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Graduate Attributes in Relation to Curriculum Design and Delivery in a Bachelor of Materials Engineering Programme*

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This paper presents a critical analysis of the Bachelor of Materials Engineering programme compared with the expectations of the Institution of Engineers Australia (IEAust) and of UQ. To set the scene, the graduate attributes are listed, the programme framework is presented and the educational culture and available facilities are described. Then, the programme delivery is described; this includes an analysis of the learning opportunities that allow students to develop the graduate attributes. Finally, an assessment is made of programme outcomes relating to graduate attributes.

INTRODUCTION

THIS PAPER deals with graduate attributes in the Bachelor of Engineering (Materials Engineering), the BE(Mat), programme at The University of Queensland (UQ). The aim was to undertake a critical analysis of the programme compared with the UQ statement of graduate attributes, Table 1 [1], and with the expectations of the Institution of Engineers Australia (IEAust) [2], as given in Table 2.

The BE(Mat) programme is part of the UQ Bachelor of Engineering (BE) programme. The programme aims for excellence. An environment is provided that is intellectually challenging and at the same time allows students to have fun. The BE(Mat) normally requires four years of full-time study. It is administered through the School of Engineering. Admission into first-year engineering and into each engineering undergraduate academic programme is controlled by the School of Engineering. According to the UQ strategic plan, UQ seeks to attract the largest possible portion of the most able students in its home state and seeks to attract international students of high ability. Retention in the programme requires satisfactory progress in accordance with university procedures. The BE programme objectives follow [3]. Graduates are:

- prepared for practice in a world of accelerating change through emphasis in the programme on the fundamentals of mathematics, science, engineering science and design upon which new technologies are founded;
- prepared for leadership in the profession of engineering and the community at large;
- aware of the social implications of engineering work and the responsibility of the graduate to the community;
- trained in effective communication with individuals and groups within and outside the engineering profession;
- capable of independent work to effectively identify, formulate and solve engineering problems and produce effective innovations with creative abilities in these areas being fostered by the encouragement of initiative and originality;
- capable of independent design and research with creative abilities in these areas being fostered by the encouragement of initiative and originality;
- able to read technical and other literature with critical understanding so as to maintain professional proficiency throughout their careers; and
- prepared for postgraduate education and continuing professional development.

BE(Mat) allows the student to acquire technical competence in the area of Materials Engineering and this is reflected in the name of the degree awarded. For the BE (Mat) programme, the 'technical competence' requirement of the IEAust graduate attributes can be expressed in the following terms. The graduate is expected to:

- have developed professional skills sufficient to advise on the analysis, use and development of engineering materials, and
- be outward looking, have an appreciation of the role of engineering materials in industry and have an appreciation for the role of research.

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Table 1. UQ statement of graduate attributes

A University of Queensland graduate will have in-depth knowledge of the field(s) studied. In addition, graduates will display effective communication skills, independence and creativity, critical judgement and ethical and social understanding.
The following statement outlines the key features of the graduate attributes indicated above.

IN-DEPTH KNOWLEDGE OF THE FIELD OF STUDY
A comprehensive and well-founded knowledge of the field of study.
An understanding of how other disciplines relate to the field of study.
An international perspective on the field of study.

EFFECTIVE COMMUNICATION
The ability to collect, analyse and organise information and ideas and to convey those ideas clearly and fluently, in both written and spoken forms.
The ability to interact effectively with others in order to work towards a common outcome.
The ability to select and use the appropriate level, style and means of communication.
The ability to engage effectively and appropriately with information and communication technologies.

INDEPENDENCE AND CREATIVITY
The ability to work and learn independently.
The ability to generate ideas and adapt innovatively to changing environments.
The ability to identify problems, create solutions, innovate and improve current practices.

CRITICAL JUDGEMENT
The ability to define and analyse problems.
The ability to apply critical reasoning to issues through independent thought and informed judgement.
The ability to evaluate opinions, make decisions and to reflect critically on the justifications for decisions.

ETHICAL AND SOCIAL UNDERSTANDING
An understanding of social and civic responsibility.
An appreciation of the philosophical and social contexts of a discipline.
A knowledge and respect of ethics and ethical standards in relation to a major area of study.
A knowledge of other cultures and times and an appreciation of cultural diversity.

The above provides two descriptions of graduate attributes: ie descriptions from (1) UQ [1], and (2) IEAust [2]. A comparison leads to the conclusion that similar attributes are being described, with each description providing a somewhat different emphasis. This paper analyses the BE(Mat) programme against the UQ statement of graduate attributes as presented in Table 1 and the IEAust statement of graduate attributes as presented in Table 2.

PROGRAMME FRAMEWORK, STRUCTURE AND CONTENT

Framework to achieve BE(Mat) programme objectives

The framework for achievement of programme objectives is summarised in Fig. 1. The graduate attributes are embedded within the programme and their attainment is assured by using standard assessment techniques. The Teaching and Learning Committee (TLC) is responsible for programme assessment and improvement. The TLC meets once every semester to review the programme and oversee the implementation of improvements and innovations. It is worth mentioning that 5% of the operating budget is related to teaching and learning quality, thereby providing a significant driving force within UQ for programme excellence.

The programme implementation strategy involves an integration of student admission procedures, programme structure and content, programme delivery and assessment procedures. Admission to UQ's BE programme requires a student to be in the top 10% of the student cohort in the state of Queensland. A suite of courses has been developed to ensure that the students are exposed to a learning environment

Table 2. IEAust graduate attributes sorted into the following groupings: (1) in-depth knowledge of the field of study, (2) ability to gain and apply knowledge, (3) effective communication, (4) an understanding of ethics

IEAust Graduate Attribute	Short Name
Ability to apply knowledge of basic science and engineering fundamentals	Basic science
In-depth technical competence in at least one engineering discipline	Technical Competence
Expectation of the need to undertake lifelong learning, and capacity to do so	Lifelong learning
Ability to undertake problem identification, formulation and solution	Problem-solving
Ability to utilise a systems approach to design and operational performance	Systems
Ability to communicate effectively, not only with engineers, but also with the community at large	Communication
Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a team leader or manager as well as an effective team member	Teams
Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and for the need for sustainable development	Social responsibility
Understanding of the principles of sustainable design and development	Sustainability
Understanding of professional and ethical responsibilities and commitment to them	Ethics

