Harmony in Engineering Curricula: Striking a Balance between Traditional, PBL and WIL Approaches to Learning and Teaching

Natalie Gamble  
Griffith University, Australia  
n.gamble@griffith.edu.au

Carol-joy Patrick  
Griffith University, Australia  
ej.patrick@griffith.edu.au

Rodney A. Stewart  
Griffith University, Australia  
r.stewart@griffith.edu.au

Charles Lemckert  
Griffith University, Australia  
c.lemckert@griffith.edu.au

Abstract: Traditional classroom-based teaching, problem-based learning (PBL) and Work Integrated Learning (WIL) are three commonly used approaches to Learning & Teaching (L&T) in universities. All these approaches have their place in engineering education, but it is important to recognise the advantages and disadvantages associated with each. As contemporary learning approaches grow in popularity in engineering curricula, it is critical for academic staff to ensure they strike a balance between providing students with the theoretical/conceptual knowledge they require for problem-solving, and the hands-on experience they need to ensure they are suitably educated and employable when they graduate. This paper provides an overview of Griffith University’s revised Bachelor of Engineering (Civil Engineering) program, and demonstrates how academic staff at Griffith University have been striving to strike a balance between the provision of fundamental engineering knowledge and the practical application of that knowledge through a tiered approach to L&T. Students are progressively introduced to PBL, beginning in first year with case studies and small group tasks, and culminating in the final year with a capstone PBL subject as well as an independent WIL exercise that integrates their learning from preceding years.

Evidence for a Blended Approach to Engineering Education

Researchers have recognised the benefits associated with problem-based learning (PBL) for decades, and it is now commonplace in many qualifications both in Australia and around the world. It was conceived in the 1960s as an alternative to the traditional classroom-based teaching style for medical students (Rhem, 1998; Chin, 2001). Studies confirm that graduates from many disciplines emerge from university with poor employability skills (King, 2008), and industry feedback suggests that engineering students are particularly lacking. Now, PBL is beginning to assimilate into engineering curricula, although for this discipline, it is still in its relative infancy. PBL may just turn out to be the catalyst that is required to produce more professionally competent engineering graduates.
PBL is a teaching methodology that engages the students, and gives them a context and a greater understanding of their skills and how they may be applied in the real world (Rhem, 1998). In PBL, groups of students are typically presented with a life-like problem or task (Lemckert, 1998), and they work together to identify appropriate solutions to the problem. It fosters active learning and research skills, facilitates higher levels of comprehension, and affirms the relevance of the theories that underpin the processes (Gibson, 2003).

PBL also allows students to develop the ‘soft skills’ that aren’t necessarily part of their qualification – they are actively involved in team work, and are given the opportunity to develop their interpersonal and communication skills, their project management aptitude, their critical thinking and problem-solving capabilities, and generally, an understanding of business and management processes (Du and Kolmos, 2006). It makes the transition from the classroom to the workforce significantly easier because it imbues student participants with a sense of preparedness (Hadgraft, 1995; Kanet and Barut, 2003; Du and Kolmos, 2006).

In contemporary engineering education programs, there is a real push to develop graduates who have more than just the theoretical knowledge and technical skills that are associated with ‘traditional’ (theory focused) engineering. ‘Traditional’ engineers are not what industry is looking for today. Instead, businesses are seeking graduates who can do more than merely develop products and improve technologies – they must be practical and creative, able to work with different people, quick to solve problems and make critical business decisions, and be professional and ethical in their conduct (Mills and Treagust, 2003). These are the outcomes that a well structured PBL program should achieve (BIHECC Report, 2007).

In response to these industry demands, Engineers Australia amended their membership competency standards to include PBL outcomes, such as team work, problem-solving, communication and self-directed learning skills (de Silva, 2004). Professional bodies and associations in other countries, including the USA and the UK, have also revised their criteria in an attempt to shift the focus in engineering education from ‘what is being taught’, to concentrate instead on ‘what is being learned’ (Mills and Treagust 2003). Moreover, generic graduate attributes are now recognised and valued by professional bodies (de Silva, 2004).

