Accreditation Inspired Project Oriented Design Based Learning Curriculum for Engineering Education

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ABSTRACT

Purpose:

This paper focuses on accreditation inspired project oriented design based learning (PODBL) curriculum for engineering education. To be an accredited curriculum, education programs must incorporate graduate attributes mentioned by program accrediting professional bodies. This paper firstly looks at the program educational objectives, student outcomes, assessment methods and evaluation of different undergraduate engineering programs that shows how design is practiced and incorporated as an important element of the graduate attributes through project oriented design based learning curriculum inspired by professional accreditation requirements. It describes a detailed outcomes based category mapping of the Deakin University Engineering programs to the Engineers Australia, Accreditation Board for Engineering and Technology, and the European Accreditation of Engineering Programmes. The paper also describes a detailed outcomes based mapping matrix, which could be used to evidence the alignment of accreditation requirements with engineering learning outcomes.

Design/Methodology:

This research study illustrates mapped outcomes by analyzing each study unit of all different engineering disciplines against the three professional accrediting bodies' elements of competencies for professional engineers. The detailed

outcomes based mapping matrix for the Electrical and Electronics major within the Bachelor of Engineering at Deakin University was mapped against the Engineers Australia Stage 1 competencies and the elements of competencies for Professional Engineers. The purpose of this mapping was to identify the relative occurrence of the various Stage 1 competencies as evidenced by the assignment of unit learning outcomes against elements of competency.

Findings:

The mapping result illustrates that every Deakin engineering discipline has 'design work' as a most important element or aspect of engineering. These mapping results show that Deakin engineering is providing good practice in design and technology through projects. The final paper is intended to show the detailed outcome based mapping matrix that could be used to evidence the alignment of accreditation requirements with engineering learning outcomes.

Conclusions:

There are many research studies that justify the benefits of design-based learning (DBL). By looking at the world accreditation bodies focus on design based learning as an approach for learning and teaching, this research identifies the need to enhance important skills such as innovation and creativity through a holistic learning process that incorporates design based learning features. From the in-depth analysis of all program educational objectives, student outcomes, assessment methods and evaluation of different undergraduate engineering programs, it is clear that design can be learned and taught through project oriented design based learning approach in a convalescent way which is inspired by accreditation requirements.

Keywords: *Accreditation requirements, design based learning, Project Oriented design based learning, outcome based mapping matrix.*

INTRODUCTION

Accreditation is a periodic assessment of an education program for any discipline against the accreditation standards. Appropriately trained and independent practicing engineers from both industry and academic will be the peer reviewers for a professional accreditation panel. Graduate attributes are the required benchmarks for students to attain their specific qualities and abilities within a higher education institute. Most higher education institutions identify a list of expected graduate attributes or outcomes that are incorporated in their educational programs to be accredited by a accrediting professional body such as Engineers Australia (EA) in Australia, Accreditation Board of Engineering and Technology (ABET) in United States, and the European Accreditation of Engineering Programs (EUR-ACE) in Europe. Engineers Australia is a professional accreditation body for graduate and higher education programs in engineering. When students graduate from an accredited engineering program, they are

required to be assessed by the relevant professional accrediting body to become a qualified engineering graduate.

WORLD ACCREDITATION REQUIREMENTS

Implementing the graduate attributes in professional education programs varies from one institute to another. Each attribute has a range of elements that students must demonstrate depending on the comprehensive program structure requirements. When identifying graduate attributes particularly for undergraduate engineering programs in Australia, the program accrediting body (EA) initiates a set of attribute elements mentioned in "Stage1 competencies and elements of competency"(EA, 2012). It states that one of the important engineering application ability is application of systematic engineering synthesis and design processes. Every unit outcomes in all engineering courses should meet the standards required by the newly introduced Tertiary Education Quality and Standards Agency (TEQSA) and Australian Qualifications Framework (AQF) to provide a high quality education to students. Figure 1 shows overall percentage of three professional accrediting bodies' standards in incorporating design, project and practice level of student outcomes in accredited engineering programs.