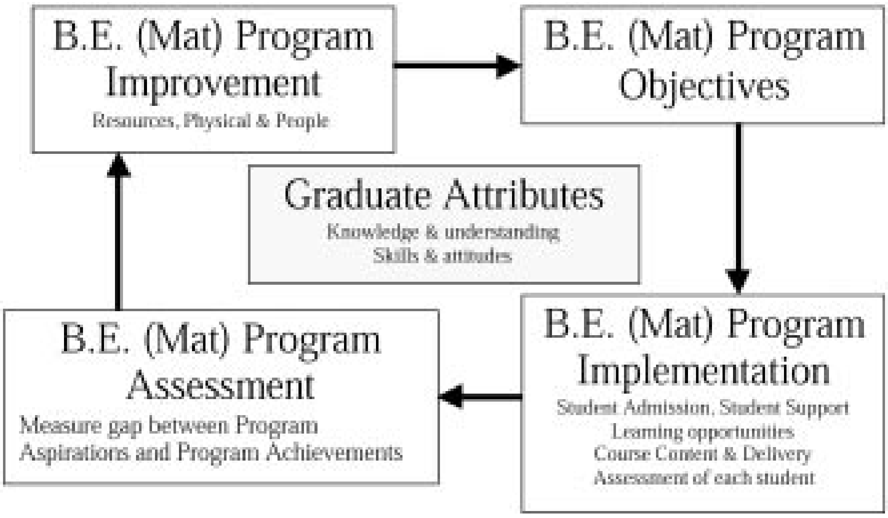

Fig. 1. The framework for achievement of programme objectives lies within a continuous improvement paradigm. The graduate attributes are embedded within the programme and their attainment is assured using standard assessment techniques.

appropriate to each graduate having achieved the required graduate attributes. Each course is designed to ensure that both content and delivery is appropriate. Furthermore, the suite of courses is balanced to provide an appropriate range of delivery methods from traditional 'chalk and talk' to innovative delivery methods that place emphasis on self-discovery learning with the student driving the learning experience. It is recognised that people learn and thereby gain the required graduate attributes in different ways.

Course design can be described in relation to Fig. 2. Each course has been designed with specific course learning objectives informed by the IEAust graduate attributes. To achieve these learning objectives, learning opportunities are designed to allow the student to acquire the necessary abilities, skills and knowledge. Assessment is designed to allow each student to demonstrate having achieved the course objectives.

This approach, integrating admission, programme structure, content, delivery and assessment encourages each student to acquire the required skills, knowledge and attitudes.

Programme overview

The BE(Mat) programme consists of courses as shown in Table 3. The programme evolves as part of the continuous improvement paradigm expressed in Fig. 1. A student is required to obtain #64 comprising all compulsory courses and the balance from electives or other courses approved by the executive dean. For a 'standard' load, each student completes 16 units (normally designated as #16) each year. This typically corresponds to eight standard courses, each worth #2. Table 3 specifies all the compulsory courses.

Electives, minors and flexibility

The materials major has a high degree of flexibility. There are #12 electives available. These electives may be used to gain experience in other engineering areas, other areas of university study, or for carrying out the concentrated sequence of courses leading to a minor, or they may be used to facilitate a double degree programme with other degree programmes (e.g. science, arts, law, commerce, management, etc.) within the university. For a student undertaking a minor, #10 is prescribed, so that there are only #2 electives remaining.

USLP/student exchanges

Quality control indicates that our students generally have a good experience whilst at UQ and that our graduates rate well when compared

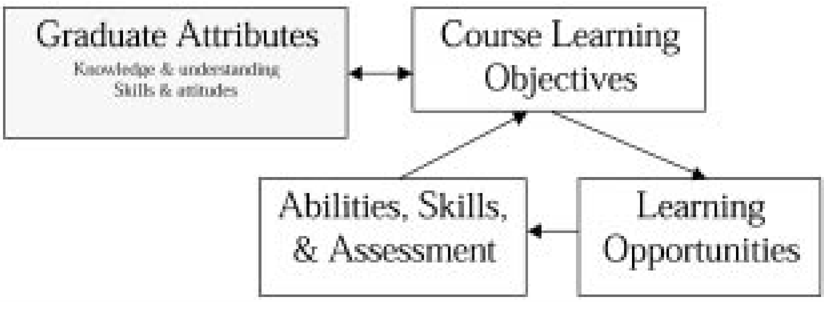

Fig. 2. Course design and delivery is presented in relation to graduate attributes. Assessment in each course is carried out in a manner that enables each student to demonstrate achievement of the graduate attributes relevant to that course.

Table 3. Programme outline for the BE(Mat) for 2004

Year	Courses							
1	ENGG1000 Professional Engineering	ENGG1010 Applied Mechanics	ENGG1020 Physics & Engineering Materials	MATH1050 Mathematical Foundations	ENGG1040 Applied Chemistry for Engineers	COMP1500 Software Engineering	MATH1051 Calculus & Algebra	MATH1052 Calculus & ODEs
2	MATH2000 Calculus & Algebra	MECH2300 Structures & Materials	MMME3303 Materials Characterisation STAT2201 Engineering Statistics	Elective/Minor	MECH2400 Thermofluids	MMME2302 Manufacturing Operations	MMME2303 Materials Science	Elective/Minor
3	Elective/Minor	MECH3300 FE, Fracture, Fatigue	MMME3304 Biomaterials	Elective/Minor	MECH3600 Management	MMME3301 Polymers	MMME3304 Net Shape Manufacturing	Elective/Minor
4	MMME4305 Thesis	MMME4301 Materials Selection	MMME4302 Corrosion	Elective/Minor	MMME4305 Thesis	MMME4303 Advanced Materials	MMME4304 Light Alloys	Elective/Minor

against the graduate attributes that are related to discipline skills, knowledge and abilities. However, it has been suggested that, whilst our graduates are competent in interacting outside the professional areas, there is room for improvement in this area. Furthermore, it is thought that student exchanges and the Undergraduate Site Learning Programme (USLP) are appropriate methods to improve graduate attributes in these extremely important areas related to human interpersonal interactions.