On the PBL continuum, work-integrated learning (WIL) would be positioned at one end, with fundamental engineering theory at the opposite end. There are two schools of thought on PBL, and the extremes on the continuum are best exemplified by the approaches of two continents (Richardson, 1994, cited in Kolari et al., 2006). In Asia, engineering education is typically theory-driven, with students spending minimal time in laboratories or obtaining hands-on experience. Instead, they focus on established formulae and calculations (Huang, 2005). At the opposite end is the European attitude, which is driven by experiential learning. Here, students spend the majority of their education undertaking field work and gaining practical experience in anticipation of their post-university life (Du and Kolmos, 2006).

There are advantages and disadvantages to each of these approaches. The theoretical perspective is critical for students to develop conceptual knowledge. Typically, students spend long hours studying and memorising text, but the learning process takes place independent of any real context. Thus the knowledge they acquire is only surface-level (Kolari et al., 2006). Deeper learning occurs when students can see how their knowledge may be applied in the real world (Cawley, 1989), and this is the aim and case in WIL programs, and in some PBL programs. However, studies indicate that in order for WIL to be an effective mode of learning, students must understand the principles of what they are practising (Kember et al., 1995, cited in Kolari et al., 2006). Without the integration of the theoretical background and appropriate program design, workplace learning becomes inefficient, and is merely ‘work experience’ rather than a proper WIL experience. Such an experience sees the successful integration of theory and practice, which solidifies both the theoretical knowledge and practical capabilities of the learner (Smollins, 1999).

In summary, PBL is a balanced approach that blends aspects of traditional and contemporary teaching and learning styles, offering students a learning experience that demonstrates the
significance of the underlying theories, and teaching students how those theories relate to real-world problems. Students learn to practice their profession in a ‘safe’ environment (Mills and Treagust, 2003; Rhem, 1998), and it affords teaching staff greater control over academic outcomes than a WIL project conducted in the workplace. Today, most tertiary institutions in Australia incorporate an element of PBL in their curricula, although the scale varies, and Griffith University is no exception.

**Case Study – Bachelor of Engineering (Civil Engineering)**

As a new generation Australian university, Griffith University has always been responsive to feedback from internal reviews, students and industry, modifying its degrees to provide the outcomes sought by multiple parties. It takes a ‘blended’ approach to teaching, recognising the value that comes from studying fundamental engineering concepts, but also showing an appreciation for the benefits associated with PBL and WIL experiences. Consequently, Griffith University has developed an engineering program across all of its offered disciplines that progressively introduces students to PBL/WIL over four years of study, beginning with small scale PBL scenarios in first year, and working up to a fully integrated full-semester WIL project and subsequent PBL course in the final year. This will ensure that Griffith University continues to produce quality, work-ready engineering graduates that will meet the needs of recruiters.

Griffith University’s approach to teaching engineering is flexible, and the curriculum continues to evolve. In 2009, for example, the School of Engineering will be introducing a modified program for the commencing Bachelor of Engineering (Civil Engineering) students. The revised degree further incorporates elements of both traditional classroom-based teaching and PBL, culminating in a semester-long WIL project in the final year. This new program includes some distinct PBL and WIL focused courses intended to integrate previous learning, as well as numerous courses with significant PBL elements. This blend is unique to Griffith University, and allows the use of PBL practices without placing a strain on the limited teaching and other resources. Figure 1 maps the learning pathways from first through to fourth year and the links between traditional-type and PBL courses.

At Griffith University, first year students enrol in Engineering Practice, which is a core unit in the program. This is predominantly a traditional teaching-style program, but students are introduced to PBL with case studies in tutorials, and small design assignments. This balance is considered critical for first year students, as the theoretical component ensures students are familiar with engineering concepts, and the PBL component stimulates their ongoing interest in engineering. In comparison to the existing course, the result was improved student learning and a greater student retention rate.

In the second year, Structural Design and Hydrology provide students with an opportunity to work in groups on small simulated design projects. Here, they begin to develop some of their soft skills, including their interpersonal and communication skills, and their capacity to work in teams. Again, the overall second year approach is predominantly traditional, but the PBL component is greater than for first year students (Figure 1).

As third year students, the Civil Engineering Design Project course sees them begin to integrate different aspects of their fundamental studies in soil mechanics, civil design fundamentals, hydraulics and hydrology. Students are presented with a civil design problem and associated documentation (including survey drawings, soil reports, municipal requirements, and site locality) and are required to produce civil design drawings and engineering specifications, based on the information they have been given. Moreover, four other applied courses have a significant component of PBL embedded into them (Figure 1). Again, the move towards independent learning is built into the program as students take on a life-like problem and produce accurate workable drawings and specifications.
Note: Solid arrows indicate direct linkages, dashed arrows show the general flow; while non linked courses will often be associated with most others more broadly.