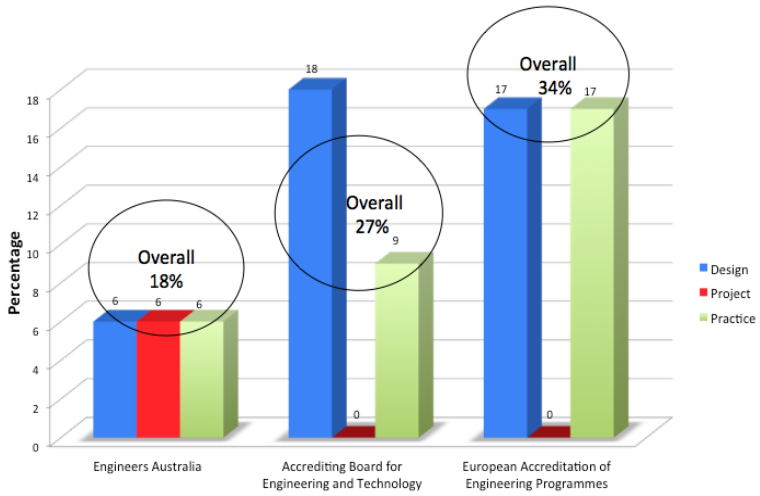

Figure 1: World Accreditation bodies' focus on Design Based Learning

Figure 1 illustrates that large amount of the overall accreditation competency elements of all three, Engineers Australia (18%)(EA, 2012), Accreditation Board for Engineering and Technology (27%)(ABET, 2012-2013), and the European Accreditation of Engineering Programmes (34%)(ENAEE, 2008) focus on design processes, ability to design, engineering design practice as important attributes of the engineering outcomes based education.

LEARNING PRINCIPLES OF THE MODEL

The learning principles are developed to provide a structure for the teaching and learning process. These principles are not standards or curriculum statements but they provide strong basement for an effective pedagogy. It ensures the teachers' involvement in teaching that fulfills the students expected standards (Erik De Graaff and Anette Kolmos, 2007).

- Participant directed or self-directed learning – Through this learning principle, students completing a research or investigate project on an assigned topic by working independently which will improve their personal development, problem solving, decision making skills and technical competence.
- Activity based learning – It is an action-oriented way to teach, which encourages the participants to get involved in intelligently designed activities and learn through their own experience. It involves activities such as research, decision-making and writing that motivate the students to get an opportunity to acquire deeper learning (Erik De Graaff and Anettee Kolmos, 2003).
- Interdisciplinary learning – A common goal of understanding unites the various methods and acknowledges a common or shared subject or problem. It enables students learning through exploring their knowledge across various disciplines. It provides opportunities for students to develop their awareness and understanding of problems across different subject areas.
- Analytical learning – A process where theory and practice come together to provide a unique solution that extends the students' lifelong learning.
- Team based learning – The team based learning aspect is a social approach where learning takes place through dialogue and communication. The majority of the learning process takes place in group or teams. Students got the opportunity to develop their personal competencies.

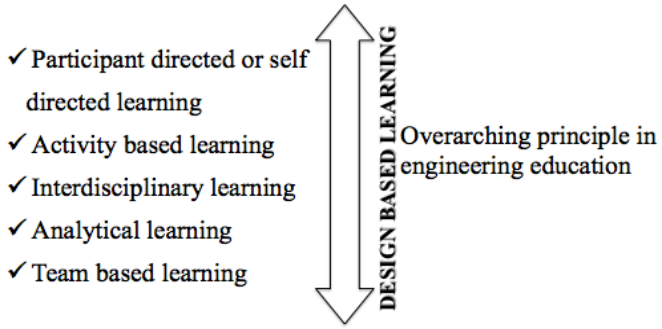

Figure 2: Learning principles relating to Design Based Learning

Figure 2 shows design-based learning as an overarching principle that incorporates all of the above learning principles. The learning principles described here show a change in curriculum towards a student centered learning in engineering.

Design Based Learning

Design based learning (DBL) is a self-directed approach in which students initiate learning by designing creative and innovative practical solutions which fulfil academic and industry expectations. Design based learning is an effective approach for learning that is centred on a design problem solving structure adopted from a combination of problem and project based learning. Design projects have been used to motivate and teach science in elementary, middle, and high school classrooms and can help to open doors to possible engineering careers. Design based learning has been implemented more than ten years ago, however it is a concept that still needs further development. Therefore it is very important to characterise DBL as an educational concept in higher engineering education (Dopplet, 2008; S.M. Gómez Puente, 2011; Yaron Doppelt, 2007).

