Shifting the Engineering Education Paradigm - Challenges and Experience in Curriculum Development and Delivery

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Abstract

It is being recognised around the world that educating future professionals as building practitioners requires a fresh approach. This school of thought stems from the fact that the industry puts higher value on efficient knowledge managers armed with emotional intelligence as compared to traditional knowledge sinks. Especially in the field of engineering, on the one hand engineered proprietary products, new construction materials and processes are becoming globally competitive and therefore technical data and design guides are readily accessible. This inevitably questions the prominence, teaching and learning effort and time invested gaining skills in numerically deductive reasoning in the traditional manner. On the other hand in the building industry, digital architecture, form finding techniques and computational mechanics skills are being complemented or replaced by ultra efficient software tools. In this fast moving and globally competitive environment, the industry recognises that what has been perceived as “know-how” can become stale in a much short time than the time required to acquire and preserve it. Forward thinking building education thus bears the challenge of training a new breed of practitioners who are robust self learners relentlessly in pursuit of skill transformation within short life cycles. This paper presents the teaching and learning paradigm which is aligned to the above school of thought.

Keywords: Engineering education, WIL, PBL, Co-rational design, PBL, Curriculum development

1. Background

1.1 Need for shifting the paradigm

The modern practice of building and construction engineering is evidence-based critical decision making achieved through team networks. However, engineering was traditionally taught in a content intensive, compartmentalized and prescriptive manner, focusing on numerically deductive reasoning. That approach had little focus on generic graduate attributes expected of the future engineering practitioner. There is an increasing trend to suggest that the professional and the tertiary education institutions are jointly addressing the concerns of this widening gap. For example, The Engineers Australia manual for the accreditation of professional engineering programs [1], issued in 1999, called for a major shift in the way
universities train engineering graduates. This demanded the inclusion of generic graduate attributes in all programs, driven by capability agenda which was linked to re-accreditation in 2004. In a way, this was the first formal acknowledgement of the widening gap between engineering education and industry expectations mentioned above in Australia and the strategy adopted to address the issue. Those who have been practicing engineers involved in the graduate recruitments and mentoring schemes around the world no doubt would have great insight into the issue and appreciate the need for such a paradigm shift.

In response to this and also as a part of the general quality assurance process, the faculty of engineering at RMIT University issued, in 2002, a project plan titled: ‘Renewal of the Bachelor of Engineering 2002-2004’ [2], encouraging project based learning methods in teaching practices at RMIT. The paper discusses the challenges faced and the experiences gained transforming a prescriptive type teaching and learning paradigm in the field of civil engineering design stream aligning to a capability agenda. The curriculum development and the delivery presented here evolved over five years (2002-2007), and the first batch of engineering students benefited from this undertaking is graduating at the end of 2007.

1.2 Essential elements of change

In line with the Engineers Australia recommendations and the faculty directive, the author undertook creating and developing work integrated learning (WIL) environments using project based learning (PBL) methods to align the civil engineering degree program towards the set objectives. Six civil engineering design and analysis courses were created [3], and arranged in a scaffold-like, vertically integrated stream. By immersing students in realistic and team oriented integrated learning activities, analysis and problem solving skills were simultaneously developed with teamwork and communication skills (our core graduate capabilities). As demonstrated here through a sample of project descriptions and outcomes, the author managed to arouse enough curiosity and enthusiasm in them to foster independent learning which, in our view, would encourage them to become reflective practitioners later in their careers [4].

The fundamental difference we made was changing the mind set of the teacher and the student. To get more insight to the teaching and learning philosophy and the course development models influencing this change, the reader is directed to a 2004 publication [5]. The desired paradigm shift was achieved affecting the following three areas,

- Acknowledging, in principle, the problem or project based approach to teaching and learning (PBL) as the preferred method to simulate work integrated learning (WIL)
- Creating student centeredness within both teaching and learning opposed to content and teacher centeredness
- Acknowledging the engineering design as a multi disciplinary, evidence based decision making process where know-how of the whole of design process, negotiated compromise
and project delivery capabilities are as equally as important as numerically deductive reasoning.

Colony of migrating student population-leaders, managers cruisers, masters dynamos, piggy-backers etc.

