REFLECTIONS ON CHANGING THE CULTURE OF ENGINEERING EDUCATION AT QUT

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Abstract
The seminal investigation of Engineers Australia into how education providers should respond to changes in the profession of engineering inspired the Faculty of Built Environment and Engineering at the Queensland University of Technology to initiate several projects all with the broad aim of developing the skills capabilities and attributes of graduating students.

Each initiative has been successful to a limited extent. However in terms of a quality cycle, it is pertinent to conclude that each has been piecemeal. In that sense they are partial, albeit valuable and significant improvements towards achieving the objective. They could be strategically positioned on a continuum of a framework that relate to each other and contribute to the whole picture. The development of graduate attributes has been embedded into each of them but at this stage, there are no clear connections between them or to an overall objective.

In order for synergetic interaction of these (and possibly more) developments onto the continuum of changing the culture and to ensure its sustainability, there needs to be appropriate resourcing, for example staff training in teaching pedagogy generally but specifically the importance of assessment on student learning experiences.

Introduction

The seminal investigation of Engineers Australia into how Universities must respond to changes in engineering scholarship resulted in the "Changing the Culture" review of Engineering Education. The message is that Engineering is a profession needing to be outgoing and connected, enterprising and innovative, responsible to community and society by embedding sustainability in its work, and providing and focussing on leadership.

Considering the way engineering advances are being realised, it is clear that important breakthroughs and innovations in engineering are increasingly being achieved as a result of the work of multidisciplinary teams operating across boundaries that once existed between their disciplines, and addressing global issues beyond the strict technical expert knowledge to incorporate and interact with the social and environmental dimensions.

Inspired and motivated by these influences, the Faculty of Built Environment and Engineering, at the Queensland University of Technology, has developed a vision for its future and a model for its operations that provides a clear philosophical position with the Scholarship of Integration as the dominant work of the Faculty's leadership. The principles of valuing and utilising the enormous potential of interdisciplinary, collaborative and integrative approaches paved the way for innovative opportunities for development at the intersection of other forms of scholarship. These opportunities advance Ernest Boyer's work by using it to set the agenda and drive the endeavours of a large academic unit.

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Over the past few years, a number of developments have been implemented within the faculty, with widely varying objectives that range from integrating the development of the students' graduate capabilities (through the Student Capability Profiling (SCP) system), to integrating the work experience with the academic curriculum (through the Work Integrated Learning (WIL) project), to addressing issues of assessment and general enhancement of the curriculum.

This paper identifies the main developments at QUT that address issues of changing the culture of Engineering Education and highlight their achievements as well as reflecting on the effectiveness of these initiatives.

Changing the Culture – A Framework

In any development activity, a quality cycle process should be followed: plan the activity based on available information, implement it, review/reflect/evaluate its implementation/progress, modify any component of it for improvement and then return to the planning stage. This cycle is depicted in Figure 1.

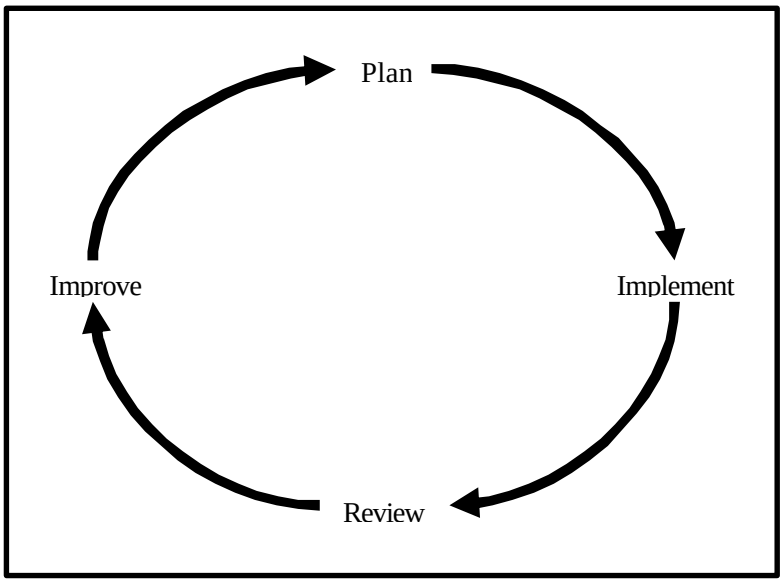

Figure 1 Typical quality improvement cycle

An analogy of this educational development of students might be that of flow in a pipeline – see Figure 2. As students progress through the course, their learning is enhanced and they develop skills, capabilities and/or attributes to be prepared for employment as professionals. The effectiveness of these qualities does depend on a number of important factors such as learning design, the curriculum, delivery approaches, assessment, the learning environment, administration, quality systems etc. Inefficiencies in any or all these result in graduates exhibiting characteristics that are short of what the employers or the profession need/accept. Such characteristics can be seen as symptoms of problems in the education system.