**Figure 1: Learning Pathways for the 2009 Bachelor of Engineering (Civil Engineering)**

In the final year students complete two very different PBL programs – Integrated Design Project, and the Industrial Affiliates Program (IAP). In Integrated Design Project, students combine the knowledge they have acquired for an independently managed simulated civil/structural engineering project. And the IAP sees students spend a semester in industry, utilising the knowledge they have acquired throughout their degree (especially in the area of generic skills) to complete a real workplace project with meaningful outcomes for the organisation which hosts them. As a final note, all Discipline Electives taken up by third and final year courses will have a strong PBL focus (i.e. minimum of 50% PBL).

It is important to acknowledge that Griffith University students are provided with appropriate levels of academic support as they journey towards independent thinking. The level of program support and classroom contact hours for first year students is substantially different to that provided for final year students. As first year students, resources that will assist students with their PBL work are readily available, and by the time students reach their final year, they are able to research independently to identify their own resources. First year students spend more time in the classroom than their fourth year counterparts, but the fourth year WIL students have additional support mechanisms built into their program, including a workplace supervisor and an academic supervisor. They are eased out of the classroom and...
into the workplace, and they are supported by staff from the IAP office as well as their appointed mentors.

**Graduate Outcomes**

At Griffith University, the importance of lifelong learning and its applicability to personal and professional development has been well recognised (Patrick and Crebert, 2004b). The value of these skills and other graduate attributes has been stated explicitly in the University’s Strategic Plan (2003-2007), and the need for programs that develop such skills has become a priority for academic staff.

King (2008) identified several generic competencies that tend to be underdeveloped in university graduates, including creativity, communication skills, business acumen, and problem solving. Engineering graduates were singled out for being particularly lax in these areas. Additionally, the report affirmed that employers expressed dissatisfaction with these same shortcomings.

Participation in a WIL project through the Industrial Affiliates Program (IAP) has been shown to significantly improve graduate attribute outcomes for final year engineering students (Patrick and Crebert, 2003). The results of this study showed that students with WIL experience not only demonstrated enhanced generic skills, but that they also have a greater understanding of the significance of those skills in industry.

Consequently, staff from the Griffith School of Engineering have worked to devise a curriculum that provides a balanced approach to learning and teaching, integrating traditional teaching methodologies with contemporary approaches, resulting in well-rounded engineering graduates. This approach has resulted in a blended curriculum that is not only considerate of the theoretical constructs that underpin much of what engineering is based on, but also flexible enough to allow students to develop individually and to acquire the soft skills that will see them make the transition from the classroom to the workforce with confidence and success. As a final note, an in-depth evaluation of Graduates Outcomes will be conducted pre- and post- implementation of the blended Bachelor of Engineering Program, commencing in 2009, to measure the extent of improvements or otherwise.

**Conclusion**

The literature clearly makes a case for the inclusion of PBL in engineering curricula, especially when one considers the paradigm shift imposed on engineering schools by Engineers Australia. This new requirement has seen a change in the approach engineering schools take to the design and content of their programs, as they strive to strike a balance between traditional teaching models and contemporary approaches. Griffith University has endeavoured to develop a new program for its 2009 Civil Engineering cohort that balances the theoretical constructs that are critical from a technical perspective, as well as the hands-on skills that are demanded by employers with its integrated approach.

Best practice seems to suggest that the incremental inclusion of PBL from the first year of an engineering qualification not only improves student retention rates, but also enhances the self-directed learning competency, which in turn eases the transition from the classroom to the workplace. A significant WIL and/or PBL capstone project in the final year ensures that engineering students are able to integrate their learning in such a way that it translates readily to real-life situations. This is one of the desired outcomes of PBL programs in general, and it is the model that Griffith School of Engineering has emulated with its new curriculum.

Studies indicate that PBL contributes significantly to the development of generic skills in graduates, and enhances learning outcomes and knowledge retention, providing the theoretical foundations have been laid in the early years. Given this past evidence, it is anticipated that future graduates from Griffith University’s School of Engineering will not only be technically competent, but will also be equipped with the attitudinal and skill objectives that make them sought-after in industry.
References


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