# *Master of Engineering Management: A Reference Curriculum Development*

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**Abstract**
Due to the *multidisciplinary nature* of Engineering Management (EM), understanding core requirements for the curriculum design is critical for the growth of this discipline. However, Australia still lacks agreement among universities on Master of Engineering Management (MEM) program curricula with no professional quality standards. *Aim:* This study aims to provide an insight into MEM curriculum development in Australia through benchmarking with the standards from a global professional society - the American Society of Engineering Management (ASEM). *Methodology:* Firstly, from preliminary research of MEM programs, a database of course structure is developed. Then, word cloud and text analytic techniques are used to provide an insight into the current curricula. Benchmarking is made by comparing these current practices with ASEM curriculum requirements and EM domains. Finally, an in-depth case analysis serves as a self-assessment example.*Findings:* The results show the maturity in Australian MEM program quality. Curricula meet the rigorous standards of ASEM and align with the EMBoK guide. However, this benchmarking exercise also helps to diagnose the problems, such as EM domain balance, integrating emerging trends into curricula, and the scatter in the course structure. The case study provides an in-depth analysis of using this reference of curriculum development to seek for excellence in program quality.*Originality:* This study is the first one to suggest a benchmarking method for MEM programs in Australia with global professional standards. It raises the question of a professional body for this discipline, and also provides a seed study for similar benchmarking exercises for other programs.

Keywords: Engineering Management, Australia, Master Program, Curriculum, ASEM, Benchmark, Certification

## 1. Introduction

The EM concept is affirmed to have a long history back with around a thousand years ago (Dow, 2010). This term is well-known as the transition of an engineer from a technical to management responsibility (Palmer, 2003). This promotion happens some time in a typical engineering career path regardless of whether and when (Palmer, 2003; Srour, Abdul-Malak, Itani, Bakshan, & Sidani, 2013); and is usually after the first 5 years in the technical field (Lannes, 2001). EM degree, on the other hand, is quite relatively new with the history of the US courses in business and management aspects of engineering from the 1910s (Kotnour & Farr, 2005). Until the mid-1940s, EM officially became a formal degree (Lannes, 2001).

Since EM is expected to be used more extensively as an engineer's career progress when the transition to the management phases happens (Edgar, 2002; D. J. Pons, 2015), more and more engineers are seeking postgraduate studies in management (Palmer, 2003). Practitioners also agree that a postgraduate degree in EM is one of the factors on engineering career progression (Srour et al., 2013). In addition, many organizations start to require certificates for engineering managers (Remer & Ross, 2014). Realizing this need, there has been a rapid growth of graduate EM related-programs (Kauffmann, Farr, Schott, & Wyrick, 2015b) and also EM certifications (Remer & Ross, 2014).

While academic discipline EM is well-established and recognized by Accreditation Board for Engineering and Technology (ABET) (Sarchet & Baker, 1995), MEM programs are somewhat inconsistent and the content is lacking the agreement among educational institutions (J. D. Westbrook, 2005). Instead, these programs are relatively an ambiguous discipline and selected courses are specifically developed to meet the demand (Bozkurt, 2014; Sarchet & Baker, 1995). While ABET is the lead society for accreditation of EM undergraduate programs, ASEM is responsible for the recognition of quality programs at graduate levels (Peterson, 2005).

Specifically, in Australia, EM is found as far back as 1968 with the definition of the coupling of management with technical work (Lloyd, 1968). And the demand is increasing the with the prediction of 12.8% growth over the next five years for engineering managers (Diemar, 2021). Regarding education, the research has shown that the dominant choice for continuing professional development in engineering is pursuing management postgraduate study in Australia (Kean, 1997). And the modern workplace is also contributing to the choice of professional master's programs of engineering graduates (Goh, Jokic, & Hartle, 2010).

Management practices are now the focus of continuing professional education to fill the gap of management competency for engineers and engineering managers in Australia (King, 2008). However, at the graduate level, the standard for curriculum quality is somewhat in its infant (Goh et al., 2010), despite the fact that scholars have stated that understanding the curriculum design with core requirements is critical for the growth of this discipline (Bozkurt, 2014; Kotnour & Farr, 2005). Engineers Australia (EA), the engineering profession body and the *accreditation* authority for tertiary institutions in Australia, does not accredit "stand-alone" master programs (King, 2008). And no professional body or association is guiding or managing the quality of MEM programs in Australia.