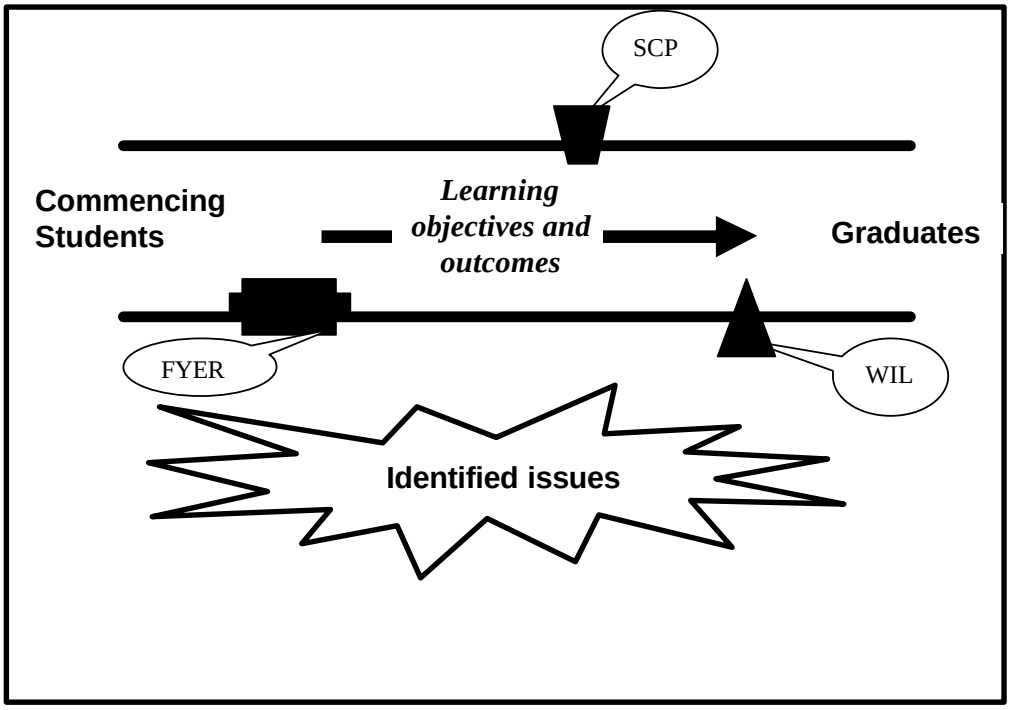

Figure 2: An analogy of the development of learning outcomes of students.

Considering the flow in the pipe of Figure 2, these symptoms can be seen as identified issues, as if leaking and taking away from the strength of the flow in the pipe (representing the learning objectives and outcomes). In order to address these leakages, bandaids/stoppers/corks can be employed. In this case, QUT has specifically developed three techniques shown in Figure 3 as "Actions"; the Student Capability Profile (SCP) project, the Work Integrated Learning (WIL) project and the First year Engineering Review (FYER) project. Figure 4 expands on these initiatives. These projects are teaching and learning projects that tend to address specific problems but remain in many cases isolated and localised, thus the temporary bandaids can help but may fall short of what is desired in terms of a whole picture.

