with a routine accreditation-related exercise on how to perform the quantitative assessment of the course learning outcomes as part of measuring the overall programme (student) learning outcomes [6-10].

In developing students' competence for their future careers, the evaluation and improvement in assessment of competence standards need to be continuously upgraded, as well as explored or carried out in any engineering education and industry institutions [10].

Assigning grades for courses that apply traditional assessment tools, such as homework, quizzes and examinations are a relatively straightforward process. Academic teachers can assign student grades based on the total points collected (1-100) from all applicable assessment tools, including their associated percentage, and assign final letter grades (A to F) based on a *fixed* or *normal curve distribution* system. For non-traditional courses, such as internship and senior design courses, rubric-based grading is needed since these courses assess student performance in various non-technical areas mentioned before. A rubric is designed to reduce grading subjectivity, and to improve inter-assessor reliability amongst different types of non-traditional assessment tools (e.g. report writing, oral presentation, professional and ethical behaviours). In principle, a rubric contains assessment criteria (key performance indicators), scale and descriptors for each scale [11].

Table 1 shows an example of rubric for teamwork performance using two major assessment criteria and several descriptors for each scale that is ranged from excellent, good, needs improvement and low/poor. The rubric scale used throughout this study is 1 to 4 points (not 1 to 5 points) to avoid the assessor assigning a neutral score, and thereby maintaining objectivity.

Table 1: Sample of rubric for teamwork performance.

Assessment criteria	Scaling and descriptors			
	Low (Score = 1)	Needs improvement (Score = 2)	Good (Score = 3)	Excellent (Score = 4)
The team allocated resources and tasks clearly	• Only one person contributed to tasks • Tasks were handled randomly, no clear criteria imposed	• Half of members contributed to tasks • One or two member/s handled tasks based on their subject strength	• Majority of members contributed to tasks completion • Most of tasks were handled by each member based on student subject strength	• All members contributed to tasks completion • All tasks were handled by each member based on student subject strength
The team members participated and functioned effectively	• Members were always late in completing tasks even after constant reminders, too much unnecessary (speaking) excuses • Group meetings conducted were very minimal • Frictions were still detected between members, and no resolution was found to resolve them	• Members were sometime late in completing tasks and needed constant reminders, too much speaking • Group meetings conducted were adequate • Little friction was still detected between members after trying to resolve it	• Members completed tasks on time with occasional reminders, and not too much speaking • Group meetings were conducted regularly with occasional excuses • No frictions were detected at the end, after initial issues resolved	• Members always completed tasks on time without being reminded, with less speaking • Group meetings were conducted regularly, at least once a week • No frictions were detected between members since the start

There have been previous studies on senior design project assessments using the ABET student outcomes as the main criteria. Davis discussed assessment techniques for an electrical and computer engineering capstone design course to quantitatively determine the ABET *a-to-k* student outcomes based on many assessment tools, such as project-specific assignments, peer and self-assessments, and student surveys [7][12]. Students' performance during the course was assessed based on rubric scoring with a different scaling system, and the final grade score (1-100 point) was obtained based on the average of class assignments (25%) and the average of technical advisor evaluation (75%), after it was normalised by individual performance over team participation and progress. The applicable ABET *a-to-k* student outcomes were determined based on a combination of direct and indirect (survey) methods. A similar technique was implemented by Biney and Quadrato to assess the ABET student outcomes and student performance in a capstone design course using a rubric with a 100-point score distributed over non-uniform five-scaled performance [8][9].

Some studies reported a grading system, where the evaluators assigned scores to certain performance criteria over a wide range of numbers, and this could lead to grading subjectivity since most of the content of the assessment tools were non-traditional in nature [1][13][14]. A more comprehensive rubric-based scoring system was practised by Estel and Hurtig to assess and grade fairly their electrical and computer engineering, and science senior design projects [15]. They applied a rubric consistently in key assessment tools, such as report, presentation, design and teamwork evaluations using detailed 1-4 scale performance criteria. Although it was not entirely purposed for assessing design projects, detailed rubric scoring for assessing key performance indicators for technical reports was also presented by Cong and Romkey [16]. However, no further discussions were presented on the ABET student outcomes in those two papers. This article is intended to complement existing techniques on how to quantify senior design course assessment comprehensively based on the recent ABET 1-7 student outcomes and, at the same time, to assign the student final (letter) grade fairly.