To provide students with a better practice in design and technology, DBL involves several advantages such as good design that meets the social, economic and industrial needs. It is also an active learning process that makes students to practice and recognize different learning styles and team based activity that support learning and sharing through cooperative methods (de Vere, 2009; Wijnen, 1999). Teaching with a purpose of facilitating creativity helps students learn more about their own creative abilities and to attain greater personal and professional success and satisfaction through creative efforts (D.J. Treffinger, 1994; Liu, 2004). The important goal for educators is to encourage students learning on design process, which develops their creative thinking skills in engineering (Davis, 1998; Doppelt, 2009).

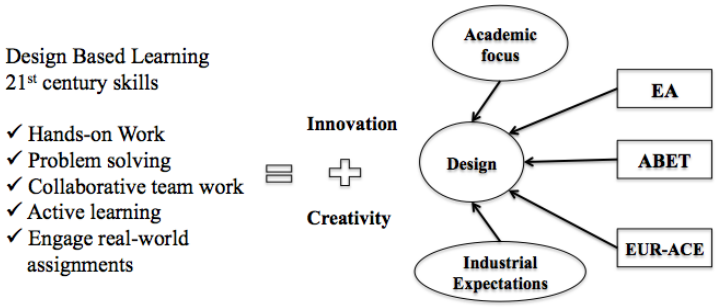

Figure 3: Design focused education

Figure 3 illustrates the focus of three professional accreditation bodies; focus of academic and industry requirements is on design, which incorporates innovation and creativity as an important skills. A design based learning environment helps a curriculum to practice 21st Century Skills for students such as hands-on work,

problem solving, collaborative teamwork, active learning, and engagement with real-world assignments.

Project-Oriented Design Based Learning Curriculum

The newly proposed approach, Project-oriented design based learning is applicable to motivate the students and also to teach engineering design in classrooms to get more practical experience that fulfill the academics and industry needs. Project-oriented design based learning is established to have a positive effect on student content knowledge and the development of skills such as innovation and creativity which increases their motivation and engagement (Chandrasekaran, 2012b). It is an interesting research work to develop a framework and implement a PODBL approach in meaningful ways. The research aim is to find an approach, a method or a framework, which will balance the teaching and learning by incorporating design, innovation and creative skills in engineering education.

When students are involved in solving a problem through a creative project, they will experience meaningful ideas that allow them to analyse the suitable solution for it. It is a basic quality for a professional to deal with problems and to find solutions for the problems. Educational institutions need to teach and train students not only to be a problem solver but also should think about achieving innovative and creative skills. There are different kinds of problems existing in engineering; Design problems are most important one that attracted young and imaginative students'. The Projects are considered to be the best way of student interaction with teachers (Chandrasekaran, 2012a).

In addition to providing students with a better practise in design and technology, project oriented design based learning will involve several advantages such as good design that meets the social, economic and industrial needs. This is an active learning process, which makes the students to practice and recognize different learning styles that support learning and sharing through cooperative methods (Chandrasekaran, 2012c).

FOCUS OF PODBL AT DEAKIN ENGINEERING

At Deakin University, students undertake common subjects in their first year and then choose a discipline to specialise in. This includes civil, electrical and electronics, mechanical or mechatronics and robotics engineering. This format allowed students to make a more informed decision and to gain a broad base of knowledge in engineering. These undergraduate engineering courses are designed to meet the requirements of Engineers Australia (EA). This research paper looks into the program educational objectives, student outcomes, assessment methods and evaluation of different undergraduate engineering programs at Deakin University that shows how engineering design is practiced and incorporated as an important element of the graduate attributes through project oriented design based learning curriculum inspired by professional accreditation requirements.

Figure 4 illustrates the percentage of design, project and practice in all four different disciplines at Deakin engineering. The results were mapped through an analysis of each study unit of particular disciplines against the three professional accrediting bodies' elements of competencies for Professional Engineers, as shown in figure 4. The research paper looked into the program educational objectives, student outcomes, assessment methods and evaluation of all 32 units in every discipline. Through qualitative analysis, the data was mapped against elements of competencies to obtain the percentage of design, project and practice.