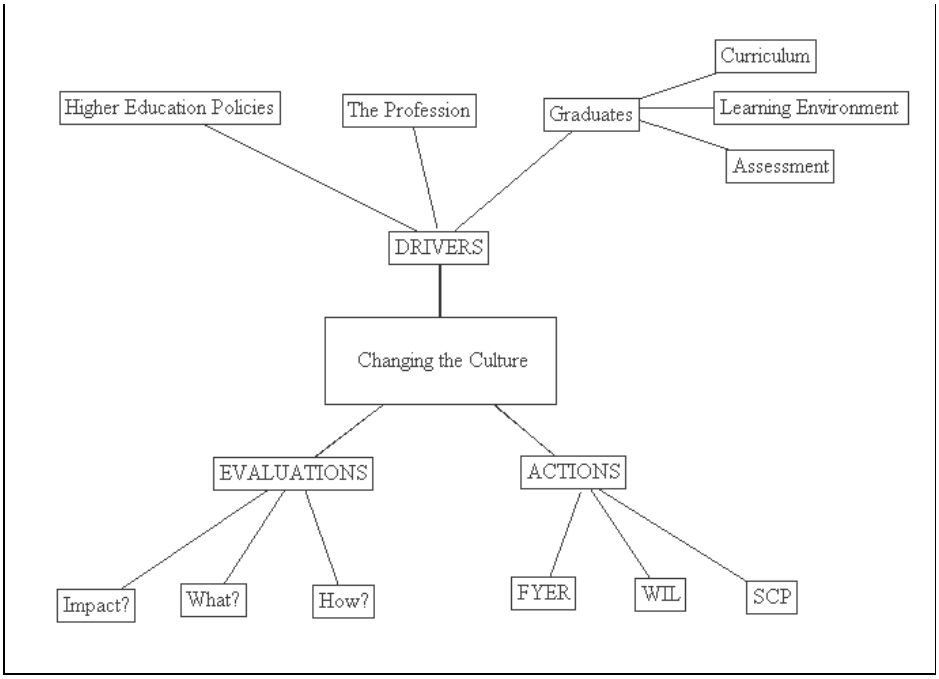

Figure 3 Some drivers and subsequent actions taken at QUT to address the changing nature of engineering education.

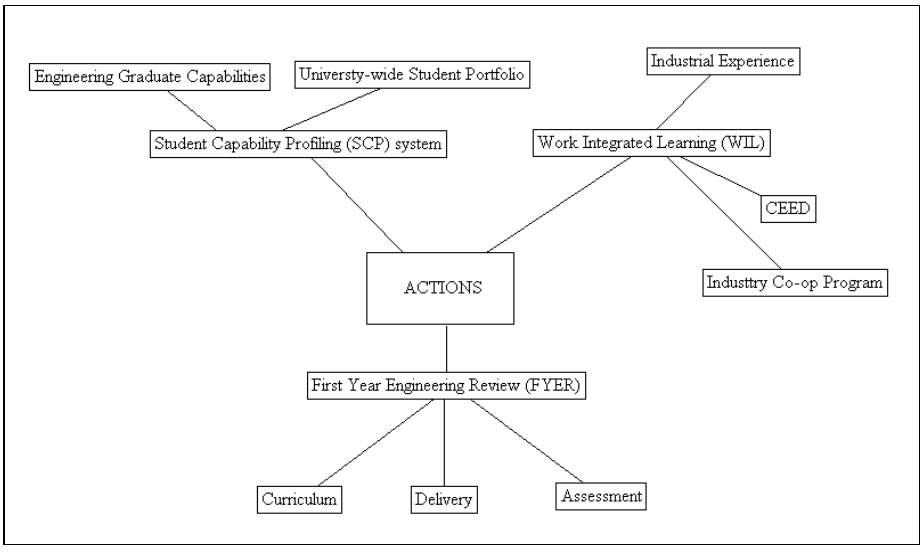

Figure 4 Expansion of three activities initiated at QUT to enhance graduate attribute development.

These reflections on the current situation at a faculty level, activities and projects have been implemented to address identified issues. At the university level, the same drivers for improvement of the learning process and students' learning outcomes have resulted in implementing a number of very important policy matters. An example is the recent policy on Criterion-Referenced Assessment (CRA).

Criterion-Referenced Assessment (CRA)

Learning environments are designed to achieve clear learning outcomes. Assessment is an integral component of the learning environment, and refers to the processes involved in achieving the major purposes of assessment of student learning:

1. to encourage students to achieve the desired learning objectives;
2. to monitor students progress, and to provide feedback so that students can plan future learning;
3. to document students learning and development over time;
4. to assure academic standards; and
5. to certify achievement.

In order to achieve these purposes, the following set of principles is used.

- Assessment is aligned with learning outcomes
- Assessment is standards based
- Assessment is valid and reliable
- Assessment is comprehensive, coherent and sequenced
- Assessment is equitable and inclusive
- Assessment is authentic
- Assessment provides feedback to staff

QUT's assessment policy is one of criterion-referencing. Criterion-referencing requires students' work to be assessed by a pre-determined set of standards or competencies rather than in relation to the performance of their peers (norm-referencing). Students are therefore rewarded on the merit of their individual work, independently of other students.

Criterion-referenced assessment requires the determination and communication of detailed and clear criteria in advance of the assessment. Students need to understand the criteria but also need to appreciate that the application of the criteria relies on expert judgement and is an inexact science.