The Civil Engineering Programme at Prince Mohammad Bin Fahd University (CE-PMU) offers 139 total credit hours distributed over 50 courses that can be completed within eight semesters excluding the preparatory programme. The PMU is one of private universities in Saudi Arabia with English as the main medium of instruction in teaching and learning. Out of 139 credit hours, 108 credits hours (78%) comprise of mathematics, science, basic engineering and civil engineering courses. The PMU is considered a unique university in terms of offering explicit competency-based courses, such as teamwork, leadership, critical thinking and professional development relative to other universities in the region. This practice is accentuated in terms of six PMU graduate attributes that students bear in their academic transcripts after graduation [17].

The CE programme at the PMU has been accredited by the ABET Engineering Accreditation Commission and will undergo a second ABET evaluation and visits during the 2021-2022 academic year. The senior design course is offered regularly each semester, and it has typically 12-20 students distributed to four or five groups. The following sections

describe in detail the senior design course delivery at the CE-PMU, followed by descriptions of the assessment tools and associated rubrics, and conclude by discussion about the key findings and future improvement.

SENIOR DESIGN PROJECT AT THE CE-PMU

General

The senior design project at the PMU is officially called Learning Outcome Assessment III (course code ASSE 4311), and is required to be completed by civil engineering students in order to graduate. It is offered every semester as a three credit hour course. The main prerequisites of this course are that students must pass previous Learning Outcome Assessments I and II, and must be in the academic standing of senior second semester. Learning Outcomes Assessments I and II are sophomore and junior courses that prepare students competencies in non-technical areas, such as written and oral communication, learning development portfolio and teamwork learning. Although it is not required in the senior design project syllabus, students are recommended to complete major design courses including materials in civil engineering, design of steel structures, reinforced concrete design, introduction to geotechnical engineering and environmental engineering fundamentals. Also, students are strongly recommended to complete an internship course to gain some actual design experience and to search for any potential project topic based on their day-to-day interactions with engineers. Another important contributing course in the senior design project, such as construction management, can be taken along with this course.

The main teaching objective of the senior design course is to facilitate students to have their own design experience that incorporate learning outcomes gained from previous design courses using as realistic as possible various design constraints and specifications under a teamwork environment. The course learning outcomes of this course match the new (1-7) ABET student outcomes [18]. Table 2 shows the course learning outcomes and the associated key performance indicators that will be used as criteria in the senior design course assessment.

As can be observed, three outcomes (1, 2 and 6) are technical or engineering skills, and the other four outcomes (3, 4, 5 and 7) are non-technical skills or professional competencies [12]. Learning outcome 6 is rarely applicable in a civil engineering senior design project, since most of the student work focuses on design exercises and the majority of design data are taken from available literature or engineering standard practices. Outcome 6 is not eliminated from the teaching practice to leave potential projects that could combine laboratory experimentation and design exercises. It should be noticed that in relation to the ABET student outcome assessment, the laboratory experimentation skill is assessed through courses that require laboratory exercises in their syllabi [17].

Table 2: Course learning outcomes and key performance indicators.

Student outcomes [15]	Key performance indicators
1. *An ability to identify, formulate, and solve complex engineering problem by applying principles of engineering, science, and mathematics.*	1.1. Identify the problems and applicable theories and concepts.
	1.2. Formulate the problem using appropriate objectives, assumptions and constraints by applying the principles of engineering, science and mathematics.
	1.3. Solve and evaluate problem solutions and adopt the optimal solution by applying the principles of engineering, science and mathematics.
2. *An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.*	2.1. Define design specifications and constraints and utilise proven design methodologies and practices, and available resources to achieve the design intent.
	2.2. Produce design alternatives.
	2.3. Verify the component/system/process design against the design specifications and constraints.
3. *An ability to communicate effectively with a range of audiences.*	3.1. Communicate technical ideas in written technical reports including engineering graphs and drawings, etc.
	3.2. Conduct effective oral technical presentations to target audiences.
4. *An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.*	4.1. Understand and apply engineering professional and ethical standards in dealing with public safety and interest considering social and economic guidelines and regulatory laws.
	4.2. Recognise the impact engineering solutions in global, economic, environmental and societal contexts using current updated research and development in civil engineering.
	4.3. Recognise contemporary local, national, regional and global issues in the civil engineering discipline.