USLP was developed and piloted in 2000 [4, 5]. It provides a student with the opportunity to undertake a semester (or two) at an industry workplace, while simultaneously undertaking a structured academic programme for credit towards his/her degree. The company gains by having an additional person to do daily tasks and to perform valuable project work and the student gains a much better appreciation of the context of engineering practice. An aim of the programme is to develop better graduate attributes in people and business skills. It is also expected to lead to better student motivation and thereby to better study habits and a deeper appreciation of the course content, leading to enhanced professional skills, particularly in the practical application of theoretical knowledge.

Comparison with IEAust guidelines

Table 4 relates the materials engineering curriculum to the typical course content suggestions by IEAust. Note that, in the words of IEAust, these elements are not mutually exclusive. In fact, there is considerable overlap.

EDUCATIONAL CULTURE AND FACILITIES

Materials paradigm and educational culture

The UQ BE(Mat) falls within the normal materials engineering paradigm, with a solid coverage of the interplay between materials structure, materials properties, materials processing and materials

Table 4. Materials engineering curriculum related to the typical suggestions by IEAust

Requirement	IEAust Guidelines	Courses making a major contribution	Courses making a substantial contribution	%
Basic science & mathematics	Not less than 40%	ENGG1000, ENGG1010, ENGG1020, ENGG1040, MATH1050, MATH1050, MATH1051, MATH1052, MATH2000, MECH2300, MMME3303/STAT2201, MECH2400	MMME2302, MMME2303	24#/64# + 0.5 (4#/64#) = 40%
Engineering discipline specialisation	About 20%	MMME2302, MMME2303, MECH2300, MECH3300, MMME3304, MMME4301, MMME4302, MMME4303, MMME4304, MMME4305, MMME4305	ENGG1020	22#/64# = 34%
Engineering design & projects	About 20%	MMME4301, MMME4305, MMME4305	MMME2302, MMME3304, MMME4302, MMME4303, MMME4304	6#/64# + 0.5 (10#/64#) = 17%
Ethics & management	About 10%	ENG1000, MECH3600,	MMME2302, MMME4302, MMME4304, MMME4305	4#/64# + 0.5 (8#/64#) = 13%
More of above or electives	About 10%	16#		16#/64# = 25%

behaviour during service. The emphasis might be characterised as being on mechanical properties. Strengths include casting, metals (particularly light alloys), polymers and corrosion. We are also conscious of the trend towards functional materials and are altering the programme's balance to include new courses in these areas as described below. The educational culture is outward looking, strongly linked to industry and research intensive. This culture has developed to ensure survival of the materials group at UQ. This culture permeates all activities and is reflected in the graduates produced.

Coverage

A strategic decision was made to provide a world-class curriculum in the fundamental aspects of materials with special emphasis on areas of research strength, rather than to provide mediocre learning opportunities across the whole field of materials engineering. We therefore concentrate on the basic principles and how these can be applied across all classes of materials. We provide high-level courses in solidification and the light alloys. Thus we focus our resources in areas of strength and do not offer elective courses in materials. This means that a student undertaking a materials major must complete all the courses listed in Table 3 and must in addition complete #14 from other courses, the electives.

Materials engineering

The materials division has a research-intensive culture, as is to be expected with an interesting and advancing field of endeavour. Materials is the science of everything you see and touch. It is materials – metals, alloys, ceramics, polymers and composites – that give manufactured products their functional and aesthetic properties.

Materials Science & Engineering is concerned with the selection, processing, understanding, development and service performance of materials. Materials engineers apply their skills and knowledge to optimise materials processing and manufacturing with materials and to improve the properties of manufactured products. Understanding and controlling the service behaviour of materials leads to improvements in the performance of machines, products and structures.

Major technological advances in materials manufacture have occurred in recent years. Developments in light-weight metals, composites, high temperature materials, surface treatments and materials with special mechanical, electrical, optical and magnetic properties have opened new horizons for product design. The results are all around us, enriching our everyday lives.

Employment

Sources of employment for Materials Science & Engineering graduates range from heavy industry to electronics to medicine. Materials engineers are employed in the materials processing and manufacturing industries, including the auto, biomaterials, electronics, whitegoods, general manufacturing, steel, aluminium, ceramics and polymer industries, which create wealth and add value to Australia's mineral resources. Materials engineers are employed in large multinational companies and small to medium enterprises, in research establishments, in public utilities and in consulting engineering firms. There are career paths in design, operation, management, research and consulting in Australia and worldwide.

Academic staff

The academic staff in the area are all active researchers with strong links to industry and this informs their undergraduate teaching. In addition, a number have done the Graduate Certificate in Education and there is considerable interest in appropriate educational design (see [6]). The quality of the staff ensures a positive learning experience for students and graduates, with a strong external industry focus and an appreciation of research.

The undergraduate teaching in the materials division is heavily linked to the ongoing research activities in the divisions, where all teaching staff have significant ongoing research. Staff linked to CAST, the powder metallurgy, polymer, wear and corrosion groups, all conduct leading-edge research with significant industrial interaction. Experiences from these projects are often used as examples in the different undergraduate courses, which therefore provides exposure to the cutting-edge status in the different areas (e.g. magnesium). The research groups often offer part-time and vacation work for undergraduate students, both themselves and/or with their affiliated companies. Linkages with the research teams have also led to final theses projects being linked to students' past experiences (e.g. part-time or vacation work).

Joint teaching

The division staff are involved in the joint teaching of courses, which necessarily involves integration of subject areas. Examples include: Physics and Engineering of Materials, Structures and Materials and Finite Element and Fracture Mechanics, and Polymers. These courses are delivered in collaboration with Physics, Mechanical Engineering, Civil Engineering, Chemistry and Chemical Engineering (i.e. utilising expertise from across the faculty divisions, providing a very dynamic learning environment and different approaches to problems).

Such an approach to providing learning opportunities provides graduates with a broad vision, an appreciation of the inter-relationship of knowledge and its effect on industry, an appreciation of the need for integration and a systems approach.