Figure 1: Model Illustration of Paradigm Shift

Figure 1 illustrates, conceptually, the new paradigm, its influence on our student population and our observations in seeing them grow. The important thing in student centeredness is that it is up to the student to reflectively and relatively evaluate how he/she travels within the population. More importantly, this is the best way we can observe them closely at play in a simulated work environment. We are convinced that this way, students have a far better opportunity to get feedback and seek suggestions in order to develop as rounded personalities in professional practice.

We give equal emphasis on the key skills discussed in sections 4.1-4.3 to their comprehension in technical content, in assessing engineering excellence.

2. Work integrated learning and audit readiness

Unlike a couple of decades ago, the current marketplace demands work ready graduates. Therefore the key focus of the forward thinking educational institutions in our view, striving for quality value added delivery, is to ensure students’ readiness to work at different stages of their growth, even before they complete their degree.

Work Integrated Learning (WIL) basically refers to the institutions’ ability to simulate or mimic workplace process mechanisms and emotional/behavioural intelligence within the constraints of the “class room” or learning environment. Audit readiness here refers to students’ ability to be competitive in seeking a placement as early as possible in their undergraduate program. These two objectives require a significant departure from training graduates through text books, tutorials and exams. WIL can vary from designing a simple learning activity, a single course or
an entire degree program. Problem or project based learning is increasingly being recognised as the means to that end. In a more provocative approach, one can create functioning virtual communities where multi-disciplinary student teams work in collaboration to solve simulated real-life scenarios. For example, challenging students by engaging them in university capital development project initiatives or university asset management strategies where students offer solutions on competing teams can become a refreshing experience. In many cases we find that the solutions proposed by them are exciting and innovative to the extent that all involved exceed their own expectations.

Audit readiness is a concept we introduced to encourage our students to be confident and upfront in sharing and discussing their work in progress. This concept was introduced in 2004, after careful monitoring of students’ lack of confidence and transparency in sharing and discussing their work in progress. I found this reluctance to be not very healthy from a professional education standpoint. Audit readiness and transparency at work are undoubtedly the pillars of quality and safety assurance mechanisms in the building industry. My concerns were further accentuated with the observation that even our best performing students had this reluctance. The concept of audit readiness was therefore introduced to reverse this bad habit, apparently a wrong perception of assessment inherited through traditional education.

To put this succinctly, our endeavour is to transform “student hours” to “engineering hours” as early as practically feasible within the degree program so that our students are highly sought after within the workplace.

3. Teachers’ role

Obviously, re-defining teachers’ roles and teachers’ mindsets is fundamental to shifting an education paradigm, especially in creating student centeredness. This requires significant commitment, resources and bold decision making at the institution level. We acknowledge that the future role of quality educational institutions would need to change from being the “centre of knowledge” to being the “centres of opportunity/experience”. In this regard, the teacher’s role would shift from being the knowledge provider to a facilitator’s role in knowledge management. Although the volume of information available and the speed of accessing it have reached phenomenal levels of efficiency, the obsoleteness and the lack of credibility of the knowledge that is within reach are also on the rise. As a result, the teacher’s role as the sole guardian of knowledge and the ability to police students’ leaning is going out of fashion. In the new paradigm shift, the teacher can command respect only if she/he possesses great motivational skills, vision, reach, can interpret information in a speedy manner and is capable of real-time responses to students’ enquiries regarding various sources of information. In other words, building education is moving from having a pseudo-static status to a dynamic mode. It is certainly challenging and for many, it is outside their comfort zone. That is where institutional level intervention is required, and adequate resources should be utilised in ensuring that the teaching resources are continually groomed.
4. Curriculum, learning outcomes and performance indicators

In this endeavour work integrated learning (WIL) environments were created in a scaffold-like manner by a vertically integrated stream of engineering design and analysis courses offered from second year through to final year. By immersing students in realistic and team oriented integrated learning activities, analysis and problem solving skills were simultaneously developed with teamwork and communication skills (our core graduate capabilities). As demonstrated here through a sample of project outcomes, the author managed to arouse enough curiosity and enthusiasm in them to foster independent learning which, in our view, would encourage them to become reflective practitioners later in their careers. A brief sampling of curricula and learning outcomes is presented to support the conceptual model illustrated in Figure 1. They are discussed under three key performance indicators which are of great importance to future engineers and highly valued by the Australian building industry. Namely, gaining skills in co-rational decision making, skills in virtual mobility and work ethics are all required to succeed in inter-discipline and intra-discipline engineering services.