5. *An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.*	5.1 Develop teamwork plans and allocate resources and tasks.
	5.2 Participate, communicate and function effectively in teamwork projects.
6. *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.*	6.1 Use laboratory equipment to conduct experiments.
	6.2 Use data acquisition systems, hardware and software to collect, analyse and interpret data.
	6.3 Prepare a professional technical report.
7. *An ability to acquire and apply knowledge as needed, using appropriate learning strategies.*	7.1. A recognition of the need for, and an ability to engage in independent and lifelong learning strategies.

Group Formation and Topic Selection

Most of project topics are initiated during major design courses including internship, which normally are offered one or two semester/s preceding the senior design project course. Brain storming about design processes is provided in those courses, and students are recommended to form a group and start practising teamwork exercise in their limited course project. A group leader is appointed by respected course instructors during those periods in consultation with the senior design course coordinator. A group typically comprises of three to four students with members' selectivity based on the grade point average composition. However, the group formation derived during design course deliveries does not constitute the final one due to a few students failing to pass the courses or deferring the senior design project to the next one or two semesters. The group formation is refined during the early days of the senior design project course based on the previous group composition and availability of students while retaining the group leaders. Some students voluntarily withdraw from one group and move to another one due to; for example, changing interests or incompatibility issues between group members. The course coordinator offers some flexibility in exchanging group members depending on student cases. At the end, all group formations must be approved by the department council before proceeding to decisions on project topics and proposal development.

While forming groups, students are also recommended to search and refine their project topics in consultation with civil engineering professors and the senior design project course coordinator. Project ideas can be solicited from industry, community, professors, students or any combination of them. But it is highly suggested that project ideas be initiated from construction industry and community needs. That is why having internships prior to the senior design project would be a good practice. In general, projects should be design based (not research based), covering at least three to four major design exercises (capstone based), applying realistic design constraints and specifications, using applicable design standards, and needed by industry or the surrounding community [1][19].

Each group could have different project topics, and if all groups have the same topic, a design competition mode will be practised simulating the actual design bid competition. As was in the group formation, all project topics must be approved by the department committee within the first week of the senior design course. An example of last semester's project topic that incorporated all requirements above was *designing parking structure at the university*. The project was needed by the PMU to expand existing parking capacity by 1,000 cars (major design constraint), and groups in the senior design course were asked to obtain best design solutions by giving them flexibility in exploring various different structural, foundation and construction systems (Table 4). Apart from awarding the best design solution, appreciation was also given to a group who performed the best in the overall assessment category. The competition mode in the senior design course is strongly recommended by the department to increase student motivation and project quality.

Administration and Supervision

A coordinator is assigned by the department to give general guidance to students on how to execute their design project according to the ABET standards and practice. In collaboration with the involved faculty members who act as project advisors/examiners, the coordinator manages and monitors project progress, while at the same time conducts the evaluation and assessment of the overall teaching and learning of the senior design course. Each group is assigned with one or two advisors who give guidance on day-to-day activities during the project execution. An external advisor from industry can also be added to give students input and data during the design work. Two examiners from within the department are assigned to evaluate each student's project progress via oral presentations and written reports.

There are three group presentations (proposal, midterm and final), and two written reports (midterm and final) that are evaluated by the examiners. Each group is required to meet with the advisor at least once a week, and all meetings must be recorded in minutes that will be evaluated by the course coordinator. Also, the recorded group meeting minutes, at least once a week, must be submitted as part of evaluation by the advisor and course coordinator. The advisor has his or her own recorded meetings including group progress performance and evaluations. The class meeting that must be attended by students is conducted once a week to discuss progress and challenges faced during the project execution. Additional training or a workshop to enhance student skills and competencies performing the design project is added to the senior design course activities as needed; for example, inviting people from industry to give a general lecture on ethics and professionalism, training on modern computer software for design and drawing, etc.