Realizing this shortcoming, this study aims at exploring the current practices of MEM program curricula in Australia through using benchmarking. To conduct the analysis, text analytics is used to describe the current practices and the performance of curricular will be

measured based on ASEM curriculum requirements. Considering ASEM standards as guidance for achieving excellence in quality, an in-depth exploration of a specific MEM curriculum is illustrated as a self-assessment which will provide the institution with an improvement strategy to seek for a higher maturity as well as recognition worldwide. ASEM certified MEM programs will add value in advertising in the company of programs for Australian institutions.

This paper is then organized into 5 sections. The next section provides the background of ASEM certified programs as well as the current practices of MEM programs in Australia. It is then followed by data collection and findings. The fourth section discusses these results and gives recommendations to improve the situation. The paper continues with an in-depth case study and ends with conclusions.

## 2. Background

### 2.1. ASEM Certified Programs

EM discipline is mentioned to be a big tent (Kauffmann, Farr, Schott, & Wyrick, 2015a) and there are significant differences found among EM programs (J. Westbrook, 2006). Regarding MEM programs, there is still a lack of agreement among universities on program content (J. D. Westbrook, 2005). As such, there is the need for sharing the common ground for this degree (Kauffmann et al., 2015a).

MEM programs have received high demand and interest from employers and engineering professionals from all disciplines (Daughton, 2017; Kauffmann et al., 2015b; Sarchet & Baker, 1995; J. D. Westbrook, 2005). While ABET accreditation is well-known for undergraduate programs (Peterson, 2005), master programs tend to seek recognition from ASEM (Daughton, 2017; Peterson, 2005). ASEM provides a standard framework to define the characteristics of a successful EM master program, which meets a reasonable set of minimums (Peterson, 2005; J. Westbrook, 2006). According to the EM Master's Program Certification Academic Standards by ASEM, these criteria include requirements of Faculty, Curriculum, Students-Admission, and Administrative Support (Headquarters, 2021). To accomplish the goal of building the commonality for MEM programs, ASEM has published the EMBoK guide which serves as a foundational reference for the discipline and curriculum development (Dow, 2010; Radhakrishnan & Pettit, 2019). There are 10 EM domains that are built from a global perspective (Shah, 2019). They are illustrated in Figure 1.

The scope of this study is focusing on curriculum perspective with structure and management, which include 10 criteria as follows:

- #1. A balance between qualitative and quantitative courses. Curriculum should reflect the domains of the EMBOK.
- #2. At least one third of the curriculum will be management-related including management of people, projects, and strategy courses.
- #3. A third of the courses in the Engineering Management Program have a coordinator from the EM program who has oversight for the course content.
- #4. Course material must be directly related to technology driven organizations.
- #5. The curriculum must require each student to demonstrate a command of written and oral communication skills in English or in the language of instruction in countries where English is not the language of instruction.
- #6. Courses must relate to knowledge workers in a global environment.

- #7. Each student is required to perform a capstone project or thesis using analysis and integration of Engineering Management concepts. For programs that do not have a capstone project or a thesis option, project work from individual courses in the program should demonstrate application of theory in real world settings.
- #8. A minimum of one course in statistics or Quality Engineering or a related area.
- #9. A minimum of one course in engineering economy or Financial Management or a related area.
- #10. Two courses in quantitative analysis are required.

