Heat maps: evidence-based addressing of generic graduate attributes

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Structured abstract

Over the last few years, several standard frameworks have been in wide use in the Higher Education area intending to codify graduates' knowledge and skills. Academic institutions are striving to unify all these frameworks and produce work-ready graduates, with not only the necessary technical ability, but also other qualities such as the ability to work in groups and communicate effectively.

The—somewhat artificial—division of an academic program into units of study means that course outcomes are achieved based on the individual unit's learning outcomes. Achieving these generic course outcomes may be difficult though, because although some units may be designed to exercise the desired attributes (e.g. communication, group work), these would have to compete with other technical units for learning space. In addition, this may not be holistic enough, as the attributes are conveyed in abstract rather than in the target professional context. A better approach may be to incorporate the attributes as an integral part of each unit learning, but this raises another question: how is it possible for a particular course to ensure that the attributes have been addressed to the required extent?

This paper discusses how the School of IT and Engineering (SITE) in the Melbourne Institute of Technology (MIT) addresses Graduate Attributes in its academic programs. Rather than as an add-on, addressing the attributes forms an integral part of the learning in each unit of study. The SITE provides specific criteria in order to establish to what extent each attribute is covered in each unit, and constructs Heat Maps showing how attributes are addressed over a whole course of study.

KEYWORDS
Graduate attributes, standard frameworks, graduate competencies, professional competencies.

Introduction

In the IT and Engineering areas, the standard frameworks to codify knowledge and skills can be roughly divided into three variants, each with a different emphasis:

- Academic-oriented: specify what the students should know, or should be able to do, at a particular time in their studies (including at the time of graduation). The Australian Quality Framework (AQF) (AQF, 2013) standard framework is an example of this category.
- Professional-oriented: specify what a graduate should know and be capable of doing in a professional context, such as ICT, Engineering or Business Management. Professional bodies' frameworks such as Engineers Australia (EA) Competency Standards (EA, 2013) and the Australian Computer Society (ACS) SFIA (ACS, 2013) are in this category.
- Graduate attributes: of late, most academic institutions have established their own sets of attributes—values and skills—that their graduates should exhibit, such as effective communication and life-long learner (Griffith, 2013; UNSW, 2013; RMIT, 2003).

To address the graduate attributes in their courses, several issues are now apparent:

1. There is a need to align academic learning with generic graduate attributes.
2. Since academic learning is broken down into units of study, course teams must ascertain to what extent each individual unit addresses the attributes, to be able to establish to what extent the attributes have been covered over a whole course of study.
3. Individual units of study must provide activities conducive for students to achieve the academic learning outcomes, but also to acquire the professional and graduate attributes.
4. Course teams should provide guidelines to link a required level of achievement to a set of activities designed to attain that level.

The rest of this paper is organised as follows. Section 2 explains the SITE model for the level of coverage of MIT graduate attributes in each unit of study. Section 3 describes the SITE approach to addressing MIT graduate attributes in each unit, and Section 4 provides an analysis of assessment tasks to achieve the required level of graduate attributes. Conclusions are provided in Section 5.

The site approach

The use of professional and generic attributes frameworks by academic institutions is a response to the common perception by employers of the difficulties that graduates experience when trying to adapt to a professional environment (Scott and Yates, 2002; Faulkner *et al*, 2013). The attributes that MIT expects its graduates to acquire are summarised here:

- *Communication*: The ability to communicate effectively and appropriately in a range of contexts.
- *Independent and lifelong learning*: A capacity to be a self-directed learner and thinker and to study and work independently.
- *Ethics*: Awareness, sensitivity, and commitment to ethics and ethical standards in personal, social, business and professional contexts.
- *Analytical and Problem Solving*: The ability to collect, analyse and evaluate information and ideas and to solve problems by thinking clearly, critically and creatively.
- *Cultural and Global Awareness*: An acknowledgment of and respect for: equality of opportunity; individual and social responsibility; and a recognition and appreciation of other cultures.
- *Team work Cooperation, Participation and Leadership*: A capacity to relate to, collaborate with, and, where appropriate lead others.

- *Specialist knowledge of a field of study*: Comprehensive specialist knowledge of a field of study and defined professional skills ensuring work readiness.