Time Line and Project Outcomes

Fifteen-week design project activity is a relatively short period as it is a common practice recently to have two semester courses for senior design projects [2][20]. However, one semester is doable without compromising the course learning outcomes achievement and quality. Students are required to write and present a proposal outlining their objectives, methodology and planning within three weeks since the first day of the semester. Right after the proposal, the examining committee will give input to the project scope and method for efficient project execution and anticipated realistic outcomes. A midterm report and presentation are held around the mid-semester week (week 8 or 9) with the main intention to evaluate the project progress. One week prior to the final oral presentation, which is normally held at the end of semester, students are required to submit the final report draft to be evaluated by the examining committee. Comments and suggestions on the draft are given back to students for improvement in their written reports before they officially are printed out for the final submission.

Along with the final report, each group is required to submit a project portfolio (hard and soft documents) containing all activities including meeting minutes, draft design calculations and analyses, responses to examiners' evaluations, computer software modelling and references. The project portfolios are used as additional materials for the evaluation conducted by the course coordinator. During the final oral presentation, students are required to develop a brochure outlining their project and are optionally given an opportunity to build a prototype to attract audience, which comprises of faculty and students from within and other departments, and invited community and engineers from industry.

ASSESSMENT

The assessment of the senior design project is based on rubric scoring conducted by the examining committee (40%), advisors (45%), course coordinator (10%) and peer student evaluation (5%). The advisor has the highest evaluation percentage, because he or she has close interactions with students throughout the semester regarding their detailed academic performances, skills and behaviours, either as an individual or as a team. Peer student evaluation is given the smallest percentage since it is generally found that they will give a complacent evaluation in relation to their peers. The 40% assessment given by the examining committee comes from the evaluations of three oral presentations conducted during the proposal, midterm and final project stages (25%); and two written technical reports submitted prior to the midterm and final project stages (15%). Table 3 shows detailed assessment of a student by various evaluators that is tied with the course learning outcomes and associated key performance indicators. As an illustration, filled out scores are also shown in the table based on the actual assessment of that student from the last semester senior design course.

Table 3: Student assessment (individual).

Name: Student 01, Project A: *Design of multi-storey parking structure with precast concrete elements*																
			Outcome 1			Outcome 2			Outcome 3		Outcome 4			Outcome 5		Outcome 7	Avg. grade
			1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	4.1	4.2	4.3	5.1	5.2	7.1	
1	Proposal (5%)	Prof. A								3	3			3	3		2.6
		Prof. B								2	2			3	2		
2	Midterm (10%)	Prof. A								3	2			3	2		2.8
		Prof. B								3	3			3	3		
3	Final (10%)	Prof. A								3	3			3	3		3.1
		Prof. B								3	3			3	4		
4	Reports (15%)	Prof. A	3	3	2	3	2	3	4	3						3	2.7
		Prof. B	3	3	3	2	2	2	3	2						3	
5	Advisors (45%)		3	3	3	2	2	2	3	3	3	3	3	3	3	3	2.8
6	Peer student evaluation (5%)													4	4		4
7	Coordinator (10%)		3	3	3	2	2	2	3	3	3	3	3	3	3	3	2.8
		Avg.	3.0	3.0	2.8	2.3	2.0	2.3	3.3	2.8	2.8	3.0	3.1	3.0	3.0	3.0	2.9

As can be seen in Table 3, all scores assigned by the evaluators were in integer numbers to reflect the nature of rubric-based scoring. But the average for each assessment category was calculated in the last column to distinguish the individual performance of each student and to investigate whether a certain assessment category needs improvement during the project exercises. The example shown in the table (last column) indicated that the team oral presentation exercises had shown improvement from the proposal to final presentation stages. The last row shown in the table indicates the average score of the given student with respect to the key performance indicators of each course learning outcome. This number will be averaged with the other student numbers to obtain the overall achievement of student outcome in a certain semester, and it will be used as one of the main contributors to the overall ABET student outcome achievement. The student grade, which was calculated based on the weight formula described above, was shown in the table at the right bottom corner. This grade will later be converted into a letter grade (A to F) as per the university grade system. Table 4 shows an example of rubric scoring results and the associated letter grades obtained from the last semester senior design course.

Table 4: Grade results of the senior design course (Fall 2019).