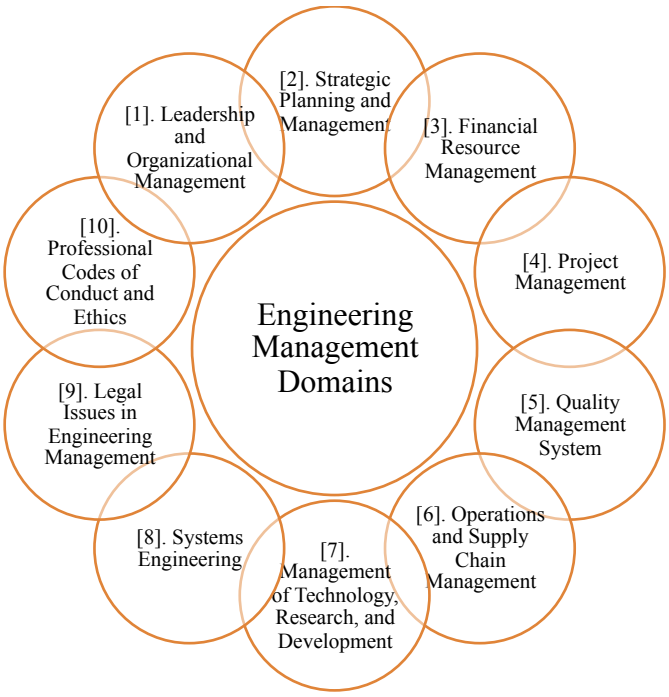


Figure 1: EM body of Knowledge (Shah, 2019)

## 2.2. Australian MEM Programs

Australia is mentioned to be the second country distributing engineering and technology management programs after the US in the early days (Kocaoglu, 1994). Nationwide, from the 1980s, the role of management has been confirmed to play a vital role in practice for professional engineers (Young, 1986) and to be a requirement for all engineering activities (Young, 1987).

Australia is home to 43 universities. Preliminary research of universities offering graduate-level EM programs is conducted through multiple sources. The results show 16 institutions with 17 MEM programs. This data is collected through the main source CRICOS (**Commonwealth Register of Institutions and Courses for Overseas Students) and** additional online research. Table 1 illustrates MEM programs in Australia.

Table 1: EM Master Programs in Australia

| | **Program name** | **Institution** | **Duration** | **Note** |
|---|---|---|---|---|
| 1 | Master of Engineering (Management) | Royal Melbourne Institute of Technology | 2-year | |
| 2 | Master of Engineering (Engineering | University of South Australia | 2-year | |

| | | | | |
|---|---|---|---|---|
| | Management) | | | |
| 3 | Master of Engineering Management | La Trobe University | 2-year | |
| 4 | | The University of Melbourne | 1-year | |
| 5 | | Curtin University | 1-year | |
| 6 | | Torrens University Australia Limited | 2-year | |
| 7 | | Flinders University | 2-year | |
| 8 | | Macquarie University | 2-year | New program from 2020 |
| 9 | Master of Engineering Management | University of Wollongong | 1-year | |
| 10 | Master of Engineering (Management) | | 2-year | |
| 11 | Master of Management f or Engineers | Central Queensland University | 2-year | |
| 12 | Master of Engineering Management | University of Technology Sydney | 1-year | Double degree with MBA, MEng |
| 13 | | Southern Cross University | 1-year | Double degree with MBA |
| 14 | | Queensland University of Technology | 1-year | Double degree with MEng |
| 15 | Master of Engineering Science (Management) | The University of Queensland | 2-year | Combining selected engineering field with business |
| 16 | Master of Engineering (Professional) | Deakin University | 2-year | EM specialization |
| 17 | Master of Engineering Management | The University of Newcastle | 1-year | Teach-out |

It can be easily seen that MEM education is scattered in many different programs. The dominant is the "stand-alone" MEM program, followed by Master of Engineering with EM specialization. Institutions also provide a "dual-program" between MEM with Master of Engineering or MBA. And there has been no standard for curriculum development and quality management of these programs.

## 3. Data Collection and Results

Data collection process is involved 2 steps.

*Step 1:* Firstly, from the list of 16 MEM programs, course names and descriptions are collected through the university website and handbook as data for each program. This step is to form the curriculum database with two groups: core/foundation, and elective unit.

For the core unit group, there are 158 units, including Research methods and Thesis/Internship/WIL/Project Capstone. And 206 units are found as electives.

*Step 2:* Based on the database of step 1, the main analysis conducted for the curriculum structure is developing a conceptual map based on text analytics and benchmarking with ASEM standards for curriculum requirements.

- For the core unit group, for each curriculum, course names and course descriptions are mapped with 10 EM domains. The next figures and tables show the results.