The establishment of assessment criteria contributes to the reliability and validity of the assessment task. Clear standards that are high but attainable, motivate students and focus their energy on learning rather than on competition with peers.

The Student Capability Profile (SCP) Project

At QUT, we have developed a web-based database that leads to individual Student Capability Profiles (SCP). It is a statement of the holistic nature of capabilities involving the integration of personal qualities, a wide range of generic attributes and discipline-specific knowledge which enables students to be effective beyond technical competence. The SCP therefore provides employers with a more holistic view of potential employees.

The SCP is on-line, on-demand and enables a "just-in-time" approach to professional development of students. The objective is to produce a portfolio from which they can draw catalogued information of their growth over their years at QUT, which is valuable to their employment prospects.

Students are able to audit themselves at any stage through a system of questions and answers built around defined capabilities and skills. They select answers which help them to identify their level of ability from one of the four levels of capability identified by the ATN generic attributes project, from the lowest level of "scoping" through to the highest level of "relational".

Activities in which students participate can be specified by lecturers as an essential part of assessment in a unit of study, can be whole-of-course activities, or even can be actions undertaken by students outside QUT and not directly related to courses. All can be captured and submitted by students for verification by QUT as contributing to the personal and professional growth of the student.

Students are able to reflect on their activities and release any information they have entered, for inspection, verification or assessment by mentors. Mentors may be academic staff, tutors, senior students, alumni, practising professionals, or indeed anyone in whom QUT is able to build confidence regarding their oversight of a student's development. This is whole-of-life learning. The SCP is a core component of a student's learning experience at QUT. Details of this project can be found in Hargreaves et al [1].

The principles and ideas developed for the SCP project have now been incorporated into the QUT-wide Student Portfolio (SP).

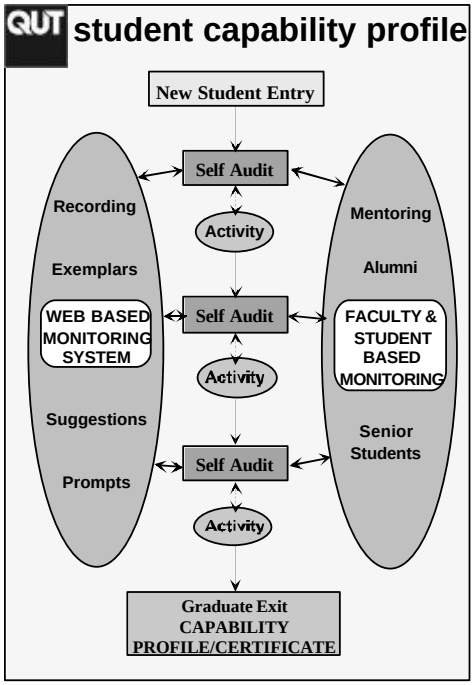

Figure 5 Student's Track of Capability Development

The Work Integrated Leaming (WIL) Project.
Work Integrated learning is a form of (practical) education that integrates periods of academic study with periods of work experience in jobs related to the students' studies WACE[2]. Hager[3] described the process as, "Learning in one's discipline occurs within the slipstream of engagement". It may be called by a different name, for example, "industry experience", "practicum", "co-operative education", or as in nursing, "clinical practice", but all mean basically the same thing: an opportunity for undergraduate students to apply and develop their knowledge and skills in a working environment. The common function of all work integrated learning is twofold: to accelerate professional readiness for the workplace, and to provide organisatio ns with better educated and work-ready employees.

There is no doubt that students acquire the skills of their discipline profession by being immersed in the corporate culture; learning how to process information and solve real problems within context, as well as working and communicating with technical and non-technical colleagues. The experience of QUT is that on their return to university after such an experience, students apply themselves more diligently to their studies and appear to achieve better results.

It is quite clear that there is a need for a formal approach to integrating the students' work experience with the curriculum and providing a means for students to enhance their experience and integrate it with their study at the University. A detailed description of this project can be found in Mahalinga-Iyer et al[4].

The Cooperative Education for Enterprise Development (CEED) Program
There are other parts of the curriculum which involve the work place in a more organised manner. An example of this is the CEED (Cooperative Education for Enterprise Development) Program, in which a student will undertake a project with an industry partner with a formalised contract. The student is supervised by an academic supervisor as well as by one from industry. A set of deliverables is written into the contract for the student to achieve. The student uses this as his/her final year capstone project with academic credit equivalent to two or three (sometimes four) units. There is anecdotal evidence that the students become better learners after they have been through an industrial experience program in a discipline related organisation. The students who have been involved in industrial experience were also observed, from presentations of their final year projects, to have better generic skills, especially communication skills.