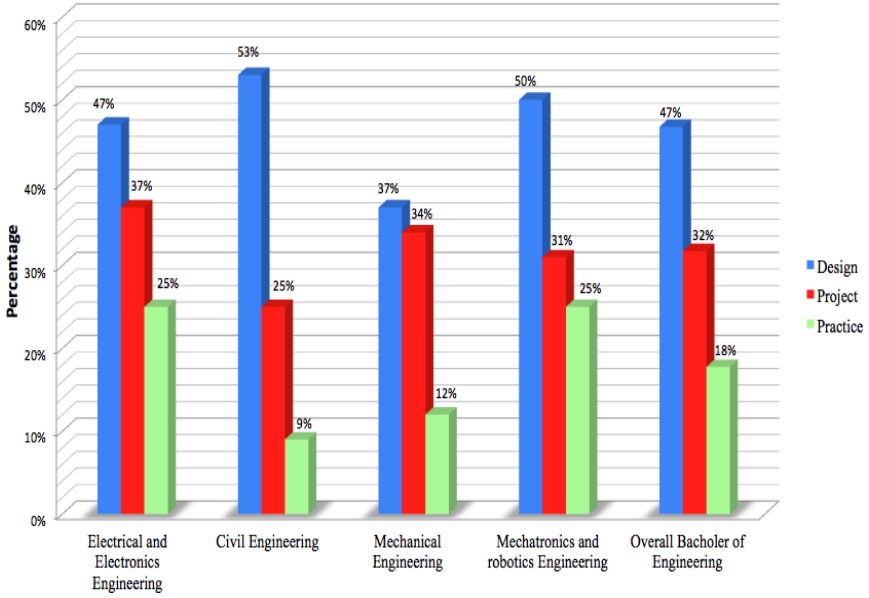

Figure 4: Focus of PODBL in various disciplines of Deakin engineering

The mapping results illustrate that every engineering discipline has design as a most important element or aspect with Civil at 53%, Mechatronics and robotics at 50%, Electrical and Electronics at 47%, and Mechanical at 37%. 'Project' work forms 37% of the Electrical and Electronics, 34% of the Mechanical stream, 31% in Mechatronics and 25% in Civil engineering. The percentage of 'practice' is 25% in Electrical and Electronics, 25% in Mechatronics, 12% in Mechanical and 9% in Civil engineering. The above mapping results show that Deakin engineering is providing good practice in design and technology through projects. The overall percentage of Design is 47%, Project 32% and Practice 18% in all Bachelors of engineering disciplines. Figure 4 shows detailed outcomes based category mapping of the Deakin University Engineering programs to the Engineers Australia, Accreditation Board for Engineering and Technology, and the European Accreditation of Engineering Programmes. It describes the implementation phase of Deakin University accreditation alignment with a focus on project oriented design-based learning in Electrical and Electronic engineering, Mechanical engineering, Civil engineering, Mechatronic and Robotics engineering.

OUTCOMES BASED MAPPING MATRIX

The research paper also describes a detailed outcomes based mapping matrix on electrical and electronics engineering as an example, which could be used to evidence the alignment of accreditation requirements with engineering learning outcomes. Based on the revised EA Stage 1 competencies it is proposed that knowledge and base, engineering application ability, and professional and personal attributes are the key elements of competency and part of the integrative learning principle for all Deakin Engineering graduates.

Electrical and Electronics engineering

The Electrical and Electronics major within the Bachelor of Engineering was mapped against the EA Stage 1 competencies and the elements of competencies for Professional Engineers. The purpose of this mapping was to identify the relative occurrence of the various Stage 1 competencies as evidence by the assignment of unit learning outcomes against elements of competency. The mapping can demonstrate the potential capability development and capacity building of students as they progress through the course. This capability and capacity development is framed by the unit learning outcomes, the learning activities comprising the unit of study, and of course assessment tasks to allow students to demonstrate their learning. Therefore, a total constructive alignment was achieved.

Table 1: Electrical and Electronics Majors' learning outcomes map to the Engineers Australia Stage 1 competency standards

Elements of Competency	PE1 – Knowledge and Skill Base						PE2 – Engineering Application Ability				PE3 – Professional and Personal Attributes					
	P1.1	P.1.2	P1.3	P1.4	P1.5	P1.6	P2.1	P2.2	P2.3	P2.4	P3.1	P3.2	P3.3	P3.4	P3.5	P3.6
Year 1	5	4	1	0	2	1	3	4	1	0	0	2	2	3	1	2
Year 2	4	3	2	1	1	3	2	3	2	3	1	4	3	3	3	3
Year 3	2	2	2	3	1	1	1	3	2	5	1	5	3	3	3	4
Year 4	1	0	3	5	3	3	2	4	4	5	7	5	4	3	6	2
Element total (weighted)	12	9	8	9	7	8	8	14	9	13	9	16	12	12	13	11
Element % pertaining to unit	23%	17%	15%	17%	13%	15%	18%	32%	20%	30%	13%	22%	16%	16%	18%	15%
Element total (weighted)	12	9	8	9	7	8	8	14	9	13	9	16	12	12	13	11
Element % pertaining to course	7%	5%	5%	5%	4%	5%	5%	8%	5%	8%	5%	10%	7%	7%	8%	6%
Unit total (weighted)	53						44				73					
Unit % pertaining to Course	31%						26%				43%					