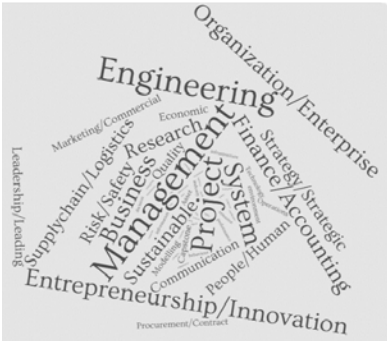


Figure 2: Word Cloud of Core Unit Group

Table 2: Core Units of MEM Syllabi Mapping with ASEM Embok Domains

| **Domains** | **Percentage of programs** |
|---|---|
| [1]. Leadership & Organizational Management | 81.25% |
| [4]. Project Management | 81.25% |
| [2]. Strategic Planning and Management | 31.25% |
| Sustainable theme (exclusive) | 50.00% |
| [7]. Management of Technology, Research, and Development | 75.00% |
| [6]. Operations & Supply Chain Management | 62.50% |
| [3]. Financial Resource Management | 62.50% |
| [5]. Quality Management System | 25.00% |
| Risk theme (exclusive) | 37.50% |
| [8]. Systems Engineering | 43.75% |
| [9]. Legal Issues in Engineering Management | 6.25% |
| [10]. Professional Codes of Conduct and Ethics | 0.00% |

- Electives, on the other hand, are scattered in many different programs. The curriculum design in elective units is diverse enough to support different demands in society. These programs may provide elective units from either "only-engineering theme" (such as La Trobe University and University of Technology Sydney), "only-management theme" (such as Macquarie University), or from both themes (such as RMIT). Table 3 illustrates the percentage of elective course themes. Furthermore, to have an insight on this, a text analysis (software Gephi) is used to illustrate a concept map of themes for these units.

Table 3: Elective Course Theme

| **Theme** | **Percentage** |
|---|---|
| Only- engineering/ technology units | 12.5% |
| Only - management/business units | 43.75% |
| Combined | 43.75% |

