Program Renewal for Sustainable Engineering
at RMIT University

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Introduction

Program Renewal is the process of moving existing engineering degree programs at RMIT in line with the University’s Teaching and Learning Strategy 1,2, enabling students to:

- develop a framework for understanding validated knowledge and cultural achievements
- contribute to their further development and to the well-being of society
- engage with the processes of innovation and global change and to deal with new challenges
- develop sustaining values, including a commitment to their own learning.

It is maximised in learning environments which focus on:

- knowledge—contemporary content, clear goals, deep learning focus, global focus
- learners—adequate preparation, interactive engagement, adaptation to individual learning styles
- assessment—specific standards, range of assessments, progressive feedback
- community—application and transfer focused, cross-disciplinary, problem-solving, vocationally recognised, socially inclusive orientation, internationally relevant.

Overview

This paper discusses the key design concepts being used to develop these new engineering programs, namely:

- The Institution of Engineers, Australia’s graduate capabilities 3 are placed within a sustainability framework. This framework captures the essence of what it means to do engineering. The key components are: sustainability, problem solving, engineering analysis, communication and relationships.

- The program renewal process follows the teaching cycle of identifying professional needs, defining learning outcomes, creating learning activities and finding learning resources, assessing and evaluating, leading back to a review of the needs in each cycle. This is consistent with a quality approach, such as that expected by the AUQA 4 and the IEAust 3.
The first stage of this process is an engagement with *stakeholders* that is providing a more detailed view of the capabilities appropriate for each program.

- **Year themes** are proposed as a way of focussing our attention on the changing needs of students at each year of our programs. The four themes are:
  - *Connection to their own purpose* in first year, to studying at university and to the profession
  - *Fundamental principles* (founded on practice) in second year
  - *Application* in third year
  - *Transition to the profession* in fourth year, including specialisation.

- **Learning styles** are introduced as a means of creating an *inclusive teaching* environment. The four learning styles match the four stages of good teaching, namely: engaging with the problem, understanding theoretical ideas, applying this new knowledge and seeking new possibilities.

- **Collaboration** is a powerful way of helping students to be more effective learners and of helping staff to be more effective teachers. Together they create a *learning community*. This collaboration can proceed through project-assisted, project-based and problem-based learning.

**Graduate capabilities for sustainable engineering**

The IEAust ³ has stated that:

*Graduates from an accredited program should have the following attributes:*
- understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;
- understanding of the principles of sustainable design and development;
- ability to undertake problem identification, formulation and solution;
- ability to utilise a systems approach to design and operational performance;
- ability to apply knowledge of basic science and engineering fundamentals;
- in-depth technical competence in at least one engineering discipline;
- ability to communicate effectively, not only with engineers but also with the community at large;
- ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;
- understanding of professional and ethical responsibilities and commitment to them; and
- expectation of the need to undertake lifelong learning, and capacity to do so.

The points have been reordered from their original form, although the wording remains the same.

These graduate capabilities are summarised (and expanded) in the mindmap ⁵,⁶ on the next page to present an overview of what it means to do engineering.
An important role for the initial stages of Program Renewal is to meet with stakeholders to elaborate this group of capabilities. Each discipline also needs to identify those technical capabilities that will define the RMIT graduate.

**Stakeholder needs**

Some simple questions used to open the discussion with stakeholders were:

- What *industry segments* are represented?
- What are the emerging *trends* in your businesses?
- How are your businesses *responding* to these trends?
- What are the *roles* that you expect young graduates to play in this process?
- What are the *capabilities* and *values* that you are looking for?
- What *challenges* do new graduates face in the transition from university to work?
- What are the *problems* that a young graduate might need to solve?
- What are the *big ideas* of your discipline and how do they fit the business framework within which you operate?

Some answers to these questions gathered from a range of industry meetings are summarised in the following mindmap (developed from 7):
These trends, strategies and capabilities suggest the need for a holistic approach to teaching engineering that goes well beyond the need to teach understanding and algorithms for solving well-formed technical problems. Engineers must cope with a rapidly changing business, social and biological environment that will stretch their capabilities in problem solving, teamwork, communication, and technical skills. We need to address all of these things within the four years of an engineering degree.

A Teaching Cycle

In planning new teaching and learning situations, it is important to consider the whole cycle...
from identifying the professional needs, through to evaluating the quality of the course or program, at its end:

The process of identifying professional needs has been briefly described above. This has required us to engage with our stakeholders (industry, students, staff, and the community) to identify what it means to do engineering in each of our disciplines.

