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Embedding Employability Skills in Engineering Education

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ABSTRACT

CONTEXT

It is essential to make sure that students' knowledge reflects the needs of the industry. The higher education sector should adopt new ways of re-equipping learners with skills needed to improve graduate's prospects of safeguarding high-skilled jobs. However, employability skills development is not yet widely considered as the core of the curriculum and there is a gap between academic and industry expectations. This paper focuses on the benefit of embedding employability skills into the curriculum. A 3rd year engineering unit has been used as a case study example, designed to closely align with the project-based learning (PBL) approach.

PURPOSE OR GOAL

There is a gap between the traditional learning of higher education studies and the development of employability skills. By considering the need for employability skills when designing curriculums, we can make a significant difference and facilitate job-ready graduates for the future. The study aims to embed employability skills as a part of the assessment that facilitates student learning linkage through cutting-edge technologies, collaborative research projects and extensive laboratory demonstration so that the students can be work-ready upon graduation.

APPROACH OR METHODOLOGY/METHODS

A set of critical employability skills has been identified from the available literature, and industry communication has been reviewed by local energy industry professionals to incorporate into learning and teaching. This information is then collated into a set of skills needed for employment in sustainable engineering. Finally, these skills are incorporated into the broad unit learning objectives and assessments. The assessment tasks were designed to reflect skills directly applicable to the job market to ensure that the students learned the appropriate skills. To solve the assessment, students need to think critically and apply their innovative, problem-solving and communication skills in addition to theoretical topic-oriented knowledge.

ACTUAL OR ANTICIPATED OUTCOMES

An integrated and/or embedded approach to gain comprehensive knowledge of the principles and critically analyse the operation and maintenance of future-proof energy systems. Stand-alone teaching method of the unit is an invaluable experience considering the job market is intensely competitive and employers are looking for people who can demonstrate the specific tasks needed for the job such as energy auditing, energy measurement, design of renewable energy systems.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The proposed approach helps students develop flexible knowledge, advanced systematic approach, modern technologies, innovative and problem-solving skills, collaboration and communication skills. From the student survey feedback, it is evident that the applied approach fulfilled most of the student requirements as they believe that the unit's learning makes them ready for future jobs. This unit is expected to produce quality professional engineers, technologists, and researchers ready to meet current industry and global needs and are highly sought after.

KEYWORDS

Engineering education, Employability skills, PBL, Teaching evaluation

Introduction

The demands from the industry keep changing due to the emergence of new technologies and approaches e.g., Internet of Things (IoT), the fourth industrial revolution (Industry 4.0), etc, which is changing at a very fast pace (Valero et al., 2020, Thirunavukarasu et al., 2020). Therefore, it is essential to ensure that students' knowledge reflects industry needs and can be job-ready upon graduation. Higher education sectors are now adopting new ways of re-equipping learners with skills needed to improve graduate's prospects of safeguarding high-skilled jobs and competencies (Bennett, 2018, Valero et al., 2020). Competencies are bundles of the essential knowledge, skills, and attitudes required to achieve an acceptable level of performance in the world of practice. During COVID pandemic, the Australian Government has initiated a 'job-ready graduates' package' for higher education sectors to ensure graduates have the skills and experience needed to enter the workforce (Australia, 2020). However, there is a gap between the traditional learning of higher education studies and the development of employability skills. A significant difference can be made by considering the need for employability skills when designing curriculums to facilitate job-ready graduates for the future.

Engineering graduates need to acquire a certain skill in addition to hard core technical knowledge that they can effectively apply and practice the knowledge in the workplace. This skill is known as employability skills – the skills necessary for getting, keeping and doing well in a job (Zaharim et al., 2009, Robinson, 2000). Graduates need to develop this set of skills beyond discipline-specific knowledge to deal with complex situations, work in a multidisciplinary team, and establish relation between theory and practice (Huber, Hutchings & Gale, 2005).