Facilities

The division has fully equipped, state-of-the-art metallurgical laboratory facilities. These include equipment for materials characterisation including optical and electron microscopy (SEM, TEM, AEM, microprobe), surfaces (XPS, AES, SIMS, AFM, STM), mechanical, corrosion, physical and wear properties for metals, ceramics and polymers. Processing equipment includes heat treatment facilities, an experimental foundry, a powder metallurgy laboratory, polymer processing and a mechanical workshop. Collaboration with the Queensland Manufacturing Institute (QMI) allows access to FEM/CAD design software, Rapid Prototyping equipment (Stereolithography/ Quickcast, Selective Laser Sintering, Actua 2100, RTV Silicone Tooling, Injection Moulding) and an Investment Casting Facility. These state-of-the-art facilities provide the students with a rich learning environment at the cutting edge of technology.

Student support

There is extensive student support. Each year has its own academic adviser. Every lecturer has an open door policy (i.e. can be approached by students on an informal basis). In addition, lecturers have a designated contact time when they are available for consultation. An extensive tutoring programme is available, and tutors are available for consultation at any time. (Tutors are postgraduate students in the division and are therefore knowledgeable in the area of materials.) Thesis projects are integrated into the division's overall research activities, thereby providing an extensive number of people with knowledge and skills suitable for advising the students on any practical and theoretical problems. The division financially supports the undergraduate student society and the students' field trip. Eac semester, several social functions are organised for all staff and students by the division. There is a Student Liaison Committee, with one representative from each year, which meets regularly with the head of division to discuss ongoing issues.

Experience in an engineering environment

As part of the BE degree course at the UQ, all students must complete 60 days of practice approved by the executive dean. Students studying materials engineering have conducted this practice in a variety of companies, such as: Comalco, PBR, ETRS, G James, Fischer and Paykel, ANI Bradken, Hardies, CSIRO, CAST CRC.

Final-year students are required to complete a major project. In most years, there are several projects that have followed from vacation employment undertaken by the student in the previous summer vacation. Moreover, there is also a strong link between the research interests of the division, which are strongly industrially based, and many of the final-year projects. For example, the link with the light metals industry and casting is usually reflected in several projects on alloy development and casting methods and defects. Other industry-based research in powder metallurgy, corrosion and polymers is also represented in the projects available for students in the final year.

In many years, materials students, with the support of the division and individual staff, organise an interstate trip to visit materials manufacturing sites. This has proved a powerful broadening experience and a useful context for their classroom work.

Industrial relevance

All of the staff in materials have close links with industry. Several of the staff joined academia after working in industry. In addition, staff members often spent their Special Studies Programmes in an industry setting. A large percentage of the research conducted by the materials staff is directly funded by industry or has a strong industry focus. This research focus is reflected in the course material presented.

Many of the staff members are also involved with consulting work for industry, which again provides examples and context for teaching purposes.

Several courses use invited lecturers from industry. For example, MMME4302–Environmental Performance of Materials has guest lectures from an expert in cathodic protection and another from an industrial galvaniser. The galvaniser company also sponsors a prize for the best assignment on galvanising, which is a part of the course. Several courses utilise plant visits to familiarise students with industry practice (e.g. MMME3301 Polymers and MMME4302 Environmental Performance of Materials). It should also be noted that MMME3304 Net Shape Manufacturing and MMME4304 Light Alloys have a significant input from members of CAST CRC, which brings a strong industry bias to these courses. Several courses also have guest input from CSIRO personnel.

MMME3304 Net Shape Manufacturing has an innovative practical component that takes the students through the design, prototyping and production of a component. This work has largely taken place at QMI, a government, industry and university organisation that supports innovation and new product development in industry.

GRADUATE ATTRIBUTES

The BE(Mat) programme has been developed to provide the student with an integrated suite of learning opportunities so that, on successful completion of the programme, a student is expected to have achieved the graduate attributes as well as the objectives specific to materials engineering. By the fourth year, each student is expected to be fully responsible for his/her own learning. Table 5 provides a map of the BE(Mat) course, based on compulsory courses. The following sections provide a description of how each of

Table 5. Map of UQ graduate attributes for the BE(Mat) programme, based on compulsory courses

A. IN-DEPTH KNOWLEDGE OF THE FIELD OF STUDY

A comprehensive and well-founded knowledge of the field of study.
ENGG1000, ENGG1010, ENGG1020, ENGG1050, MECH2300, MECH3300, MECH3600, MMME2302, MMME2303, MMME3301, MMME3304, MMME4301, MMME4302, MMME4303, MMME4304, MMME4305, MMME4315.

An understanding of how other disciplines relate to the field of study.
ENGG1000, ENGG1010, ENGG1020, ENGG1050, MECH2300, MECH3300, MECH3600, MMME3301, MMME3304, MMME4302, MMME4303, MMME4304,

An international perspective on the field of study.
ENGG1000, ENGG1020, MECH3600, MMME3301, MMME3304, MMME4303, MMME4305, MMME4315.

B. EFFECTIVE COMMUNICATION

The ability to collect, analyse and organise information and ideas and to convey those ideas clearly and fluently, in both written and spoken forms.
ENGG1000: MECH2300: MECH3300: MECH3600: MMME2302: MMME3301: MMME3304: MMME4301: MMME4302: MMME4303: MMME4304: MMME4305: MMME4315.

The ability to interact effectively with others in order to work towards a common outcome.
ENGG1000: ENGG1020: MECH2300: MECH3300: MECH3600: MMME2302: MMME2304: MMME3301: MMME3304: MMME4303: MMME4304: MMME4305: MMME4315.

The ability to select and use the appropriate level, style and means of communication.
ENGG1000: ENGG1010: MECH3300: MECH3600: MMME2302: MMME3301: MMME3304: MMME4302: MMME4303: MMME4304: MMME4305: MMME4315.

The ability to engage effectively and appropriately with information and communication technologies.
ENGG1000: ENGG1020: MECH3600: MMME2304: MMME3301: MMME3304: MMME4303: MMME4304: MMME4305: MMME4315.

C. INDEPENDENCE AND CREATIVITY

The ability to work and learn independently.
ENGG1000: ENGG1010: ENGG1020: ENGG1050: MECH2300: MMME2303: MMME3301: MMME3304: MMME4301: MMME4302: MMME4303: MMME4304: MMME4305: MMME4315.