Group number and project title	Student	Average grade (1-4 scale)	Letter grade (PMU)	Total score (competition)
Project A: *Design of PMU multi-storey car park using precast concrete elements*	Student 01	2.9	B+	11.8
	Student 02	2.9	B+	
	Student 03	2.9	B+	
	Student 04	3.1	A	
Project B: *Design of PMU multi-storey car park using steel frame elements*	Student 05	3.6	A+	12.4
	Student 06	3.2	A	
	Student 07	2.8	B+	
	Student 08	2.8	B+	
Project C: *Design of PMU multi-storey car park using cast-in-situ reinforced concrete elements*	Student 09	2.8	B+	12.0

In other traditional courses, instructors assign a letter grade based on a fix 100-point scale, with A+ ranging from 95-100, A (90-94), B+ (85-89), B (80-84), C+ (75-79), C (70-74), D+ (65-69), D (60-64) and F (lower than 60). The passing grade is D+ or the students must have accumulated points above 64. In the senior design course, grading based on rubric scoring (1-4 scale) needs to be refined and converted into letter grades, with A+ ranging from 3.5-4.0, A (3.0-3.4), B+ (2.5-2.9), B (2.0-2.4), C+ (1.5-1.9), C (1.0-1.4). No grade below C is assigned since the rubric scale starts from 1 and not from 0. The target performance average for continuous improvement purpose is set at 2.5 with minimum 25% of the students receiving grades lower than 2.5. As described implicitly above, the main reason students could receive different grades within a group is due to individual evaluations performed by the advisor, peers and course coordinator. The last column in Table 4 was the total score from all students in the group, and it was used as the main criterion to award the best design project (e.g. Project B was the winner in this example). Due to consistency in the grading and assessment, it is anticipated that this assessment practice will also be applicable to find the best performer amongst different types of project topics, e.g. environmental versus transportation engineering projects.

Table 5: Evaluation of team oral presentation.

Group (title): Project A: *Design of multi-storey park structures using precast concrete elements*		
Examiner: Professor B	Presentation event: ~~Proposal/Midterm~~/Final	Date: 10.12.2019
Assessment criteria		Score
Oral communication skill (ABET Outcome 3.2)		
The project title, topic, and objectives were clearly identified		☐4 ☑3 ☐2 ☐1
A clear outline of the presentation was provided		☐4 ☑3 ☐2 ☐1
Sufficient background information was provided		☐4 ☑3 ☐2 ☐1
Work tasks performed or methods used were presented		☐4 ☑3 ☐2 ☐1
Information was presented in a logical and well-organised manner		☐4 ☐3 ☑2 ☐1
The presentation was audible, well-paced and well-articulated		☐4 ☑3 ☐2 ☐1
Any major constraints, problems or challenges were discussed		☐4 ☐3 ☑2 ☐1
Conclusions and recommendations were clear and drawn from findings		☐4 ☑3 ☐2 ☐1
Presentation slides were clear, concise and attractive		☐4 ☑3 ☐2 ☐1
Presentation slides were supported with pictures, diagrams and tables		☑4 ☐3 ☐2 ☐1
Presentation slides were supported with animations and/or video clips		☐4 ☑3 ☐2 ☐1
Average outcome 3.2		2.91 (rounded as 3)
Professionalism (ABET Outcome 4.1)		
The team demonstrated professional attitude, appearance and body language		☐4 ☑3 ☐2 ☐1
Team members cited references and acknowledged help/support received from others		☐4 ☐3 ☑2 ☐1
Team members responded positively and professionally to criticisms/suggestions/ comments		☐4 ☑3 ☐2 ☐1
Average outcome 4.1		2.67 (rounded as 3)
Teamwork (ABET Outcome 5)		
The team allocated resources and task clearly (Outcome 5.1)		☐4 ☑3 ☐2 ☐1
Transitions and rapport between team members were strong (Outcome 5.2)		☐4 ☐3 ☑2 ☐1
Team members participated and functioned effectively (Outcome 5.2)		☐4 ☑3 ☐2 ☐1

Table 6: Evaluation of team written report.