Many countries across the globe have introduced national frameworks on employability skills as a guideline for employers, employees, and graduates (Zaharim et al., 2009). Higher education sector has also been working towards adopting employability skills in their curriculum by introducing certain courses, seminars/workshops, industrial visits, practical training, project-based learning (PBL) and work-integrated learning (WIL). However, the initiative is not yet adequate and hence, graduate performance is deemed not satisfactory. The Institution of Engineering and Technology (IET) reported in a 'Skills and Demand in Industry' survey by UK employers that many new engineering graduates have significant skills deficiencies (Valero et al., 2020). A report by Department of Education and Training, the Australian Government, stated that, "*Employability development is not yet at the core of the curriculum because it has been poorly defined as the acquisition of generic skills which are developed separately from the core business of learning a discipline*" (Bennett, 2018). This report also presents a set of recommendations highlighting the responsibilities of involved stakeholders; students, faculty and careers professionals, institutions and finally governments to ensure employability development in Australia.

The outlooks on employability are classified as; 'possessive'- conception of skills and attributes that add dominance to the theoretical aspects, 'positioning'- solidarity in the social positioning theory that enhances the employment outcomes, and 'processual' - approach that highlights the concept of graduate identity (Holmes, 2013, Thirunavukarasu et al., 2020). Graduate employability is multi-dimensional and incorporates academic performance, career planning and management, job market awareness, workplace management and personality theory (Jackson, 2013). Embedding employability skills should now be an integral part of undergraduate education. The aim is that the graduates will be confident that their knowledge and skills are appropriate for work and can articulate these to potential employers (Butcher et al., 2011). The higher education sector is now working towards embedding employability skills that make students job-ready (Thirunavukarasu et al., 2020). However, from the literature review, it is evident that low graduate employment and lack of a solution to enhance graduate employability are still barriers that drive researchers to explore significant issues of the stakeholders in higher education.

Over the last decade, much research has been conducted to investigate the need and usefulness of project-based learning (PBL), work-integrated learning (WIL) and the integration of employability skills in PBL and/or WIL approaches. Research has also been done on "self-directed learning", "case-based learning", "inquiry-based learning", "experiential learning",

“service learning”, “project-based service learning”, “active learning”, and “problem-based learning” (Kolmos and Graaff, 2015). PBL is a systematic, collaborative, progressive, student-centred and interactive teaching approach involving students learning essential knowledge and life-enhancing skills through an extended, student-influenced inquiry process (Guo et al. ,2020, Chowdhury,2015). PBL has been widely accepted by many universities across the globe and has been the subject of numerous publications in engineering education sector (Guo et al. ,2020, Chowdhury, 2015, Mills and Treagust, 2003, Kolmos, A., Graaff, E., 2015).

WIL is a collaborative effort by the higher education sector and industry to boost student learning through work placement that facilitates the application of theory into real practice (Bates, 2011, Jackson, 2013). This approach encourages interest and plays a pivotal role in improving students’ professional practice and work-readiness skills that the industry expects from new graduates (Jackson, 2013a). Thirunavukarasu et al. (2020) evaluated the learners’ experiences, expectations, and perceptions of graduate employability in an engineering curriculum. It is evident that different levels of expectations and experiences are considered in the course accommodating graduate employability needs substantial focus in future curriculum development. Zaharim et al. (2009) investigated engineering employability skills for Malaysia, Japan, Singapore and Hong Kong. Authors suggested that engineering graduates should acquire communication skills, problem-solving, and interpersonal skills to make them job-ready once they graduate.

From the above discussions, it is evident that many researchers are investigating the characteristics and usefulness of the PBL approach; hence, this approach is widely used nowadays. However, very limited research explores the PBL approach integrating employability skills in engineering education which is the key milestone in the student learning journey. A few studies considered this approach at the course or program level; however, no study described the approach at the unit level. Therefore, this study attempts to consider the PBL approach embedding employability skills at the unit level.