The ability to generate ideas and adapt innovatively to changing environments.
ENGG1000: MECH3600: MMME3304: MMME4303: MMME4305: MMME4315

The ability to identify problems, create solutions, innovate and improve current practices.
ENGG1000: MECH2300: MECH3600: MMME2302: MMME3301: MMME3304: MMME4302: MMME4303: MMME4305: MMME4315.

D. CRITICAL JUDGEMENT

The ability to define and analyse problems.
ENGG1000: ENGG1010: ENGG1050: MECH2300: MECH3300: MECH3600: MMME2302: MMME2303: MMME3301: MMME3304: MMME4301: MMME4302: MMME4305: MMME4315.

The ability to apply critical reasoning to issues through independent thought and informed judgement.
ENGG1000: ENGG1020: MECH2300: MECH3300: MECH3600: MMME2302: MMME2304: MMME3301: MMME3304: MMME4302: MMME4303: MMME4304: MMME4305: MMME4315.

The ability to evaluate opinions, make decisions and to reflect critically on the justifications for decisions.
ENGG1000: MECH3300: MECH3600: MMME2302: MMME3301: MMME3304: MMME4302: MMME4304: MMME4305: MMME4315.

E. ETHICAL AND SOCIAL UNDERSTANDING

An understanding of social and civic responsibility.
ENGG1000: ENGG1010: ENGG1020: MECH2300: MECH3300: MECH3600: MMME3301: MMME3304: MMME4301: MMME4302: MMME4303: MMME4304: MMME4305: MMME4315.

An appreciation of the philosophical and social contexts of a discipline.
ENGG1000: MECH3600: MMME4303.

A knowledge and respect of ethics and ethical standards in relation to a major area of study.
ENGG1000: MECH3600: MMME4302: MMME4303.

A knowledge of other cultures and times and an appreciation of cultural diversity.
ENGG1000

the years, one through four, allows students to develop the IEAust graduate attributes.

Year 1

The course learning objectives contribute to the IEAust graduate attributes, as indicated in Table 6. Year one can be described as a foundation year that is largely devoted to basic sciences and mathematics. These are the foundations on which technical engineering competence is built.

The first-year course ENGG1000 Professional Engineering is particularly noteworthy as playing a major role in providing significant opportunities for the development of a large number of graduate attributes. This includes a team-based semester-long project that provides students with the

Table 6. Learning opportunities of each course, designed to allow development of graduate attributes during Year 1 in order of decreasing intensity: major, substantial, minor, some

Attribute	Contribution made by each course							
	ENGG1000 Professional Engineering	ENGG1010 Applied Mechanics	ENGG1020 Physics & Engineering Materials	MATH1050 Mathematical Foundations	ENGG1040 Applied Chemistry for Engineers	COMP1500 Software Engineering	MATH1051 Calculus & Algebra	MATH1052 Calculus & ODEs
Basic Science	Some	Major	Major	Major	Major	Major	Major	Major
Technical competence			Substantial					
Lifelong learning	Substantial		Some					
Problem-solving	Minor	Some	Minor	Some	Some	Minor	Minor	Minor
Systems			Minor					
Communication	Major		Some					
Teams	Major		Minor					
Social responsibility	Substantial		Some					
Sustainability	Substantial		Some					
Ethics	Major		Some					

opportunity to research a topic in depth (nurturing lifelong learning skills), to compose a written report and make a formal presentation. The lecture material fosters considerations of ethics, social responsibility and sustainability. It is particularly appropriate that this course is offered by the most senior academic in the school, Professor Simmons, Head of the School of Engineering. Ethics and the moral tone of an organisation are accorded primary importance.

Year 2

The course learning objectives contribute to the IEAust graduate attributes as indicated in Table 7. Year two includes learning opportunities that build on the basic sciences presented in the foundation year, as well as starting to build a substantial technical competence in materials engineering. The courses MATH2000 Calculus and Algebra and MECH2400 Thermofluids are in the basic sciences. MECH2300 Structures and Materials and MMME2303 Materials Science present the basic science of materials engineering and so allow the start of the process whereby the student acquires technical competence. Both courses present the student with the opportunity to practise, and thereby develop, problem-solving skills through tutorial and problem exercises. The two assignments in MECH2300 are particularly worthy of mention. One is materials selection, the other failure analysis. These assignments are designed to integrate the two strands of this course and are presented by the two academics involved in team-teaching the course: Lecturer V from Mechanical Engineering and Rowan Truss from Materials Engineering. The failure analysis assignment involves integrating fracture mechanics, stress analysis, materials properties and risk management. The risk management includes a significant element of social responsibility.

MMME2302 Manufacturing Operations is a typical second-year materials engineering course. MMME2302 builds on the solid foundation of the first year. On completion of this course, a student is expected to be able to critically analyse the various manufacturing methods for producing useful metal products by casting, plastic forming of metals, welding and joining, and machining. This includes, but is not limited to:

Table 7. Learning opportunities of each course, designed to allow development of graduate attributes during Year 2 in order of decreasing intensity: major, substantial, minor, some

Attribute	Courses							
	MATH2000 Calculus & Algebra	MECH2300 Structures & Materials	MMME3303 Materials Characterisation STAT2201 Engineering Stats	Elective/ Minor	MECH2400 Thermofluids	MMME2302 Manufacturing Operations	MMME2303 Materials Science	Elective/ Minor
Basic science	Major	Substantial	Major		Major	Some	Substantial	
Technical competence		Substantial	Substantial			Major	Substantial	
Lifelong learning		Some	Some			Substantial	Substantial	
Problem-solving		Substantial			Some	Substantial	Substantial	
Systems		Substantial					Some	
Communication		Minor				Substantial	Some	
Teams		Some	Some			Substantial	Some	
Social responsibility		Minor					Some	
Sustainability							Some	
Ethics		Some					Some	

Table 8. Learning opportunities of each course, designed to allow development of graduate attributes during Year 3 in order of decreasing intensity: major, substantial, minor, some

Attribute	Courses							
	Elective/ Minor	MECH3300 FE, Fracture, Fatigue	MMME3305 Biomaterials	Elective/ Minor	MECH3600 Management	MMME3301 Polymers	MMME3304 Net Shape Manufacturing	Elective/ Minor
Basic science		Substantial	Substantial			Substantial	Some	
Technical competence		Major	Major			Major	Major	
Lifelong learning		Minor			Minor	Some	Major	
Problem-solving		Substantial	Substantial		Substantial	Some	Major	
Systems		Some			Substantial	Some	Major	
Communication		Some	Some		Some	Some	Major	
Teams		Some				Some	Major	
Social responsibility					Some	Minor		
Sustainability					Some	Minor		
Ethics					Some	Some	Some	

- an economic appreciation of the competing manufacturing unit processes;
- a knowledge of the appropriate concepts and terminology;
- an understanding of the science and metallurgy appropriate to (1) casting, (2) metal flow during forming, (3) welding and joining, (4) machining; and
- familiarity with the equipment commonly used, the types of parts commonly produced, their properties and limitations.