Many ideas for our programs are emerging from these meetings. These need to be transformed into intended learning outcomes. One useful way of doing this is to think about the professional tasks that a young graduate might be expected to tackle. Use these in a project-based approach to construct the curriculum as a set of educational experiences.

Use the tasks to create learning activities that really engage the students. Engineering is fundamentally about design (and planning, construction and maintenance) and complex problem solving, yet the latter is often confined to the later years of the course.

In association with each of these tasks, identify good learning resources – books, lectures, CDROMs, websites, etc. Students can access many of these resources in their own time. If we are to develop skills in lifelong learning, students need to become independent learners while they are at university. RMIT already has a commitment to flexible learning through the development of print-based and online learning guides through its Learning Development Unit.

Plan how students will demonstrate their competence. If possible, engage students in the design of the assessment. This assessment should test the full range of graduate capabilities, not just technical skills. Assessment should cover all levels of Bloom’s taxonomy⁸.

Evaluate your success. This should include staff evaluation, eg through a reflective journal, student evaluation of the course and of themselves, and external evaluation.

Having completed the cycle, the whole process can start again because the evaluation process revisits the professional needs, which can then be revised.
Year Themes

Four themes have been chosen for the four years. Each theme is designed to bring some wholeness to the year, and the four themes together provide a sense of professional development from years 1 to 4. The four themes are:

- **Transition from school: connecting the student to self and to engineering.** The first year should help students make the gigantic leap from a (for many purposeless) school existence, to beginning a purposeful career in engineering. The idea is to help them connect with themselves, their colleagues (staff and students), a sustainable approach to engineering, and the university. Becoming a self-directed, self-evaluating learner is a key step in this process.

- **The big ideas:** Basic engineering principles. By year 2, students should know where they are and where they’re going. Year 2 concentrates on the big theoretical ideas, built around practical applications so that both abstract and concrete learners can understand them.

- **Professional applications.** Students work on typical engineering problems within their discipline and within their social and environmental context. By the end of third year, the students should be useful to an employer during vacation experience.

- **Connecting to the workplace.** Fourth year should encourage specialisation and development of professional skills. It could include workplace learning and negotiated learning contracts.

These ideas are summarised below:

Learning styles

Bernice McCarthy has articulated a very simple teaching model that builds on the work of David Kolb, Carl Jung (eg) and others. The 4MAT system is simultaneously a model of learning styles and a means of inclusive teaching, by encouraging all 4 learning styles to
engage. Teaching happens *around the cycle* as each class and semester moves through the four stages of engaging with the problem in its context, understanding necessary theoretical concepts, solving the problem and then looking for new possibilities with this new knowledge.

Each of us has a *preference* for one of these learning stages. It is not surprising to find that academics are often type 2 learners (who favour theoretical understanding) and they teach engineering from that perspective.

Many (perhaps most) engineering students at RMIT are type 3 learners. They are concerned with solving the problem. They will make fine engineers but their practical focus is often at odds with their teachers.

In our classes, we also have type 1 learners who are interested in understanding the significance of the problem in its social context. These students may be drawn to disciplines such as environmental engineering and teaching, or they may be lost souls in other disciplines.

The type 4 learners are restless folk who are always looking for new, creative possibilities. They blaze trails and let others worry about the detail.

There is also quite a neat alignment between these four learning styles and Boyer’s model of Scholarship:\(^\text{12}\):

- The scholarship of teaching and learning aligns with quadrant one where the social dimension is most important.
- The scholarship of discovery is quadrant two, where theoretical concepts matter.
- The scholarship of application is quadrant three, where solving a real problem drives the learner, and
- The scholarship of integration matches quadrant four, where connection with other ideas and disciplines dominates.

Hence, this simple model of teaching can be seen to inform our teaching as well as our scholarly activities on many levels.

Finally, it is easy to see that the four themes chosen for the four years of the program reflect these four stages of the 4MAT model.
Inclusive Teaching

How can we teach in a way that includes all of these learning styles?

Bernice McCarthy suggests that all we need to do is *teach around the circle*. Each teaching event (one class, one week, one semester, one year, one program) should start in quadrant 1, and move successively through each of the remaining quadrants, in order.

Further, she suggests that each quadrant should include both right and left brain activities. Right brain activities are expansive and creative. Brainstorming is a typical right brain activity. Left brain activities rely on logic. They are contractive, whittling away the possibilities until only the “best” are left. Engineering proceeds from right brain activity (creation of a new idea) to left brain activity (finding the best configuration of that idea to solve the problem).