Methods

Upon realising the critical need that students of Engineering will need to be work-ready, in 2016 at the Discipline of Engineering and Energy, Murdoch University we designed a new PBL unit embedding employability skills for 3rd year Renewable Energy Engineering (Hons) program. In the unit, we developed the assessment tasks to reflect skills directly applicable to the job market. Figure 1 shows the methodological approach to developing the unit learning outcomes, its assessments, and evaluating the success and its implication towards engineering education. Needs analysis is a universal method of finding out what is required. The literature was comprehensively reviewed to identify the need for employability skills in engineering education, including critical employability skills. This step helps identify the workforce's learning needs and competencies to accomplish the industry tasks. This information is then collated into a set of skills needed for employment in sustainable engineering.

Upon compiling the skills summary and aligning those skills with respective assessment types, industry professionals were asked for comments and suggestions. Once finalised, these skills are incorporated into the broad unit learning objectives and assessments. The designed unit comprises weekly lectures (both face-to-face and video), tutorials to discuss real-life mathematical calculations and laboratory demonstration, and project-oriented activities to cover the main concepts of the unit.

The assessment tasks were designed and developed to reflect skills that are directly applicable to the job market. This ensures that the students learn the appropriate skills by applying those skills to real-life problems. For example, in one of the assessments, students are divided into groups to collect data and conduct an energy audit in a commercial building. Students would then analyse the data, write a report and deliver a group presentation in front of their peers and assessors. Their peers also assess their work and presentation and learn how to evaluate such activities in the profession. Working in groups gives the students a flavor of an actual job situation. Marking rubrics also developed to evaluate employability skills in consultation with industry professionals.

Feedbacks were collected from students, tutors, and industry to evaluate the unit and check whether there is constructive coherence between teaching, learning, and assessment, which is crucial for the quality of teaching and learning (Biggs, 2011; Wijngaards-De Meij & Merx, 2018). As learning is a constructive process (Bruning, Schraw, & Norby, 2011; Arif and Shafiullah, 2022), students need to integrate and apply the theories and methodologies from multiple areas different from their expertise. The assessment tasks were amended based on the student's initial feedback.

Finally, this study shares the findings to demonstrate the effectiveness of the approaches applied through a qualitative and quantitative student survey conducted by the University student evaluation program (Murdoch, 2017).

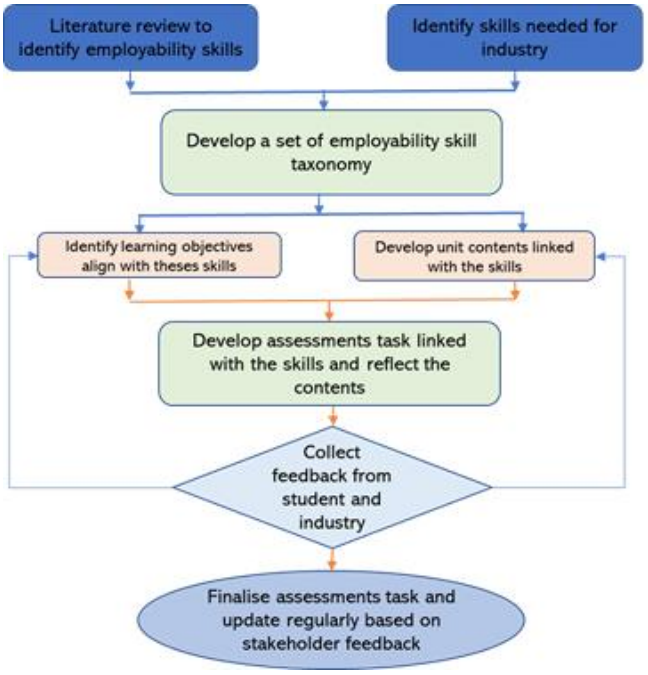

Figure 1: Step by step methodological approach

Framework of incorporating employability skills into course/unit

According to the Quality Assurance Agency for Higher Education (2015), engineering graduates should:

- be pragmatic, taking a systematic approach and the logical and practical steps necessary for, often complex, concepts to become a reality;
- seek to achieve sustainable solutions to problems and have strategies for being creative, innovative, and overcoming difficulties by employing their skills, knowledge, and understanding in a flexible manner;
- be skilled at solving problems by applying their numerical, computational, analytical and technical skills, using appropriate tools;
- be risk, cost and value-conscious, and aware of their ethical, social, cultural, environmental, health and safety, and broader professional responsibilities;
- be able to formulate and operate within appropriate codes of conduct when faced with an ethical issue;
- be professional in their outlook, be capable of a team working, be effective communicators, and be able to exercise responsibility and sound management approaches.

Engineering graduates must acquire information, communication, critical and reflective skills with the essential time and work management skills to achieve this and to be successful in their projects, appropriate codes of conduct, health and safety, and ethics.

As an employability skill, the key areas identified by most of the research/studies are: Quality-information/knowledge; Communication- communicate effectively/working in a team; Critical and reflection- awareness of professional responsibilities, conceptualisation and evaluation (Valero et al., 2020). Jackson and Chapman (2020) adapted a framework integrating non-technical competencies, broadly representing typical industry skill requirements in new graduates. The key areas identified in the framework are (Jackson & Chapman, 2012): Working effectively with others; Communicate effectively; Self-awareness; Thinking critically; Analyse data & use technology; Problem solving; Developing initiative & enterprise; Self-management; Social responsibility & accountability and Developing professionalism.

Research was undertaken to derive a catalogue of knowledge and skills from the industry on sustainable energy management. A study done by Lund C. et al (2017) developed a curriculum framework for sustainable energy integrating the generic and discipline capabilities (knowledge and skills) required by graduates which were determined from graduates who are working in the sustainable energy industry. Five key areas focus on the frameworks are inter/multi-disciplinary training versus specialist courses; specialist courses and programs versus embedding skills and knowledge; face-to- face versus online and flexible delivery; need for WIL based education; and internationalization of the curriculum.

This study designs the unit while embedding employability skills by using the lessons learned from the existing standards/frameworks and consultation with industry/stakeholders. Figure 2 shows the proposed framework applied in which, in addition to hard- and soft-core technical skills, general attributes, like communication, presentation, brainstorming, IT, self-management and social accountability skills were incorporated. The blue colors represent general attributes which is used across all activities.

Using this framework, the assessments for this unit were carefully designed considering the list of skills, knowledge and generic graduate attributes required by graduates seeking to work as sustainable energy management professionals.

Description of the unit energy supply and management

An outline/overview

Energy Supply and Management is a third-year unit in the Bachelor of Renewable Energy Engineering (Hons) Degree at Murdoch University, Australia. This unit discusses many different types of energy systems in terms of their operation and the criteria utilised in their design. The unit also teaches about energy management, particularly how to minimise energy use without reducing services and how to use energy more efficiently.
The unit consists of a number of topics that deal with different energy systems and technologies, including effective management of energy systems. This unit also deals with the tools required to set up an energy management program, such as measurement of electricity and natural gas consumption, tariff analysis and energy auditing, integration of renewable energy sources and the methods used to size and/or design them.
The competencies that students will be achieved after completing this unit are:

ULO 1: Explore and demonstrate Energy Management Systems, by investigating tools and techniques, frameworks and standards.
ULO 2: Analyse the technical and economic viability of energy management options and apply problem-solving and research skills in energy audit.
ULO 3: Apply technical knowledge and approaches in designing various technologies used in electricity and heat generation
ULO 4: Communicate effectively as part of an engineering team and contribute in designing project.