Group (title): Project A: *Design of multi-storey parking structures using precast concrete elements*		
Examiner: Professor B	Report event: ~~Midterm~~/Final draft	Date: 03.12.2019
Assessment criteria		Score
Written communication skill (ABET Outcome 3.1)		
Report is developed using standard technical report		☑ 4 ☐ 3 ☐ 2 ☐ 1
Main body of report is well organised in sections and sub-sections		☐ 4 ☑ 3 ☐ 2 ☐ 1
Figures, tables, graphs and drawings are well quoted and presented		☐ 4 ☑ 3 ☐ 2 ☐ 1
Mathematical equations are presented in clarity and explanations are provided		☐ 4 ☑ 3 ☐ 2 ☐ 1
English language is well imposed		☐ 4 ☐ 3 ☑ 2 ☐ 1
References are cited and written in standard format		☑ 4 ☐ 3 ☐ 2 ☐ 1
Average outcome 3.1		3.17 (rounded as 3)
Project objectives and methodology: introductory chapters (ABET Outcome 1)		
Project objectives and scopes are clearly stated (Outcome 1.1)		☑ 4 ☐ 3 ☐ 2 ☐ 1
Project methodology is clearly discussed (Outcome 1.2)		☐ 4 ☑ 3 ☐ 2 ☐ 1
Engineering design principles are used for optimal solutions (Outcome 1.3)		☐ 4 ☑ 3 ☐ 2 ☐ 1
Project design (ABET Outcome 2)		
Design standards and specifications are used (Outcome 2.1)		☐ 4 ☑ 3 ☐ 2 ☐ 1
Constraints considering public health, safety and welfare, as well as global, cultural, social and environmental, and economic factors are imposed in the project (Outcome 2.2)		☐ 4 ☐ 3 ☑ 2 ☐ 1
Design alternative/s is provided and verified against the constraints (Outcome 2.3)		☐ 4 ☑ 3 ☐ 2 ☐ 1
Development of advanced learning skills (ABET Outcome 7)		
Modern engineering design software and/or tools are used and applied for finding optimum design solutions		☐ 4 ☑ 3 ☐ 2 ☐ 1
Literature surveys and/or past project experience are discussed in the project		☐ 4 ☑ 3 ☐ 2 ☐ 1
Average outcome 7		3

Table 7: Evaluation of individual performance (by advisor/coordinator/student peer).

Group (Title): Project A: *Design of multi-storey parking structures using precast concrete elements* Name: Student 04	
Advisor/~~Course Coordinator~~: Professor C	Date: 17.12.2019
Assessment criteria (KPI of ABET student outcomes)	Score
1.1. Identify the problems and applicable theories and concepts	☐ 4 ☑ 3 ☐ 2 ☐ 1
1.2. Formulate the problems	☐ 4 ☑ 3 ☐ 2 ☐ 1
1.3. Solve and evaluate problem solutions	☐ 4 ☑ 3 ☐ 2 ☐ 1
2.1. Define design specifications and constraints	☐ 4 ☑ 3 ☐ 2 ☐ 1
2.2. Produce design alternatives	☐ 4 ☐ 3 ☑ 2 ☐ 1
2.3 Verify the component/system/process design	☐ 4 ☐ 3 ☑ 2 ☐ 1
3.1 Communicate technical ideas in written technical reports	☐ 4 ☑ 3 ☐ 2 ☐ 1
3.2 Conduct effective oral technical presentations to target audiences	☑ 4 ☐ 3 ☐ 2 ☐ 1
4.1. Understand and apply engineering professional and ethical standards	☐ 4 ☑ 3 ☐ 2 ☐ 1
4.2. Recognise the impact of engineering solutions	☐ 4 ☐ 3 ☑ 2 ☐ 1
4.3. Recognise contemporary local, national, regional and global issues	☐ 4 ☐ 3 ☑ 2 ☐ 1
5.1. Develop teamwork plans and allocate resources and tasks	☐ 4 ☑ 3 ☐ 2 ☐ 1
5.2. Participate, communicate and function effectively in teamwork projects	☐ 4 ☐ 3 ☑ 2 ☐ 1
7.1. Acquire and apply knowledge using appropriate learning strategies	☐ 4 ☑ 3 ☐ 2 ☐ 1

Tables 5 and Table 6 above present examples of the scored evaluation criteria for an oral presentation and a written report that were assessed by the examining committee during the last semester. While Table 7 shows the evaluation criteria used by the advisor and coordinator that are directly based on the key performance indicators of the recent ABET 1-7 student outcomes (see Table 2). Before assigning the scores (1-4 scale), the examiners were given an overview by the course coordinator about the rubrics and their descriptors for each assessment criterion, which are available on the CU-PMU senior design Web site [21].