- The focus of quadrant 1 is to provide students with **concrete experience** of the problem. This can include slides, video, a field trip, discussion, sketching and students doing their own research and coming back with their own slides, posters etc. The important focus here is to get them engaged with the topic.

  In terms of right and left brain, it is easy to start by brainstorming relevant situations, e.g. applications of structural engineering in the design of chemical plants. Once the board or overhead has been filled with words and sketches, these can be **categorised** (left brain) and organised to indicate what needs to be learned. In effect, you are doing curriculum design in front of the students. They are more likely to engage in the semester’s work if they have helped you to create it in the first lesson.

- Having created the **need to know**, quadrant 2 provides the theoretical framework. This is the bit that we all know and love so much. It is usually overdone as a consequence.

- In quadrant 3, with some theoretical ideas available, students can move to **solve** some of those useful problems identified at the start of the course. Naturally, they will only be able to tackle simple ones initially. Further trips around the cycle are necessary to get to the more complex applications.

- In quadrant 4, we look forward to what comes next. At the end of the first class, it might be what will be happening in the next class or the lab. In later classes, as students feel more comfortable with the theory and its applications, they should be encouraged to think of new ways of using their new knowledge and skills. Are there new problems that can now be solved that they hadn’t thought of earlier? Are there new situations that they’d like to be able to solve that haven’t yet been unravelled? In this way, we can continue to create the curriculum as we go.

In summary then, each teaching event should include the 4 stages of:
• Connect the students to the aspects of the problem
• Introduce enough theory
• Apply it to some of the cases to be solved
• Look forwards to the next applications or to new applications

**Collaboration**

Learning is often seen as a solitary activity and our assessment tasks usually reflect this. We, as academics, believe that we need to know what students can accomplish by themselves. However, the engineering workplace is team based and it is team effort that matters.

Similarly, many studies over many decades have shown the value of a team-based approach to learning [eg 13,14]. This can be as simple as getting students to work together in groups in a tutorial, to a team of students undertaking a large design project over a semester.

It is suggested that the four years of our programs could use different forms of collaborative learning. These can be seen to complement the four themes from earlier in this paper:

• In year 1, collaborative learning brings students together to help each other to learn. At this stage, it is likely that the focus is still on individual performance, but the team helps each other to learn. Other aspects of the educational program may be quite traditional. This approach fits neatly with the theme for first year of *Connection*.

• At stage 2 and year 2, students begin to work on small projects in association with an introduction of theoretical ideas. At this stage, many students are still grappling with the *big ideas*, and they express the need for a fair amount of hand-holding. The projects assist their learning of the key engineering principles.

• As the students become more confident with the big ideas, they move into serious application of the big ideas to progressively more complex tasks. Learning becomes project-driven rather than lecture driven. We call this project-based learning. Much of the content is still teacher-centred in this approach.

• By fourth year, students should be looking to build a career for themselves. Here they can move into formal problem-based learning (PBL) where students find learning resources for themselves, often working in interdependent teams 15,16. In PBL, students take responsibility for their own learning and, in the process, become ready for a life of learning.

**Conclusions**

The Faculty of Engineering at RMIT is engaged in a substantial renewal of its degree programs
based on graduate capabilities. This paper sets out some guiding principles and ideas:

- **Sustainability** as the defining attribute of an RMIT graduate.
- A *teaching cycle* that includes professional needs, learning objectives, activities and resources, assessment and evaluation.
- The need to define the *professional needs* through discussion with *stakeholders*.
- *Year themes* of connection, principles, applications and transition to the workplace.
- *Inclusive teaching* that recognises four *learning styles* and stages: understanding the problem in its context, theory, application and new possibilities.
- Collaboration and the learning community. These include *project-based* and *problem-based* learning.
- Some key ideas central to the process, such as *personal best*, a learning community, the profession, society and the environment.

With these guiding ideas, we are in the process of constructing some truly innovative engineering programs that will serve the students, the staff, the profession and the community and which can be self-renewing.

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**Biography**

Roger Hadgraft has a special interest in problem-based learning in engineering. (He runs the PBL-LIST). He has also been exploring the use of learning styles and computer support for learning for the last 15 years. He has combined all these interests in this paper to describe some guiding principles for program renewal at RMIT. He can be reached as: Roger.Hadgraft@RMIT.edu.au