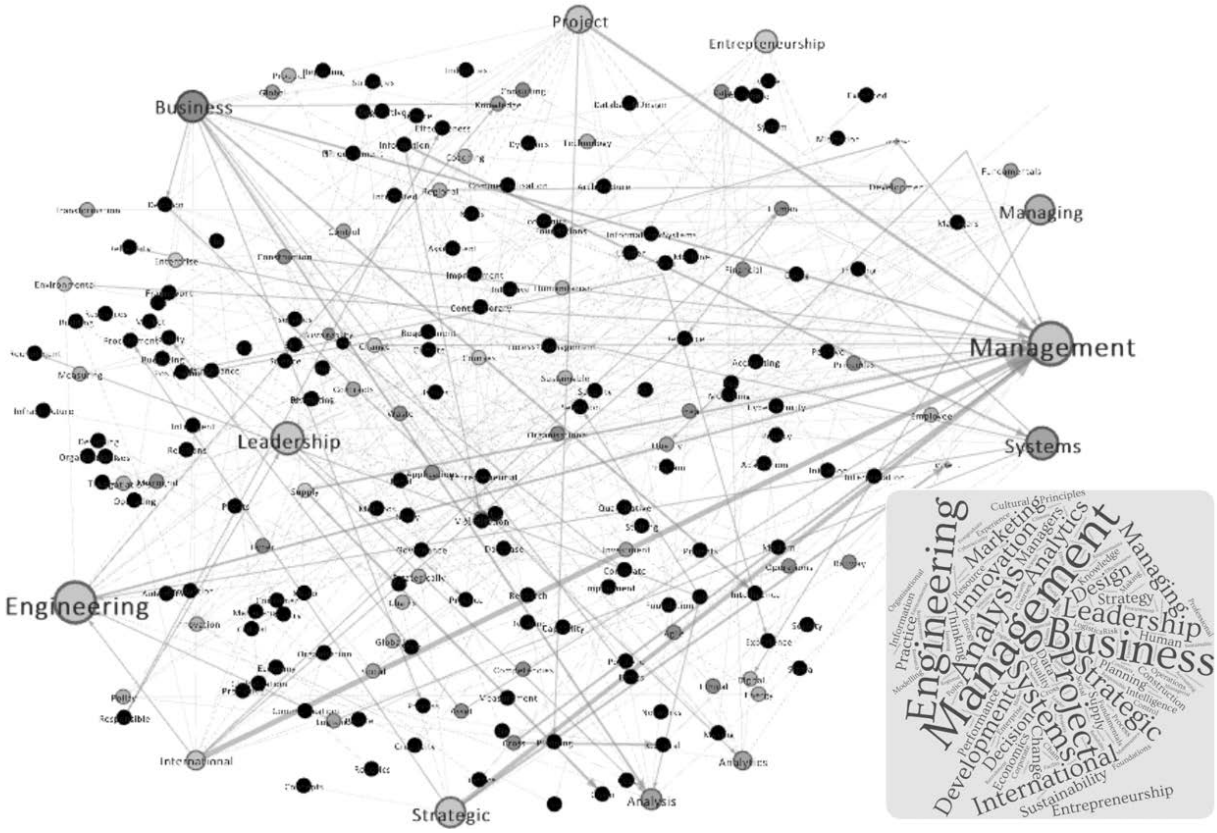


Figure 3: Word Cloud and Text Analytics of Elective Unit Group

## 4. Discussion and Recommendation

ASEM has developed broadly-based quality standards, which can be used as a benchmark to evaluate an existing Master's program. This program certification will distinguish certified programs as being in the top tier, worldwide. While there is a continuing interest of universities in offering EM master programs in Australia, a certification of EM graduate programs will add value in advertising in the company of programs.

The following section will discuss how Australian programs meet these criteria of the curriculum.

*Criteria 1 and 10:* For both groups, the word clouds shown in Figures 2 and 3 present the high frequency and the balance of terms "engineering" and "management" in unit names. EM can be the mutual efforts between colleges with the combination of Engineering and Management programs (Kocaoglu, 1994), Table 3 can also be the evidence for the involvement of both Schools in delivering these programs. This result shows the balance in quantitative and qualitative courses, which are mostly from subjects from School of Engineering and Management respectively.

*Criteria 1,2,8 and 9:* Text analytics have demonstrated noticeable words with high frequency, such as "Project", "System", "Entrepreneurship/Innovation", "Finance", or "Organization / Enterprise" at core unit group. It can be easily seen that these themes are aligning with EMBoK domains (criteria 1). Unlike core units, the figure of text analytics and word cloud shows that elective courses deal with variations in direction and topics among educational

institutions. However, noticeable terms such as project, strategy, entrepreneurship, or leadership are within 10 EM domains by ASEM (criteria 1).

A depth- analysis for these themes in core courses at Australian programs is shown in Table 2 (criteria 1,2,8 and 9). Among 10 domains, Leadership & Organizational Management, Project Management, and Strategic Planning and Management receive the greatest attention from educators. 81.25% of the programs provide these courses in their programs. This is consistent with the requirement of a management-related curriculum including management of people, projects, and strategy courses (criteria 2).

On the other hand, in 2016, a survey about the importance of EM competencies was conducted with practitioners in the industry in New Zealand, ethics is with at least 40% support (D. Pons, 2016). In a competitive environment, ethical guidance is incredibly important for the decision of engineering managers (Cook, 2008); as such, law and professional ethics would be within the primary discipline of EM (Shah, 2019). However, it is noticeable that there is less attention for the domain of Legal Issues in Engineering Management and there is no Professional Codes of Conduct and Ethics found in the current design. Scholars mentioned that the curriculum must allocate time to these topics (D. Pons, 2016). To fill this gap, there are two courses of Ethical Issues in Management, or Business Ethics found in the elective group. This shortcoming has raised the awareness for curriculum designers with integrating ethics and laws into the MEM curricula.

*Criteria 4 and 6:* Program content needs to encompass all sub-specialties to meet the contemporary demands of technology-based enterprises (Sarchet & Baker, 1995). A striking point is the "sustainability" theme. Half of the programs contain sustainability-related subjects in their core curricula. While ASEM and ABET suggest sustainability as a part of EM graduate educational program (Radhakrishnan & Pettit, 2019), c*onsistent with the global trend,* Australian MEM programs also acknowledge the role of this aspect in their programs.