Pedagogical approach for the unit

The goal of this unit is for students to understand and learn the drivers for energy efficiency, use energy more efficiently, and finally look to the future to identify zero-carbon energy resources. The PBL approach is used where the student chooses the project on their own house and applies the knowledge, they have gained in the unit to solve the problem. Knowledge of complex energy management issues, audit processes, economic viability, and understanding of using low or zero-carbon energy resources make the students unparalleled experts on becoming energy efficient and ensuring a reliable and sustainable environment.

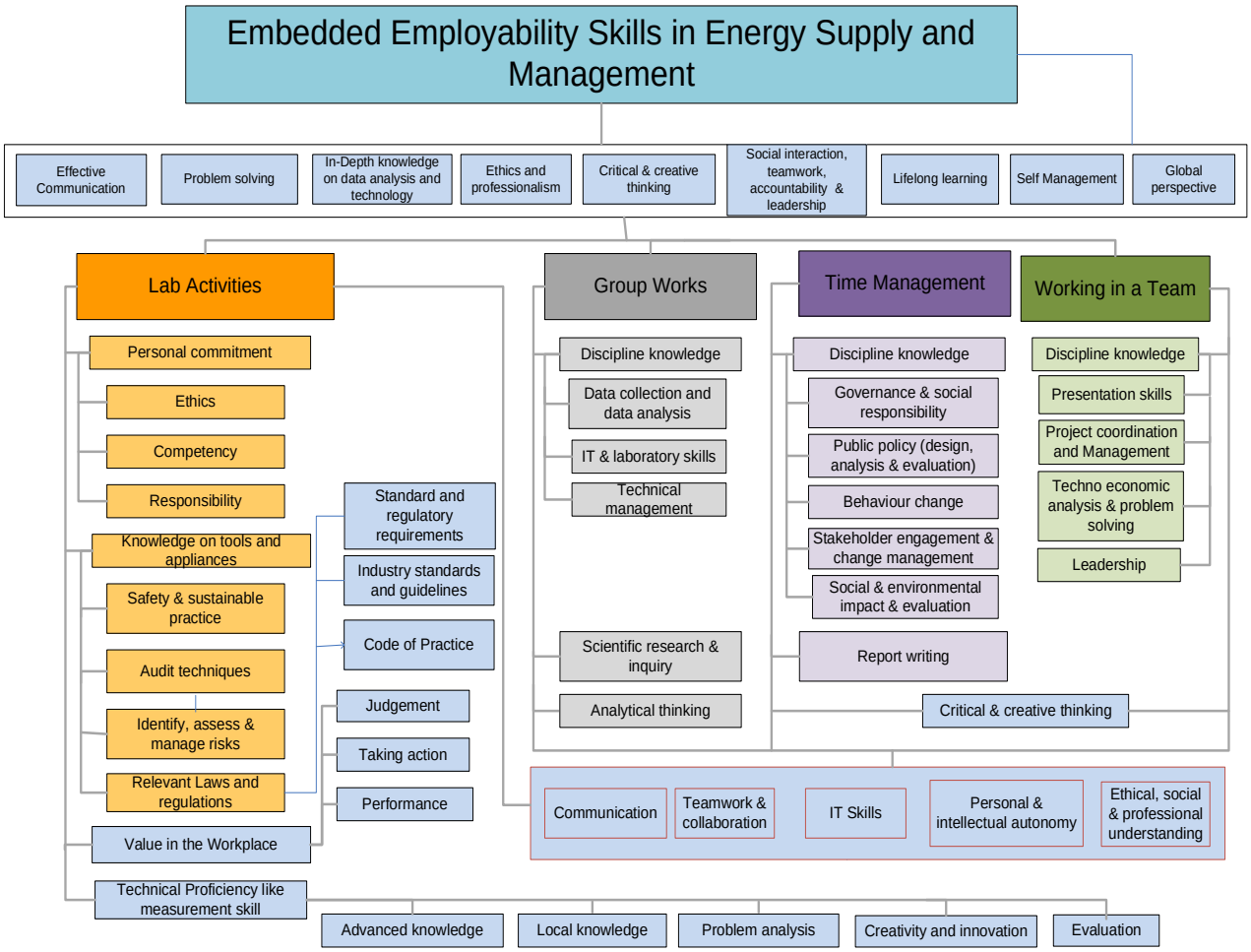

Figure 2: Framework embedding employability skills and knowledge in Energy Supply and Management unit