4.1 Skills in co-rational design

In a traditional structural engineering design office setting, there were two general process mechanisms evident – the pre-rational approach and the post-rational approach. In a pre-rational design process engineered structural solutions precede the architectural form. This approach is seldom used in current practice. In a post-rational design process architectural form finding precedes the engineering design process. This is probably the most common practice today. In both these traditional approaches process becomes inherently problematic and defeats the purpose as the architect or the engineer is in a reactive mode. This is especially the case when one considers the advances in digital architecture and its impact on engineering [6]. The co-rational design approach, which seems to be the future trend in the building industry, is more synergistic, encouraging the optimal outcome for stakeholders. In fact, from a constructability point of view, such co-rational design teams should also include building services and construction experts as well.

It is believed that during the Roman era the person in charge had a good understanding of engineering aspects such as the strength of material, structural stability, constructability as well as the architectural aspects such as form and aesthetic. Ardill [7] argues that this was the idea on which the “Master Builder” concept was evolved. Although this is still the reality, as discussed above, in practice universities around the world chose to educate and train the student counterparts in these complimenting fields in a number of different discipline specific silos which provide few opportunities for interactive team play. We observe this as a major anomaly which, in our view, warrants attention of the building educators. Our response is to bridge this apparent intra-discipline gap by engaging students and staff in simulated co-rational design projects.
A project based learning module was therefore developed under the theme “long-span and high-rise structures”. There is an ever increasing trend in constructing all-weather multi-purpose venues and tall buildings where state-of-the-art structural concepts and the new generation of materials and analysis tools are involved. Information on such high profile structures, designed and developed by the well known architect/engineer syndicates around the world on a competitive basis, serve as great case studies and learning resource for our students and staff. By engaging students and staff from engineering and architecture, we managed to mimic and enrich their learning and insight into how complementing fields can learn from one another. Figures 2(a) – 2 (d) present a representative sample of student projects developed through this course.

Figure 2: Students Co-rationally Design Long-Span and High-rise Structures

4.2 Skills in virtual mobility

Virtual mobility here refers to gaining communication and collaboration skills in order to transcend cultural, geographic, language and discipline barriers to establish new professional affiliations. We strongly believe our civil engineering graduates need such skills in the future, especially because the building industry is an increasingly globalising market. We have simulated a learning environment to provide experience and the gaining of such skills by engaging them in an internationally collaborated project. In this particular course our students have to engage with their counterparts, whom they have never met, from an international university to conduct a collaborative joint project. Our initial motivation was to provide an opportunity to expose students to international collaboration in order to gain skills in virtual mobility. The author has developed the pedagogy and provided the leadership for this ambitious project initiative, the first of it’s kind, between RMIT University, Melbourne, Australia and the Ecole Spéciale des Travaux Publics du Bâtiment at de L’Industrie (ESTP), Paris. In this course each project team comprised of two RMIT students and two ESTP students. The course, named “sustaining historical structures”, was designed in content to teach structural pathologies and structural forensics involved in extending the life of aging structures. There is limited opportunity for Australian students, being educated in a relatively young country, to investigate and learn about these aspects and how world renowned monuments are normally preserved.
beyond their designed life. Students from each university have met and communicated in a virtual class room environment over two months in scoping, researching and jointly investigating a monument in Paris of their choice. This was followed by a visit to Paris for two weeks where students were to meet their team members in person for the first time and to finalise their project and make a presentation to an international academic panel. The idea was successfully launched in the summer of 2004/05 involving nine such teams. A total of 36 students took part from both universities, investigating nine world renowned monuments. All involved - students, the ESTP academic team and the RMIT team – were unanimous in their enthusiasm as to the success of the program. This success was measured in both the quality of the academic program and the interaction between students on an academic and social level. It is refreshing to see how such an ambitious and far reaching project can speed up their process of maturing to international arena.