Some criteria need to be averaged to represent performance for either the ABET student outcome or its key performance indicator. For example, to obtain a score for the oral communication skill, which corresponds to the ABET student outcome 3.2, the average of eleven assessment criteria was calculated (Table 5). This number was then rounded up as an integer before it was inputted in Table 3. Some criteria indicated a one-to-one relationship with the key performance indicator of ABET student outcomes (i.e. no need for averaging work) as shown in Outcome 1 and Outcome 2 in Table 6, and all assessment criteria in Table 7. The peer project evaluation was conducted by students within the same group based on teamwork performance, i.e. Outcome 5.1 and Outcome 5.2 as shown in Table 5. Again, all numbers obtained from Table 5 and Table 6 and peer assessment were inputted in Table 3 for each student.

DISCUSSION

Figure 1 shows the achievement data of the senior design course and ABET student outcomes (1-4 scale) collected during the last two semesters. Data from the senior design course outcomes were determined based on averaging all student outcomes' performances as shown in the bottom row of Table 3. Whereas the ABET student outcome data were determined based on the composite of all key civil engineering courses that were used for the assessment including the senior design course. The data collection including its technique for the ABET student outcomes for the CE-PMU Programme can be seen in the article by Ayadat et al [17].

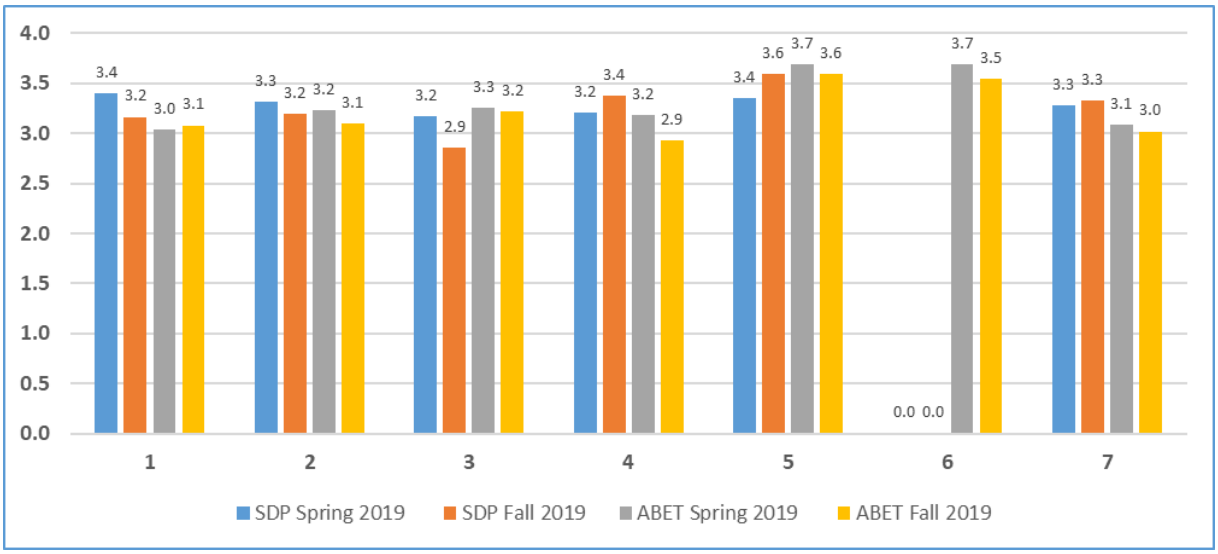

Figure 1: Senior design project (SDP) course and the ABET student outcomes.

In the assessment, Outcome 6 was not shown in the graph (Figure 1) since all the student projects were design oriented, i.e. no laboratory experimentations. Figure 1 shows the rubric scores of other design courses and the ABET student outcomes for the SDP during the spring and fall 2019 semesters.