Elective courses have been found to offer emerging training to future engineering managers; however, it is still in its infant with scattering courses offered at one or two programs. For example, with the 4$^{th}$ Industrial Revolution, engineering managers are mentioned to be well-trained to ensure a smooth transition into the new role for the changing workplace (Markl & Lackner, 2019). To meet this demand, Australian curricula have expanded the boundaries with courses of this emerging strategy or technology such as Innovation and Industry 4.0. However, only one program is found offering this course at the moment. Furthermore, the big data era also brings challenges to EM. Engineering managers need to leverage intelligent techniques to solve complex problems (Kahraman & Çevik Onar, 2015). As such, Business intelligence or Intelligent Production Systems course have been introduced as electives (3 programs). Courses of Data Modelling and Database Design, Big Data and Decision Analysis, Data Management and Analytics, or Modern Data Science have also been brought to the curriculum (3 programs).

*Criteria 7:* The analysis found that all programs meet this criterion with most of the programs using the course name of project or capstone, only program using thesis, and a few under different names such as Professional Practice.

Considering EMBoK and standards of ASEM as guidance for curriculum development and validation, the benchmarking process has shown that Australian MEM program curricula have been developed meeting worldwide standards, covering competency areas. This will

provide students with knowledge and skills that are applicable to the EM discipline. The programs are designed to focus on 10 domains of EM to prepare engineers for managerial roles. In addition, with the rise in technological innovation, programs have been designed with emerging trends, such as Sustainability, Big Data, or Industry 4.0. However, these rigorous standards of ASEM also help to notice the shortcomings in curriculum development. First of all, promoting domains of ethics and law is in need. In addition, course design is still scattering among different programs. This raises the awareness for educational managers to set a commonality to manage program quality in Australia.

## 5. A Case-study

ASEM certification also especially serves the function of validating new Master's programs. As such, this study is taking a new MEM program at Macquarie University (MQ University) as an example to examine. In this study, the focus is on the curriculum requirements.

This program was established in 2019 with the first enrolment in Feb 2020. It is the mutual effort between School of Engineering and The *Macquarie* Graduate *School of Management* (MGSM) – one of Australia's leading business schools for 50 years, and the global top 100 MGSM MBA. The curriculum is described in Table 4.

Table 4: Course Structure at MEM Program at Macquarie University

| **Foundation zone and Core zone** | | **Elective zone** |
|---|---|---|
| ENGG4104 Engineering Contracts and Procurement | ENGG8000 Professional Practice | ACCG8042 Measuring and Managing Performance |
| ACCG6003 Managing Finance | ENGG8102 Engineering Management Capstone | ACCG8048 Business and Professional Ethics |
| MGMT6008 Managing People | ENGG8104 Engineering Project Implementation | BUSA8037 Big Data and Decision Analysis |
| COMP8780 Enterprise Management | ENGG8106 Engineering Entrepreneurship | MGMT8005 Managing Technology |
| ENGG8103 Engineering Management and Communication | | MGMT8009 Managing Globally |
| ENGG8105 Quality and Reliability | | MGMT8011 Learning to be a Leader |
| ENGG8401 Safety and Risk Engineering | | MGMT8012 Managing Strategically |
| MGMT8028 Managing Supply Chains | | MKTG8031 Design Thinking for Innovation |

*Criteria 1:* This program requires students to complete 16 units in total with 12 core and foundation units, and 4 elective units. Since this program is a mutual effort between two schools, School of Engineering and MGSM, the balance contribution in program courses is illustrated in Table 4 with 8 engineering courses (starting with ENGG) and 8 management courses.

- Quantitative courses: ENGG4104, ACCG6003, ENGG8103, ENGG8105, ENGG8401, MGMT8028, ENGG8104, ACCG8042, ENGG8102, ENGG8000
- Qualitative courses: MGMT6008, COMP8780, ACCG8048, BUSA8037, MGMT8005, MGMT8009, MGMT8012, MKTG8031

Regarding the domains of the EMBOK, the following table illustrates how the curriculum reflects these EM domains.