To show how MIT SITE addresses these issues, we have taken examples of two current Engineering courses: the Bachelor of Engineering Technology (Telecommunications)-BEngTech(Tel), and the Master of Engineering (Telecommunications)-MEng(Tel).

Each time a unit is offered, SITE students are given a Unit Description, in which they are formally informed of the learning objectives, class timetable and assessment requirements and their weightings. The Unit Description includes a key map as shown in Table 3, where the level of coverage is colour-coded, and also given a score, from lower (NAVY BLUE = 0) to higher (RED = 4). (Note: the key words in the key map are in boldface only for emphasis.) These values are given and justified initially by the lecturer, and then reviewed and confirmed by the School's Teaching and Learning Committee (See Table 2).

The SITE approach places assessment at the centre of the learning, making sure that assessment tasks are clearly aligned with the intended outcomes. We argue that properly aligned assessment tends to focus the students on what they have to do, rather than what their teachers do, and encourages a deeper approach to learning (Biggs (2003)). This refers not only to technical knowledge, but also to the generic graduate skills required by MIT.

Table 1: Colour coding legend

Colour coding	Extent covered
4	The attribute is covered by **theory and practice**, and addressed by **assessed activities** in which the students **always** play **an active role**, e.g. workshops, lab submissions, assignments, demonstrations, tests, examinations
3	The attribute is covered by **theory or practice**, and addressed by **assessed activities** in which the students **mostly** play an **active role**, e.g. discussions, reading, intepreting documents, tests, examinations
2	The attribute is discussed in **theory or practice**; it is addressed by **assessed activities** in which the students **may** play an **active role**, e.g. lectures and discussions, reading, interpretation, workshops, presentations
1	The attribute is presented **as a side issue in theory or practice**; it is **not specifically assessed**, but it is **addressed by activities** such as lectures or tutorials
0	The attribute **is not considered**, there is **no theory or practice or activities** associated with this attribute

The classification in Table 1 makes a distinction between the bottom two and the top three rungs, as the latter include assessed learning activities covering the attribute. In this way, it is possible to ascertain to what level and to what extent students are achieving the desired outcomes, (Ramsden, 2003; Marton and Säljö 1976). In addition, Table 1 emphasises whether the students' play an active role in the assessment, giving students "time to interact and discuss the problems that they encounter …" (Tridwell and Waterhouse, 2007pp 58); also (Bonwell and Eison, 1991, Felder, Woods, Stice, and Rugarcia, 2000, Youngblood, Beitz, 2001, Brydges, Nair, Ma, Shanks and Hatala, 2012)

Using the key map in Table 1, Unit Descriptions show a Heat Map presenting how the different teaching and learning activities in each unit—such as lectures, tutorials, quizzes, presentations, assignments, tests and examinations—address each attribute. Table 2 below shows an example (for the Operating Systems unit) of how a Unit Description provides evidence of the extent of coverage of each attribute.

Table 2: Learning outcomes for BN104: Operating Systems unit

MIT Graduate Attributes		**Extent Covered**	**Evidence and Notes (including assessment tasks)**
Ability to Communicate	The ability to communicate effectively and appropriately in a range of contexts to achieve high order speaking, listening, reading, writing, numeracy and information technology communication skills.		Participation and discussion during weekly lectures, and tutes/labs. Writing report for laboratory submissions, individual assignment and group assignments reflect on current operating systems and practice. Students practice ICT and numeracy in laboratories.
Independent and Lifelong Learning	A capacity to be a self-directed learner and thinker and to study and work independently. Resulting in continuous learning, resilience, confidence, learning transferable and time management skills and an ability to learn independently.		Students practice and develop independent and lifelong learning by individually design, develop and criticise operating systems concepts guided by the assessments.
Ethics	Awareness, sensitivity, and commitment to ethics and ethical standards in personal, social, business and professional contexts.		Discussed in lectures, but not covered by learning activities
Analytical and Problem Solving	The ability to collect, analyse and evaluate information and ideas and to solve problems by thinking clearly, critically and creatively to solve problems and issues using established methods of enquiry.		Students will develop their analytical and problem solving in the assessments such as assignments and final exam.
Cultural and Global Awareness	An acknowledgment of and respect for: equality of opportunity; individual and social responsibility; and a recognition and appreciation of other cultures and times recognizing the global context of business.		Not addressed.
Team work	A capacity to relate to, collaborate with, and, where appropriate lead others, and to exchange views and ideas in order to achieve desired outcomes through teamwork, negotiation, conflict resolution, and leadership.		Some of the activities are in groups of two or three, but laboratory submissions, assignments and tests are individual.
Specialist knowledge of a field of study	Comprehensive specialist knowledge of a field of study and defined professional skills ensuring work readiness.		Developed through theory presented in the lectures and practical laboratories exercise throughout the unit. Tested in the mid-semester tests, final exam and explored in problem classes discussions.