On completion of this course, a student is also expected to be able to plan a production route for the production of simple items. This includes the selection of a series of appropriate manufacturing unit processes, so that a commonly available stock item is transformed into the required finished product, taking into account the economics of production and the properties required of the finished product.

Laboratory sessions for MMME2302 are also worth a mention. These provide the students with a structured framework in which to carry out a laboratory investigation into the principles involved in manufacturing operations. Students work in teams and begin by negotiating a topic with the tutor from a number of outlined topics. They then carry out a library search and literature review and propose a work plan to the tutor. After negotiations with the tutor, the students carry out their work plan of experiments over about four laboratory sessions, then spend another three weeks analysing their data and writing their reports. Students all get an opportunity to make an oral presentation of their findings to the class. This type of discovery approach to the laboratory has been very popular with the students. They value the opportunity to control their own learning. This laboratory experience also provides a firm foundation for the much more demanding self-paced team laboratory learning project offered in the third-year course, MMME3304 Net Shape Manufacturing.

Year 3

The course learning objectives contribute to the IEAust graduate attributes as indicated in Table 8. Year 3 provides opportunities for the student to increase in technical competence. In addition, the management course provides an introduction to management practice and concepts.

The laboratory sessions in MMME3304 Net Shape Manufacturing are particularly innovative and challenge the students to develop their abilities in conceptualisation, problem-solving, teams and systems in self-directed projects of substantial size. Each team of students is challenged to think of an object, to design the object using state-of-the-art 3D computer design facilities, to feed the e-design into a 3D replication process (wax printing or stereo-lithography) and then to use the 3D model to make an actual part using either a silicon mould or investment casting. Different teams make different objects using different processes, so that the whole group learns the intricacies of these processes in a hands-on approach. Systems is a major consideration, as is design for manufacturability, as well as the interaction with QMI staff who are doing commercial jobs. This provides a solid foundation, so that each student has the necessary grounding to be able to produce a thesis (compulsory) that has the standard of a scientific publication. The scene has been set and the challenge extended; each student may perform as he/she sees fit.

The teaching style in MMME3304 is similarly innovative. A substantial part of the course is presented by the students themselves. Each student chooses a topic from the list prepared by the course coordinator. These topics are central to the course content; they are not covered before or after by the lecturer, but are part of the final exam. The student is provided with a framework but must nevertheless research the topic, learn the material, extract the essential features and present these to the class. Student feedback has been enthusiastic concerning this model of self-directed learning, to the point that there was nearly a revolt when it was suggested that the approach might have to be cut.

Table 9. Learning opportunities of each course, designed to allow development of graduate attributes during Year 4 in order of decreasing intensity: major, substantial, minor, some

Attribute	Courses							
	MMME4305 Thesis	MMME4301 Materials Selection	MMME4302 Corrosion	Elective/ Minor	MMME4305 Thesis	MMME4303 Advanced Materials	MMME4304 Light Alloys	Elective/ Minor
Basic science			Major			Substantial	Minor	
Technical competence	Major	Major	Major		Major	Major	Major	
Lifelong learning	Substantial	Substantial	Substantial		Substantial	Minor	Substantial	
Problem-solving	Major	Major	Major		Major	Some	Substantial	
Systems	Substantial	Substantial	Some		Substantial		Substantial	
Communication	Major		Substantial		Major	Substantial	Substantial	
Teams			Minor			Some	Substantial	
Social responsibility			Some				Substantial	
Sustainability		Minor	Some			Some	Substantial	
Ethics	Substantial	Some	Minor		Substantial	Some	Some	

Year 4

The course learning objectives contribute to the IEAust graduate attributes as indicated in Table 9. Year 4 allows students to deepen their technical competence.

The *assignments* in the course MMME4302 Corrosion provide an opportunity to demonstrate independent learning and to simultaneously learn about two important areas of corrosion protection. To satisfy the course assessment requirements, each student needs to demonstrate that he/she can define an interesting and appropriate area for independent study, find relevant information using the UQ Cybrary and the world wide web, turn the information into useful knowledge, and present the knowledge in an interesting and engaging manner. Assignments and problem-solving opportunities in MMME4301 and MMME4304 provide further opportunities for students to develop skills and attitudes related to independent lifelong learning.

The *thesis*, MMME4305, provides an integrative capstone experience during fourth year. This allows the students to formulate a research strategy, carry out the research, and report on the results of the research through a formal thesis and two formal seminars. The students value this learning opportunity and often expend much more effort on it than would be expected in proportion to the total effort required for the year (the thesis is formally one quarter of the effort required in Year 4). The thesis also allows a valuable opportunity to benchmark students' achievements. The published grading system used for MMME4305 states that, for a grade of 7 (High Distinction) for a 'research' thesis, the effort and achievement should be such as to lead to a scientific publication. Examples of publications resulting from such work are given in the references [7–13]. For a grade of 7 (High Distinction) in an applied industry-based thesis, the thesis should provide a substantial immediate benefit to the sponsoring company.

Communication

Communication is a cluster of graduate attributes worthy of further mention. In the past, engineering graduates have been caricatured as rather inarticulate technical persons who had difficulty in self-expression. As a consequence, each student is given a number of opportunities to develop appropriate communications skills. This includes opportunities in report writing in a structured environment, in courses such as ENGG1000, MMME2302, MMME3304, MMME4302, MMME4304 and MMME4305. Furthermore, the expectations of quality of expression increase as each student progresses from Year 1 to Year 4. For example, by fourth year a student is expected to be able to give a short concise explanation of each key learning objective (KLO), a maximum of one to two pages, including relevant diagram(s) as appropriate. These explanations should be appropriate in the following situation: the student is asked to imagine him/herself as a consulting engineer who needs to explain each KLO to his/her customer, who is the managing director of a large company, and a commerce or law graduate. It is stressed to the students that it is important that he/she can explain each of these terms so that it is easily understood in such a situation.