QUT's Industry Cooperative Program (ICP)
This program offers credit towards the relevant degree and thus is integrated with the curriculum, including students' work experience requirements. During their ICP work placement students have to be enrolled in the Industry Practice Unit and one other unit of their course. Students apply for paid employment with an industry partner registered for this program. The process is open and competitive, and students are pre-selected and interviewed as they would be in a typical job application process. Students must attend a number of professional development workshops delivered on campus, including preparatory ones. These workshops are designed to present students with professional topics which they then contextualise in terms of their workplace practice, reflect upon and then communicate to their peers through other workshops and reports.

As part of their ICP work placement, third year students work for an industry for four to six months during second semester (July to December). They are employed by the industry

partner and are supervised on a day-to-day basis by an industry supervisor. During their employment students also carry out one or more tasks/projects, which are assessable components of this unit. The tasks are determined by negotiation between the student, the industry supervisor (IS) and the academic supervisor (AS) and recorded in the required format. The AS monitors student's progress on the task(s) through email and telephone communication on at least a weekly basis. The academic supervisor also visits the industry partner's premises at least twice during the semester to discuss progress with the student and the IS. As mentioned earlier, during the course of the work placement, students are expected to take part in at least three professional development workshops (on campus), covering topics in the areas of management and leadership, operations planning, quality processes and systems, their place in the organisation and specific technical issues. They may also choose to practice the presentation of their technical report in front of their peers and ASs and so receive valuable feedback before they present this report to the industry partner. All activities that are undertaken in workshops are recorded and included as part of the assessment for the unit.

After completing their industry placement, students are asked to evaluate and reflect upon their ICP work experiences, learning outcomes as well as the processes involved in the running of the ICP. When they return to the university they are able to capitalise on their work experience in the final year subjects and a Capstone Design Project, which may or may not be with their placement industry partner. A more complete description of this initiative can be found in Bodnarova et al [5].

Industrial Experience (Vacation Work)

It is almost universal that some form of industrial experience is required for graduation in all professional disciplines. Engineering degrees require evidence of twelve weeks work experience before the award of the degree. This is the basic requirement for them to be admitted as graduate members of Engineers Australia. At the Queensland University of Technology, by and large, engineering students find a place to work during their vacation. After completion of their experience they submit a report together with a single page evaluation from the employer verifying the nature of work undertaken and the general behaviour of the student during their work experience. This report and the certificate are examined by a member of the academic staff, usually the Course Coordinator, who certifies that the student has completed the work experience requirement. Some students prefer to undergo work experience in two periods, while others prefer completing it in one session. The preferred model is for the students to do it in two periods, with the first being an introduction to the industry and the second requiring more involvement in the organisation, by doing a project or an investigation or a simple design etc.

The work experience program carries no academic credit nor is it in any way integrated to the curriculum. Students are free to choose any work that is on offer with an expectation that the experience will improve some of their skills. In general, students are not required to reflect upon their experience nor evaluate it to determine whether they have really learnt anything at all. These shortcomings contributed to the development of the WIL project which is now the framework through which all industry related experience is formalised.

The First Year Engineering Review (FYER) Project

The aim of this project was to consider the existing first year units for the standard Bachelor of Engineering degrees, with a view to developing or suggesting a process to manage any improvements that may need to be made either within existing units or by the introduction of new units. Part of this process involved ensuring the needs of stakeholders such as potential

students, academic staff, industry and most importantly first year and higher year students are catered for. Further, a process for evaluation of the impact of any changes would be built into any improvements suggested. The desired impact of a possible review and resulting changes was to:

- Improve student learning and experience and therefore retention
- Ensure that first year is enjoyable, interesting, motivating and stimulating for students
- Provide flexibility in student choices
- Provide an appropriate grounding in engineering principles for all discipline areas
- Improve staff interactions across Schools
- Allow students to move more easily between disciplines if they wish
- Improve marketability of our engineering degrees.

Further there was a need to consider other issues that may be influenced by a review of first year including:

- The need for flexibility in the current competitive climate including ensuring that a diverse range of students are catered for in terms of time, type and location of learning experiences;
- The need to ensure that the Engineers Australia (EA) accreditation issues were addressed;
- The need to ensure that international and domestic (TAFE) agreements fit with any changes that might be suggested;
- A recognition of the need to focus more on students and their experiences and to ensure that retention is at an acceptable rate;
- The need to ensure that first year provides a solid foundation and an appropriate introduction to the profession of engineering, which can be appropriately built on in later years of the course. This requires a clear connection with industry;
- The potential impact on specialist courses of any course or unit changes;
- Any impacts on financial and human resources that may result from changes;
- The need to deliver quality teaching in a supportive learning environment.