This not only declares and justifies the extent of coverage of each attribute by individual units, but it also makes possible to construct a full 'Heat Map' of attribute coverage for a whole course of study. In this way, course teams can assess whether there are shortcomings and, if so, make informed decisions as to how to address them. Further, by allocating the score it is possible to calculate an average coverage for each attribute on the map. Tables 3 and 4 give the heat maps corresponding to BEngTech(Tel) and MEng(Tel) courses.

Table 3: Heat map corresponding to the BEngTech(Tel)

Unit codes	BN101	BE101	BN102	BN103	BE103	BN106	BN108	BE102	BN203	BN206	BN209	BE201	BE202	BN205	BN208	BE203	BN301	BN303	BE301	BE302	BN304	Average
Communication	2	2	2	1	3	3	3	1	4	2	3	2	2	1	3	2	4	4	1	1	4	2.38
Life-long Learner	4	3	4	3	3	4	1	3	1	4	4	3	3	4		3	3	1	4	4	3	2.95
Ethics	1	0	1	1	4	1	0	0	1	1	0	0	1	1	1	1	1	0	0	2	1	0.86
Problem Solving	4	3	4	4	1	3		3	3	2	3	3	3	4	3	3	3	4	4	4	3	3.05
Cultural Awareness	1	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.33
Team work	1	1	1	1	1	3	0	2	2	3	3	1	1	4	3	1	3	3	1	1	3	1.86
Knowledge	4	4	4	4	2	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	3.86

First Year units	Second Year units	Third Year units
BN101 Effective Participation at Work BE101 Engineering Mathematics BN102 Web Systems BN103 Platform Technologies BE103 Engineering Practice BN106 Networking Fundamentals BN108 Programming for Networking BE102 Digital Systems	BN203 Network Security 1 BN209 Software Engineering BN206 System Administration BE201 Digital Communication BE202 Local and Wide Area Network Technologies BN205 Project Management BN208 Networked Applications BE203 Telecommunication Systems	BN301 Project 1 BN303 Wireless Networks and Security BE301 Telecommunication Modeling and simulation BE302 Mobile and Satellite Communication Systems BN304 Project 2

From Table 3, it is apparent what this Heat Map indicates to the course team:

1. The attribute Knowledge (Average 3.86) is extensively covered in all the units. This is to be expected in a foundation program.
2. Lifelong Learner and Problem Solving (Average 3+) seem to be properly covered.
3. Communication (Average 2.38) and Team Work (average 1.86) seem to be adequately covered.
4. Ethics and Cultural Awareness are not covered to any significant extent.

Although it is not absolutely necessary to cover all the attributes to the same extent, the weak coverage of attributes in item 4 above is a matter currently being addressed by the course team. Another conclusion from the Heat Map is that, with the exception of Cultural Awareness, all the other attributes are covered at the RED level in at least one unit, and all except Team Work, in at least two units.