Teaching and learning approach

The unit is delivered through 12 weeks of lectures and tutorials. The lectures are theory-based covering the main theoretical concept of the subject materials and delivered in a two-hours block, while tutorials cover mathematical and conceptual problems in a one-hour block. The mode of delivery is either online or face-to-face. There are four laboratory sessions to provide detailed technical background in energy systems, energy metering, photovoltaic and wind energy technologies. Site visits are used to demonstrate the real/live operation of energy management systems and microgrid test setup. The major project topics are chosen based on the learning outcome of the unit embedding employability skills considering a PBL approach. The teaching tools/handouts made available to the students during the teaching periods are shown in Figure 3. The workshops/tutorials and laboratories are run to equip students to develop their critical thinking and analytical skills.

Through the process of learning in this unit, the students will develop their communication skills, e.g., listening, reading, writing, creative and critical thinking skills, independent learning,

teamwork and time management skills, and theoretical and practical learning of the subject materials. Students also learn how to apply this knowledge in interdisciplinary challenges in addition to theoretical/academic understanding of the subject.

Figure 3: Teaching Handouts/Tools

Assessment to judge the competencies of the students

This unit is assessed by quizzes and mini tests, laboratory assessment and site visit report, project report and presentation, and a final examination. Quizzes and mini tests are used to test the student's knowledge of each topic. Through laboratory activities and site visits, students attain hands-on and real-life experience on the subject matter. The project, which is the major assessment, is a group work to test their ability to conduct an energy audit, learn teamwork, and assess the possible solutions to the energy reductions. Students are asked to undertake a detailed energy audit of one of the buildings (or their own house) and make recommendations on reducing its energy consumption, energy cost, and greenhouse gas emissions.

Marking rubrics

A marking rubric has been constructed to evaluate the employability skills suggested by industry professionals. Throughout the period, marking rubrics were also revised/updated based on feedback from industry professionals, academics, and students. The rubrics guide the students to complete their assessments efficiently and help tutors provide distinctive and quick feedback according to the level of achievement of the learning outcomes to their students.

Effectiveness of the approach

The effectiveness of the applied approaches has been investigated through a qualitative and quantitative survey conducted by the University student evaluation program (Murdoch, 2017). The survey was open to students from Week 10 of Semester 1 until the second week of the exam period. Students were asked to respond to the below six questions to identify the quality and effectiveness of the teaching and learning approaches of the unit.

Q1: It was clear what I was expected to learn in this unit

Q2: The assessment tasks were appropriate to the learning objectives

Q3: The assessment tasks tested my understanding of the subject area, rather than just memory

Q4: Activities in this unit helped me achieve the learning objectives

Q5: The unit resources were useful for my learning in this unit

Q6: Overall, I was satisfied with the quality of this unit

There are seven scales or ranks for each question as shown in Figure 4. Students select any one option from the available seven scales for each of the questions mentioned above.

Figure 4: Ranks of each question response

Figure 5 and Figure 6 show student's feedback on the above questions from 2017-2019. Due to the pandemic situation, a different survey was conducted in 2020-2021 which is not included in this analysis. More than 95% of students agreed with the statement in the above six questions and the quality of the unit except for Q5 in which the percentage of agreement is 93% (Figure 5). Figure 6 shows that the mean value for all the questions is 5 or above at a maximum scale of 6. It

is clear from the feedback that the teaching and learning approaches, including assessment methods, were highly appreciated by the students, as they believe the applied strategies helped them understand the learning of the contents and prepare for future jobs. Survey rating was high in 2019 both in the percentage of agreement and mean of the likeness, compared to 2017 and 2018, as the unit was updated significantly by integrating feedback from students and industry professionals.