Similarly, there are structured opportunities to give presentations in the courses: ENGG1000, MMME2302, MMME4302, MMME4304 and MMME4305. Again, the expectations of quality of expression increase as each student progresses from Year 1 to Year 4. For example, Table 10 [14] provides the grades (G) and corresponding expected performance for the seminar presentation in the second-year course MMME2302. The students are challenged to perform to the standard of the performance expected for a fourth-year presentation in the two formal presentations associated with each student's thesis. The first seminar relates to the research plan, the second provides the student with the opportunity to relate accomplishments.

Assessment

Each assessment instrument is carefully designed to provide each student with an opportunity to demonstrate mastery of course learning objectives.

Table 10. Grades (G) and corresponding expected performance for the seminar presentation in the second-year course MMME2302; for each successively higher grade, competent performance in the seminar presentation at the prior level is expected, in addition to the stated performance attribute(s) appropriate for performance at that level

G	Mark %	EXPECTED PERFORMANCE	
		Technical Content Understandability and depth of treatment	**Quality of Presentation** Verbal and manner of presentation Aids – visual and other Overall coherence of presentation
3	45–49	Superficial or incoherent treatment Includes inaccurate and irrelevant information	Reads from notes but is scarcely heard Inappropriate, illegible visual aids No eye contact with audience Disorganised and unfocused (i.e. chaotic assembly of disjointed points)
4	50–64	Sound, understandable overview at 2nd year undergraduate level of engineering theory and practice relevant to the course of the talk Some minor aspects may be incorrect	Can be easily heard and understood Appropriate, legible visual aids Clear thread throughout talk including clear aim of talk, clear methods and procedures of the research project, and clear presentation of expected and/or actual project outcomes
5	65–74	The seminar provides evidence of an understanding of the most important features and of an understanding of the main inter-relationships	Appears to speak 'off-the-cuff' Sensitive to audience
6	75–84	Relevant technical detail is used to explain important aspects and relationships Seminar is readily understandable to an intelligent and interested ARTS, LAW or Commerce graduate (i.e. to a non-technical company CEO)	Clear and articulate Audience clearly understands and remembers the main points of the presentation Seminar is a convincing, integrated and coherent presentation
7	85–100	Seminar provides a convincing integration and extension of existing knowledge Seminar demonstrates evidence of critical analysis and an ability to synthesise information	Enthuses the audience with the presented ideas

The student's (assessment/exam) submission is evaluated according to the criteria supplied to each student in each course study guide. This is provided to each student at the start of each course. Each academic course coordinator is responsible for ensuring that the assessment criteria are relevant and appropriate to each course. An example is provided in Table 11 for the course MMME4302. These are typical of the assessment criteria used.

For a number of years, UQ has used criteria-based assessment, and Table 11 is typical of those used within the BE(Mat) programme. Assessment is based on the published criteria and

Table 11. Assessment criteria/standards

Grade	Mark	Performance Criteria	%
0	0	Essentially nothing is written that is both relevant and correct	
1	1–19	Failure to demonstrate relevant knowledge or understanding of the underlying concepts Most of the information provided is inaccurate and irrelevant	
2	20–44	Failure to demonstrate relevant knowledge or understanding of the underlying concepts Much of the information provided is inaccurate and irrelevant	
3	45–49	Response is disorganised and lacks focus There is much inaccurate and irrelevant information Demonstrates some relevant knowledge but only a limited understanding of underlying concepts	
4 Pass	50–64	Demonstrates a sound knowledge of the relevant information and at least a partial understanding of the underlying concepts Some of the information may be inaccurate or irrelevant	35–40
5 Credit	65–74	Demonstrates an understanding of the most important features, a sound understanding of the key concepts and an understanding of the main inter-relationships There are only minor inaccuracies	25–35
6 Distinction	75–84	Demonstrates the ability to provide a convincing, coherent overview using relevant detail to explain important aspects and relationships There are no inaccuracies	10–18
7 High Distinction	85–100	Demonstrates critical analysis, originality and flair, an ability to synthesise information from different aspects of the course and/or integration and extension of knowledge The answer generalises the coherent structure beyond the information provided Demonstrates an inspired understanding, a creative spark, a new and more useful way of looking at the question	3–9

Note. This table relates the grade (G) and standard marks to expected performance. Also provided is the prior percentage (%) distribution.
Honours levels for 2002: Honours I: GPA $>$ 5.800; Honours IIA: 5.200 $>$ GPA $>$ 5.799; Honours IIB: 4.800 $>$ GPA $>$ 5.199.

the assessment is not scaled by some expected distribution. The prior percentage distribution is given in Table 11 as a guide to past expectations. Criteria-based assessment does mean that each student has an equal opportunity to perform at the level worthy of a grade of 7 (High Distinction). There is consequently a tendency to set the criteria so that more students achieve higher grades and grade inflation can result.

Grade inflation has been resisted within the BE(Mat) programme. The expectation is that a competent performance earns a 'Pass', and that exceptional performance is acknowledged by 'Credit', 'Distinction' and 'High Distinction' grades. Exceptional performance is rare, and so are the High Distinction grades. Few people win gold medals or university medals.

ASSESSMENT OF OUTCOMES

Programme standards

Programme standards are assured through a number of benchmarking exercises. The benchmarking of the thesis by means of cutting-edge research practice has been described above.

The wealth of experience of the academic staff has been mentioned to demonstrate that the academic staff have made the effort to develop the skills and experience to be able to form considered judgements concerning the standard of UQ BE(Mat) graduates to an international benchmark. It is the combined opinion that the graduates are world-class and can effectively compete on a world scale.

In-depth knowledge of the field of study

Table 12 provides a summary of the learning opportunities designed to allow development of the four IEAust graduate attribute groupings during the BE(Mat) programme, and Table 5 provides a mapping of the UQ graduate attributes. This demonstrates that there are indeed many opportunities for gaining in-depth knowledge. Furthermore, the assessment procedures in these courses are such that a student cannot graduate without demonstrating an in-depth knowledge of the field of study.