Table 4: Heat Map corresponding to the MEng(Tel)

Unit codes	ME502	ME503	ME504	MN502	MN503	MN601	ME601	ME602	ME603	ME604	Average
Communication	2	2	2	3	1	1	1	1	2	4	1.9
Life-long Learner	3	3	3	2	4	4	4	4	3	3	3.3
Ethics	1	1	1	1	1	1	0	2	1	1	1
Problem Solving	3	3	3	4	4	4	4	4	3	3	3.5
Cultural Awareness	0	0	0	0	1	0	0	0	0	1	0.2
Team work	1	1	1	2	4	4	1	1	1	3	1.9
Knowledge	4	4	4	4	4	4	4	4	4	4	4

First Year units	Second Year units
ME502 Overview of Digital Communication ME503 Telecommunication System Engineering ME504 Advanced Networking MN502 Overview of Network Security MN503 Overview of Internetworking MN601 Network Project Management	ME601 Telecommunication Modeling and simulation ME602 Mobile and Satellite Communication Systems ME603 Project 1 ME604 Project 2

Again, the heat map in Table 4 indicates that:

1. The attribute Knowledge (Average 4) is extensively covered in all the units.
2. Lifelong Learner and Problem Solving (Average 3.3+) seem to be very well covered.
3. Communication and Team Work (Average 1.9) seem to be adequately covered.
4. Ethics and Cultural Awareness are not covered to any significant extent.

Again, Table 4 tables indicate that Ethics and Cultural Awareness are not appropriately covered. Course and unit coordinators are currently considering how to incorporate these two attributes in appropriate units.

Mapping attributes to assessments activities

Typically, a unit's assessment consists of a set of tasks, such as lab participation, assignments, presentations, quizzes and mid-term tests. A mandatory final examination—supervised, written—covers a high percentage of assessment (35-50%), normally divided into 3 sections: multiple answer questions (10-20%), descriptive answer questions (30-50%), and problem solving questions (30-50%). Assessment tasks usually include a varying percentage of these sections, depending on whether they are foundation undergraduate, advanced undergraduate or postgraduate units. Units that include more foundation knowledge tend to use more multiple answer and descriptive answer questions, progressing to PG units which include a higher percentage of problem solving questions.

The data for the Heat Maps of Table 3 and Table 4 is the result of the estimation by lecturers and the School Teaching and Learning Committee of each individual unit attribute. However, when considering a course as a whole, by allocating assessment tasks to attributes it is also possible to provide an analysis of the overall learning activities and assessment, and correlate that with the average values given in the last column of Table 3 and Table 4. This provides a 'sanity check' that confirms or refutes the analyses of Tables 3 and 4. Since an assessment task may span more than one attribute—such as lab participation spanning Knowledge and Problem Solving—the School T&L Committee provided an independent estimative break down based on the weight allocated to each attribute by assessment tasks.

Table 5: Percentage of assessment tasks covered in each unit – BengTech(Tel)

Unit codes / assessment tasks in %	BN101	BE101	BN102	BN103	BE103	BN106	BN108	BE102	BN203	BN206	BN209	BE201	BE202	BN205	BN208	BE203	BN301	BN303	BE301	BE302	BN304	Average %
Lab participation	10	10	10	15	20	10	10	10	10	10	10	10	10	10	10	10	30	10	10	10	20	12.14
Quiz test		5	10	25	10	10	4	5	10	10	5	5	5	5	10	5		10	5	5		6.86
Mid-term test	5	10	10		10	10	6	10	10	10	5	10	10	10	10	10		10	10	10		7.90
Individual assignment	20	10	15	10	10	20	15	10	10	10	10	10		10	10	10	10	10	10	10	10	10.95
Group Project	15	15	5	10	10	10	5	15	10	5	20	15	5	10	5	15	30	15	15	15	30	13.10
Presentation	10		10		10		10		10	10	10		20	10	10		30	10			40	9.05
Final Examination	40	50	40	40	30	40	50	50	40	45	40	50	50	45	45	50		35	50	50		40.00
Total average %																						100

Analyses: units vs. courses

These analyses are an independent consideration of the courses as a whole, rather than unit by unit. Table 5 shows the percentages of each type of assessment task for each unit of the BEngTech (Tel). The last column shows the average percentage allocated to each task for the whole course:

Table 6: Relationship between MIT graduate attributes and assessment tasks, BEngTech (Tel)