Table 5: MEM Syllabus and EM Domains

| **EM Domain** | **Core or foundation unit** | **Elective unit** |
|---|---|---|
| [1] | MGMT6008, COMP8780 | MGMT8011 |
| [4] | ENGG8103, ENGG8104, ENGG8102, ENGG8000 | |
| [2] | | MGMT8012, MGMT8009 |
| [7] | ENGG8106, | MGMT8005, MKTG8031 |
| [5] | ENGG4104, MGMT8028, ENGG8401 | ACCG8042 |
| [3] | ACCG6003 | |
| [5] | ENGG8105 | |
| [8] | ENGG8000, ENGG8103 | |
| [9] | | |
| [10] | ACCG8048 | |

*Criteria 2:* Half of the curriculum is from School of Business with management courses ("management" term in unit names), such as:
- Management of people and leadership: MGMT6008, MGMT8011, COMP8780
- Management of strategy: MGMT8009, MGMT8012
- Management of supply chain: MGMT8028
- Management of finance: ACCG6003

And courses from School of Engineering are designed to be management-related.

- Management of projects: ENGG8102, ENGG8104
- Management of technology: ENGG8106
- Management of quality: ENGG8105

*Criteria 3:* Program directors are from both School of Engineering and MGSM, who have oversight for courses and syllabus in general. Core units are designated "Engineering Management" courses, reflecting the domains in the EMBOK Guide. Regarding the course content, 7 courses from School of Engineering have 3 coordinators from the EM program.

*Criteria 4:* Course materials are designed for technology-driven organizations, such as Engineering Project Implementation ENGG8104, Engineering Entrepreneurship ENGG8106 or ENGG4104 Engineering Contracts and Procurement. Courses from School of Business are also related to technology driven organization, for example, BUSA8037 Big Data and Decision Analysis, or MGMT8005 Managing Technology.

Courses are designed with up to date materials, for example, ENGG8105 or ENGG8102 with the 2019 textbook version. Global concepts are effectively taught through applying international standards, such as PMBoK for ENGG8104, or EMBoK for ENGG8102.

*Criteria 5:* The program is taught in English. Students are required to provide evidence of English language proficiency as an entry requirement.

*Criteria 6:* The program is currently established (2019) and this course is designed to enable engineers to take the next step towards management positions. The program brings courses on the current economy and global competition to students, such as Managing globally MGMT8009, Big Data BUSA8037, or Innovation MKTG8031. Course content also contains emerging trends in a global environment, such as topics of covid-19 pandemic (ENGG8102), sustainability (ENGG8000, MGMT8012), or Industry 4.0 (ENGG8106) …

*Criteria 7:* The program has ENGG8102 (Engineering Management Capstone) as a core unit.

*Criteria 8:* One core course in Quality Engineering ENGG8105, and two core courses with statistics-related content ENGG8401 and ENGG8104.

*Criteria 9:* One core course in Finance ACCG6003.

*Criteria 10:* All core courses from School of Engineering are in quantitative analysis. Other courses from School of Business also have quantitative analysis in their content ACCG6003 and MGMT8028.

A short summary of the self-assessment based on ASEM standards of the curriculum has provided evidence of how MEM program at MQ university meets the worldwide criteria. The self-assessment has also provided an insight into how the program perceives the performance and identifies areas for improvements. Since this is the first-time program run, this benchmarking has helped the program directors to raise the awareness at these points:

- Criteria 1: The program has reflected almost EM domains as is mentioned in Table 5, however, less attention is given to Legal Issues in Engineering Management.
- Criteria 3: Due to the nature of engineering, managing engineering is different from general management. As such, this requires the involvement of course coordinators from EM programs to oversight for the course content. From the MGMS side, the program director at MGSM is in charge of course content; however, for specific courses, there is no course coordinator from the MEM program. This may raise the awareness of program directors for future improvement plans.
- Criteria 4 and 6: The requirements of up to date and current curriculum to meet the global demand have also required the program directors to have a strategy in reviewing and updating the program to maintain excellence in program quality.

## 6. Conclusion

The main motivation of this research is to gain an understanding of MEM program curricula in Australia, and how these programs manage the quality to achieve international recognition. This study is the first one suggesting to use global professional standards of ASEM as a benchmark for MEM programs in Australia. This also serves as guidance of self-assessment and to reflect improvements to seek for maturity in the program quality. Given the apparent market demand for EM education, a certified program is suggested for the recognition to stakeholders. This study also provides a seed study for similar benchmarking exercises for other programs. Reviewing the current practices of MEM programs also leads to a question a professional body for this discipline in Australia may open for both academic and practitioner perspectives.

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