In response to the question, “What is the best aspect of the unit?”, students highly appreciated the approach and assessment of the unit. A few of the comments were:
//The LMS materials were excellent. The unit was properly organised. Well done. The energy audit and site visits were interesting and informative. Very well throughout. //Unit Survey 2017. //Practicals and site visits allowed me to put the theory into practice and conceptualise it btter. // Unit Survey 2019
Students were also asked to provide suggestions for improvement. The following suggestions were made in 2017 and 2018 which were incorporated in the 2019 and beyond offerings.

- *So far, this unit is close to be perfect, just need to reduce lecture slides.*
- *It would be great if students were given at least 2 days to audit the building*

Remarks from a past student,
//post completing ENG338 I took away some of the skills that I learnt and applied them at my workplace. The senior management team was very happy with the report I prepared for them after conducting the audit in the workplace. // email, 2019
Overwhelming positive feedback was also received from the employers of our students.
// your students were very professional in their approach. They asked good questions in a respectful and friendly manner and were no trouble at all to have around. Well done to all. // email, 2019.

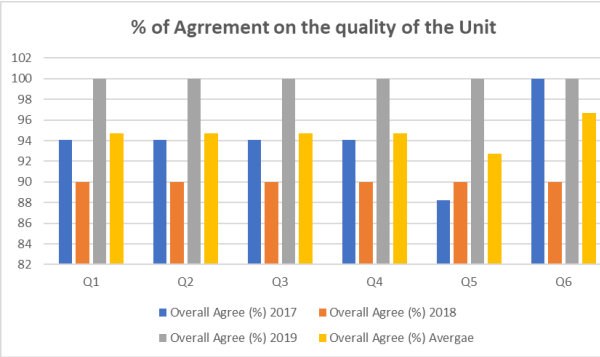

Figure 5: Percentage of agreement

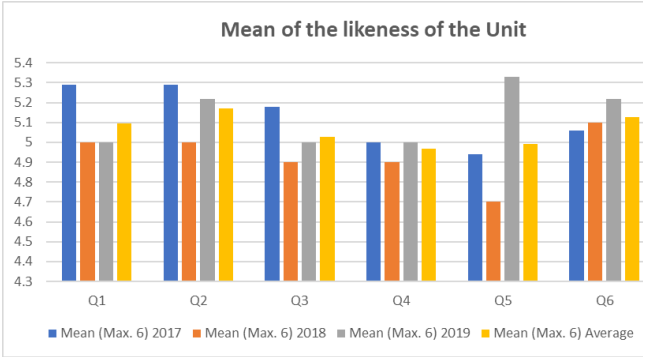

Figure 6: Likeness of the unit (mean)

Conclusions

Based on the global technology acceptance and development trends, skill-based job market demand and Government policy, it is an essential requirement today to develop the engineering curriculum to teach students how to apply their intellectual skills in their future careers efficiently. The project-based learning approach incorporating employability skills is used to ensure that students will be work-ready upon graduation. Accordingly, a unit Energy Supply and Management has been designed and delivered considering innovations in unit design, learning contents, project work, teaching methodologies and learning facilities. This helped to develop independent thinking and analytical capability, encourage collaboration, and develop presentation and leadership skills as some of the key expectations from job-ready graduate engineers. As evident in the Survey Feedback, the students highly appreciated the teaching and learning approaches of the unit. The approach and methodology developed for designing and delivering this should be easily adaptable to other similar, multidisciplinary subject areas, such as Sustainability Engineering; This unit's learning helped students develop hardcore technical knowledge and make them job-ready upon graduation learned employability skills. This unit is expected to

produce quality professional engineers, technologists, and researchers ready to meet current industry and global needs and, therefore, become highly employable.

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