Ability to gain and apply knowledge

Similarly, it has always been a traditional strength of engineering graduates that they have been perceived as practical problem-solvers able to apply engineering to provide solutions. In addition, the programme has a structured sequence of courses that provides students with a framework to acquire experience in independent gaining of knowledge to prepare each student for lifelong learning. Independence, creativity and critical judgement are embedded in the programme.

Effective communications

As has already been mentioned, we recognised about 10 years ago that particular attention was needed in the area which can be described by 'effective communications'. This is one key to long-term success for our graduates. A structured series of tasks (both written and oral) has been woven into the programme to address this area. The students are provided with tasks starting from first year and extending through to fourth year. These increasingly stretch each student's performance and challenge each student to higher achievements. The success of the strategy can be judged by the excellence of the final seminars presented by each student and the quality of the theses, judged by the objective standard of a scientific publication. Not all students achieve this level, but most have that potential.

Table 12. Summary of learning opportunities designed to allow development of the four graduate attribute groupings during the BE(Mat) programme

Graduate Attribute Grouping	Course Contribution			
	Major	Substantial	Minor	Some
In-depth knowledge	ENGG1010, ENGG1020, MATH 1050, ENNG1040 COMP1500, MATH1051, MATH1052, MATH2000, MMME3303, MECH2400, MMME2302, MECH3300, MMME3301, MMME3304, MMME3305, MMME4305, MMME4301, MMME4302, MMME4303, MMME4304	MECH2300, MMME2303		ENGG1000
Gain and apply knowledge (including independence, creativity and critical judgement)	MMME3304, MMME4305, MMME4301, MMME4302	ENGG1000, MMME2301, MMME2302, MMME3302, MECH3600, MMME4304	ENG1020, COMP1500, MATH1051, MATH1052, MMME3303, MECH2400, MMME2303, MMME4303	ENG1050, ENGG1040, MMME3301
Effective Communications	ENGG1000, MMME3304, MMME4305	MMME2302, MMME4302, MMME4303, MMME4304	ENG1020, MMME2301, MMME3303, MMME2303, MMME3302,	MECH3600, MMME3301
Understanding of ethics	ENGG1000	MMME4305, MMME4304	MMME2301, MMME2303, MMME3301, MMME4301, MMME4302	ENG1020, MECH3600, MMME3304, MMME4303

Understanding of ethics

From the very start of the programme students are exposed to concepts of professional ethics in their first year introduction to engineering. Formal presentations on professional conduct are also included in the compulsory management course in the programme.

Aspects of risk management and health and safety are woven into mainstream courses. This has been done intentionally to emphasise that these aspects are integrated into every aspect of engineering practice and cannot be isolated as a separate activity. For example, after a section on failure modes in MECH2300 Structures and Materials, an expert in risk assessment from the Minerals Industry Safety and Health Centre presents several lectures on evaluating the social and ethical consequences of failures and presenting methodologies for decision-making. An integrated assessment activity involving structural analysis, materials issues and risk management is also included.

It should be emphasised that the division strives to uphold a culture of professional conduct in all aspects of preparation and delivery of the programme and in interactions between staff and students. This culture is reinforced with articulated policies on issues such as gender and race discrimination, safety, cheating and plagiarism, completion of assignments on time and the like. Operating in an ethical and professional culture as a student should provide the basis for lifelong professional conduct.

External reviews

Feedback is sought by a number of means including various focus groups, benchmarking, the accreditation visits by IEAust and UQ internal reviews. UQ has a system of major internal reviews, which look critically at each cost centre on a seven-year cycle. At more frequent intervals, each cost centre can carry out additional reviews. Attention is drawn to the most recent review [15], set up by the Head of School of Engineering (HoSE), with the following membership: External Members – Adjunct Professor C (Chair), Adjunct Professor M, Adjunct Professor P; Internal Members – Professor J (HoSE), Professor B (Head of Minerals Processing), Professor L (Head of Chemical Engineering), Associate Professor G (Head of Materials), Associate Professor R (Deputy Head of Mining, Minerals and Materials Engineering), Professor B (Head of Mining). This review found that the BE(Mat) has a sound basic structure, with a solid foundation in physics, chemistry, engineering science and materials science, and sufficient emphasis on UQ's research strengths in solidification and the light alloys. It also services the needs of Mechanical Engineering. In order to capture recent developments in materials and to use these developments to attract students, the two new courses should be incorporated into the degree programme Biomaterials and Nanomaterials.

UQ received the best overall rating of all Queensland universities and one of the best Australian university rankings in the *Good Universities Guide* [16]. The independent consumer guide provides ratings, rankings, comment and information about Australian higher-education institutions. UQ received a three-star rating (out of a maximum possible of five stars) for educational experience graduate rating. This was the same as ANU and UWA, and better than Melbourne and Monash – Clayton (two stars) and Adelaide, Sydney and UNSW (one star). UQ received the maximum five-star rating for nine main categories: prestige, non-government earnings, student demand, research performance (the research quantum), toughness to get in (St Lucia campus), staff qualifications, gender balance, getting a job and positive graduate outcomes. UQ was the only Queensland University to receive the highest rating for getting a job, prestige, student demand, research quantum, staff qualifications and positive graduate outcomes.

CONCLUDING REMARKS

This paper has compared the graduate attributes in the BE(Mat) programme with the expectations of UQ and the IEAust. The graduate attributes are embedded within the programme and their attainment is assured using standard assessment techniques. A suite of courses has been developed to ensure that the students are exposed to a learning environment appropriate to each graduate having achieved the required graduate attributes. The suite of courses is balanced to provide an appropriate range of delivery methods from traditional 'chalk and talk' to innovative delivery methods that place emphasis of self-discovery learning, with the student driving the learning experience. Each course has been designed with specific course learning objectives informed by graduate attributes. To achieve these learning objectives, learning opportunities are designed to allow the student to acquire the necessary abilities, skills and knowledge. Assessment is designed to allow each student to demonstrate having achieved the course objectives. Furthermore, continuous programme improvement is embedded through the TLC.

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