The outcome of this project was the development of a series of units (subjects) all based on the project- and problem-based approach to teaching and learning. Individual topics in mathematics, sciences and engineering principles were integrated into these units. The intention was to introduce, for example, particular mathematical concepts when it was needed. One example was to design (in broad principles) a wind powered electrical generator. Elements of civil engineering (foundations, structural design), mechanical engineering (turbines, gearbox, condition monitoring, lubrication) and electrical engineering (electromagnetics, power distribution) could be introduced in such a manner as to engender enthusiasm in students but also an awareness/understanding of the need to learn fundamental engineering principles and where these can be applied in real life situations.

Engineering Leadership and Management in 2025.

The Centre for Engineering Leadership and Management (CELM) branch of Engineers Australia in Queensland organised a workshop in April 2005 focussing on engineering leadership for the year 2025. Fifty leading industry and academic representatives considered three questions.

- What might be the attributes of successful leadership in 2025?
- What are the characteristics of the business and social environments where engineering leadership will be exercised in 2025?
- What skills and competencies would a leader in 2025 require?

Figure 6 summarises the outcomes of this exercise and a more complete description of the process and outcomes can be found in CELM [6].

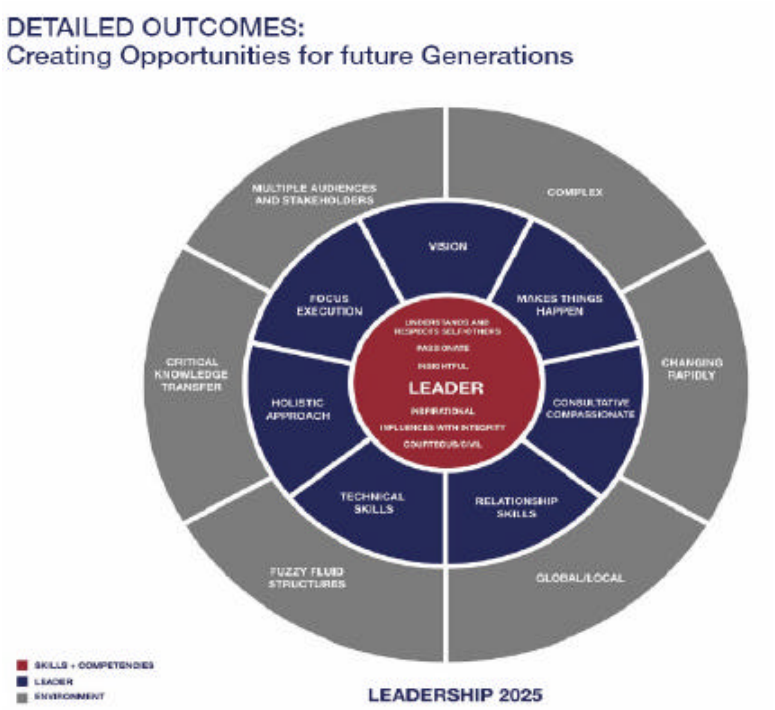

Figure 6 Diagrammatic representation of the attributes, environmental context and skills/competencies identified for successful leaders in 2025.

Reflections

Over the few years, QUT has developed several initiatives to address the general concern in the engineering profession of a need to engender skills/capabilities/attributes in graduates. These include the Student capability Profile (SCP), the Work Integrated Learning (WIL) and the First Year Engineering review (FYER) projects. Each of these in their own right has been successful to a limited extent. However in terms of a quality cycle, it is pertinent to reflect on these changes and to consider improvements/modifications. It is reasonable to conclude that each of these initiatives have been piecemeal and really part of a much larger objective of changing the culture of engineering education. In that sense they are partial, albeit valuable and significant improvements towards achieving the objective. They could be strategically positioned on a continuum of a framework that relate to each other and contribute to the whole picture. The development of graduate attributes has been embedded into each of them but at this stage, there aren't clear connections between them or to an overall objective.

In order for synergetic interaction of these (and possibly more) developments onto the continuum of changing the culture and to ensure its sustainability, there needs to be appropriate resourcing, for example staff training in teaching pedagogy generally but specifically the importance of assessment on student learning experiences.

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