As was discussed earlier, the other senior design course outcomes were the same as the ABET student outcomes. It is still premature to observe a continuous improvement pattern based on two-semester data. For the ABET accreditation purpose, the student outcome data is normally presented at every academic year over at least three- to five-year period, meaning that the two-semester data need to be averaged. However, an interesting observation can be seen in the Outcome 5 (teamwork). The teamwork criteria show the highest achievement relative to the other outcomes both for the senior design course and the ABET student outcomes. This is consistent with the observation obtained from previous studies e.g. [7][22][23], which show that students are confident in performing self- and peer-evaluations as part of the teamwork effort in their learning. Future senior design course practice at the CE-PMU is geared toward enabling active participation in learning through student peer- and self-evaluations.

Formal surveys were conducted to students and faculties about the senior design course satisfaction including the assessment method. Table 8 presents the survey questions and results. About 90% of responses received from the students and 100% from the faculty members over five semesters showed the positive support and approval of the rubric-based practices. From the survey, about 85% of students showed their satisfaction for the rubric-based scoring as a method of grading for the senior design project course. Almost 90% of the faculties approved the current grading distribution allocated for this course.

Table 8: Survey results of rubric-based scoring for the senior design course.

Questions	Students (avg. out of 5)	Faculty (avg. out of 5)
1. Rubric based scoring is an appropriate method for grading the senior design project course	4.2	5.0
2. Grading distribution allocated for this course is fair (5% proposal, 10% midterm presentation, 10% final presentation, 15% written report, 45% advisor evaluation, 5% coordinator evaluation and 5% peer evaluation)	4.0	4.5
3. Four-scale scoring used for each performance assessment criterion is appropriate	4.1	5.0
4. Performance assessment criteria used for the oral presentation are fair and adequate	4.0	4.4
5. Performance assessment criteria used for the written report are fair and adequate	3.8	4.3
6. Performance assessment criteria used for teamwork are fair and adequate	4.1	4.5
7. Performance assessment criteria used for professionalism, ethics and life-long learning are fair and adequate	4.2	4.5
8. Rubric-based grading is not too complex to follow due to many performance assessment criteria	4.0	4.5
9. Expected final score and grading would be fair due to many performance assessment criteria	4.1	4.5
10. Not too much work is expected from faculty members involved in the assessment	3.9	4.3

Based on the survey, it was established that students were satisfied (4.1 out of 5) with the grading fairness (Table 1). However, some students commented that they had difficulty in working on improving project performance due to many criteria (key performance indicators) imposed. This was a reasonable critique from students since they were used to face a more direct approach in assigning scores through the traditional assessment methods (e.g. homework, examinations). Moreover, students suggested to increase the contribution of the peer-assessment to the overall grading. To resolve the issue, the department has been continuously working on the simplification of the assessment criteria, while at the same time maintaining objectivity in assigning scores against student performances. The department would consider a higher weighting (e.g. part of grading) of the peer-evaluation as part of the teamwork exercise considering the cultural teaching norm.

The survey results indicated that all faculty members were in full support of conducting assessment based on the rubric scoring system. They suggested to add more descriptors to the assessment criteria to reduce subjectivity in assigning scores. This seemed contradictory to the students' input. This was anticipated due to the nature of relationship between the teacher judgment and student expectations with respect to the grading. The faculty members involved in the senior design course delivery (coordinator, advisors and examiners) need to justify at the end whether the assigned letter grades and their distribution would be reasonable or in need of realignment. In the latter case, the rubric scoring system need to be upgraded to reflect more of student performances and to improve inter-assessor reliability [1][15][24][25].

CONCLUSIONS

A comprehensive rubric scoring system was developed to assess and grade the senior design course of the CE-PMU Programme using the new ABET 1-7 outcomes and their associated key performance indicators. In general, the practice was found to be efficient and fair in assigning final grades based on the feedback received from the CE faculty members and students. However, the developed rubric, its assessment criteria and associated descriptors, have been under continuous refinement to reflect more of student learning in this important course and to improve inter-assessor reliability. Automation for inputting scores in the rubric via teaching tool aid is underway to reduce the amount of work for the assessor and to give students up-to-date grading information. Also, the CE curriculum has been upgraded to offer the senior design course in two semesters as part of the efforts in improving grading fairness and allocate more time to students for engineering project design.

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