Graduate Attributes	Values (Table 3)	Average% (Table 3)	Assessment tasks	Average Assessment tasks %	Average %
Communication	2.38	15.06	Presentation + lab participation	9+6 = 15	15
Life-long Learner	2.95	18.67	All activities	20	20
Ethics	0.86	5.44	Part of individual assignment	5	5
Problem Solving	3.05	19.30	Lab participation + final exam + tests	4 + 10 +6 = 20	20
Cultural Awareness	0.33	2.09	Lab participation exercises	2	2
Team work	1.86	11.77	Group project	13	13
Knowledge	3.86	24.43	Tests + quizzes+ final exam	5 + 20 = 25	25
Total	15.29	100		100	100

NOTE: column 3 values = attribute values in column 2/Total value in column 2

Selecting together Columns 3 and 6 of Table 6 into Table 7:

Table 7: Heat Map vs. Assessment Tasks (Columns 3 and 6 of Table 7)

MIT Graduate Attributes	Average Score (Table 3) %	Average Assessment Task % (Table 6)
Communication	15.6	15
Life-long Learner	19.3	20
Ethics	5.6	5
Problem Solving	19.9	20
Cultural Awareness	2.2	2
Team work	12.2	13
Knowledge	25.2	25

Table 7 supports the view that unit-by-unit graduate attribute coverage for the BEngTech(Tel) as estimated in Table 3 correlates with an independent evaluation of the weight of assessment allocated throughout the course. We can see (again) that the two attributes Cultural Awareness and Ethics are underrepresented by the assessment tasks, while Life-long Learner and Knowledge are comprehensively addressed. A similar analysis for the MEng (Tel) is shown in Tables 8, 9 and 10:

Table 8: Percentage of assessment tasks covered in each unit the MEng(Tel)

Unit codes / Assessment tasks in %	ME502	ME503	ME504	MN502	MN503	MN601	ME601	ME602	ME603	ME604	Average %
Lab participation	10	10	10	10	10	10	10	10	30	20	13.00
Quiz test	5	5	5	10	5	5	5	5			4.50
Mid-term test	10	10	10	10	10	10	10	10			8.00
Individ. assignment	10	10	10	10	10	10	10	10	10	10	10.00
Group Project	15	15	15	10	15	10	15	15	30	30	17.00
Presentation				10	5	10			30	40	9.50
Final Examination	50	50	50	40	45	45	50	50			38.00
Total average %											100.00

Table 9: Relationship between MIT graduate attributes and assessment tasks, MEng(Tel)

Graduate Attributes	Values (Table 4)	Average % (Table 4)	Assessment tasks	Average Assessment %	Average %
Communication	1.90	12.03	Presentation + lab participation	9+4 = 13	13
Life-long Learner	3.30	20.89	Almost all activities	20	18
Ethics	1.00	6.33	Part of individual assignment	6	6
Problem Solving	3.50	22.15	Lab participation + final exam + tests	9 + 10 +4 = 23	23
Cultural Awareness	0.20	1.27	Part of Lab participation exercises	2	2
Team work	1.90	12.03	Group project	13	13
Knowledge	4.00	25.32	Tests + quizzes+ final exam	5 + 20 = 25	25
Total	15.80	100		100	100

Table 10 summarises as before:

Table 10: Heat map vs. assessment tasks (Columns 3 and 6 of Table 9)

Graduate Attributes	Average % (Table 4)	Average %
Communication	12.03	13
Life-long Learner	20.89	18
Ethics	6.33	6
Problem Solving	22.15	23
Cultural Awareness	1.27	2
Team work	12.03	13
Knowledge	25.32	25
Total	100.00	100

Conclusions/recommendations/summary

Although here are complementary interests in the development of purely academic vs. professional and generic attributes, they also compete for learning space. It is then imperative that all these types of attributes are contemplated when designing curricula, and that course teams are able to determine to what extent they are exercised by the students, to ascertain which attributes are appropriately covered and which are not, and what the shortcomings might be. In this paper we show how we use Heat Maps to analyse and provide evidence of the extent to which generic graduate attributes are addressed by the teaching and, more specifically, by the assessment.

The SITE approach has been shown here applied to generic graduate attributes for two Engineering courses of study. However, a similar Heat Map approach can be employed for other education attributes; in particular, the SITE has produced similar analyses for the AQF, ACS and Engineering Australia attributes and competencies.

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