4.3 Skills in negotiating more than one solution with intra-disciplinary and inter-disciplinary work environs

To our great disappointment, engineering students who are meant to be inherently pragmatic, logical thinkers with excellent numerical and reasoning skills appear to in fact be educated and trained to become “single solution” seekers. It is intriguing to see that within our traditional education paradigm, significant class time, effort and rewards appear to be granted in calculating a “decision”, to a third decimal accuracy where as a rough estimate leads to the same outcome. More interestingly, students have no appreciation whether their solution could be acceptable to other stakeholders. It appears to us that we need to provide enough learning experiences within the classroom for our students to learn this reality and when and how to arrest obsession of over engineering, and to demonstrate that although the intent is good such endeavours can be perceived as being inefficient.

We were also keen to establish a leaning environment within which inter-disciplinary skills can be sharpened and students could experience how interface issues can become critical during the design and developing stage of a project. Here inter-disciplinary refers to the major specialization streams within the field of civil engineering such as water resources, structural, geotechnical and project management. This project based learning module was also intended to integrate three years of learning in different course to come together in a major project outcome.

The same group of students were again rallied, this time under the theme “re-imagining Australian suburb” to develop a medium density township with a sustainability focus. Such a task obviously demands a wide spectrum of expertise and skills and needs to work within a well coordinated complex organization structure. The Green Suburb Project is a 30 hectare development project to cater for a population of 2000 with 1-2% growth over a 50 year planning horizon. The project evolves in three phases. The first phase is to engage students through the competition between design consortia for the project, and through them conceiving and developing a master plan. A typical design consortium comprises of a mix of 8-10 students from different specialisation fields. The second phase is to engage students as part of a chosen specialist sub-team engineering and documenting civil works within the consortium; namely
earthworks, roads, storm water drainage, and water supply and wastewater treatment. The third phase is to engage students, as individuals, in designing and documenting a building structure of their choice. The key motives are to simulate an environment where students see the “big picture” issues. That is, to experience and resolve typical interface problems for a coherent design, as mentioned, integrating their prior learning in water resources, geotechnical engineering, surveying, project management, transport, and structures. Figures 3 provide a representative sample of student project outcomes achieved through this course.

![Inter-disciplinary Green Suburb Project Involving Specialising Streams of Civil Engineering](image)

Figure 3: Inter-disciplinary Green Suburb Project Involving Specialising Streams of Civil Engineering

It is refreshing to note that in 2005, we used the tsunami as a catalyst to positively engage students in developing planned townships for tsunami affected regions. Instead of “Re-imagining the Australian suburb” students were engaged in developing a master plan for a new township to replace washed away unplanned cities in the region including in Sri Lanka. This demonstrated the strength of using a “theme” as a backdrop in curricular development, where real engineering issues can be taken on board with least effort. I was amazed at the vigour and commitment students showed in completing and documenting the task in 2005. The most interesting aspect was how swiftly students adapted themselves to think globally and their sense of a ‘duty of care’.

One intra-disciplinary example is presented under the co-rational design section. Figures 4 illustrate a recently concluded intra-discipline pilot study where a team of thirteen students from engineering, social planning, architecture and management came together to propose a modern, responsive community centre for the Victorian Growth Authority, which was ultimately well received and commended by the client.
5. Conclusions

- The tertiary education paradigm is currently being revived in many universities around the world which are aligning to a capability agenda. The need to create Work Integrated Learning environments in professional education is gaining recognition and Project Based Learning is regarded as the best form of delivery of a capability driven agenda. However, it must be emphasised that the intension is not to undermine basic and fundamental discipline specific skills but to enhance its application by creating exciting learning environments simulating the real work place. In other words, content is taught within the context of processes, emotional and behavioural patterns of the real workplace, providing students the opportunity to experience first hand.

- The skills needed by the quality educators and the future graduates for success are changing rapidly and can no longer be regarded as pseudo-static.

- Knowledge is widely and freely accessible. Training opportunities and experiencing first hand how to apply know-how in the working life are the reasons for students attending educational institutions. This can be achieved while safeguarding and nurturing tertiary institutions’ traditional position as the institutions of scholarly learning.

References

[1] Institute of Engineers (1999), Manual for the accreditation of professional engineering programs, Institute of Engineers, 1999, Australia.

[2] RMIT (2002), Project Plan – program design and renewal project, Faculty of Engineering, RMIT University, Melbourne, Australia.