Table 1 demonstrates in summary how the Electrical and Electronics Majors' learning outcomes map to the EA Stage 1 competency standards and the elements of competency. Looking across the Electrical and Electronics major, analysis reveals 31% of the overall course unit learning outcome-elements of competency contributes to Knowledge and Skill Based (PE1). It is interesting to note that 12%

of the overall course unit learning outcome-elements of competency is mapped specifically to comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline (P1.1), and conceptual understanding of the, mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline (P1.2).

Research analysis reveals approximately 57% of the courses' unit learning outcome-elements of competency contributing to Knowledge and Skill Base (PE1) and Engineering Application Ability (PE2) – the foundation of technical capability and capacity. Looking across the Electrical and Electronics Engineering major, analysis reveals a total of 26% of the courses unit outline-elements of competency contributing to Engineering Ability (PE2). From the total 26%, 8% is aligned to fluent application of engineering techniques, tools and resources (PE2.2), and 8% aligned to application of systematic approaches to the conduct and management of engineering projects (PE2.4).

A total of 43% of the overall courses' unit learning outcome-element of competency contributing to personal and professional attributes (PE3). From the 43%, 10% alignment is across effective oral and written communication in professional and lay domains (PE3.2), and 8% is across orderly management of self, and professional conduct (PE3.5). This is a clear indication that engineering is a combination of technical knowledge, engineering application ability, and professional and personal attributes. The above detailed outcomes based mapping matrix is used to evidence the alignment of accreditation requirements with engineering learning outcomes.

CONCLUSION

Project Oriented Design Based Learning (PODBL) is set to have a positive effect on student content knowledge and the development of skills such as collaboration, critical thinking, creativity, innovation, and problem solving which increases students' motivation and engagement. The research achieved in this paper would assist to develop and implement a framework for learning and teaching to solve design problems through accreditation inspired project oriented design based learning in engineering education. This research paper identifies the need to enhance important skills such as innovation and creativity through a whole learning process that incorporates design based learning features. From the in-depth analysis of all program educational objectives, student outcomes, assessment methods and evaluation of different undergraduate engineering programs, design can be learned and taught through a project oriented design based learning approach in a convalescent way which is inspired by the accreditation requirements.

REFERENCES

ABET, (2012-2013). Criteria for accrediting engineering programs effective for evaluations during the 2012-2013 accreditation cycle: Accreditation Borad of Engineering and Technology. http://abet.org/accreditation-criteria-policies-documents/

Chandrasekaran, S., Stojcevski, A., Littlefair, G., Joordens, M. (2012a). The Process of Design Based Learning: A Students' Prespectives. *Paper presented at the Australasian Association for Engineering Education (AAEE) Annual Conference 2012.*

Chandrasekaran, S., Stojcevski, A., Littlefair, G., Joordens, M. (2012b). Project Oriented Design Based Learning: Aligning Students' Views with Industry needs. Paper accepted at *International Journal of Engineering education*.

Chandrasekaran, S., Stojcevski, A., Littlefair,G., Joordens, M. (2012). Learning through Projects in Engineering Education. *Paper presented at the 40th SEFI Annual Conference 2012, Thessaloniki, Greece.*

Davis, M. (1998). Making case for Design-Based Learning.

De Vere, I. (2009). Developing creative engineers: a design approach to engineering education.

Doppelt, Y. (2009). Assessing creative thinking in design-based learning. *International Journal of Technology and Design Education*. 19(1), 55-65.

Dopplet, Y., Christian, M.M.M., Schunn, D., Silk, E., and Krysinski, D. (2008). Engagement and Achievements: A case study of Design-based learning in a science context. 19(2), 22-39.

Doppelt, Y., Schunn, C. D., (2007). Identifying students' perceptions of the important classroom features affecting learning aspects of a design-based learning environment.

EA, (2012). Stage1 competency standard for professional engineer. Australia: *EngineersAustralia*.http://engineersaustralia.org.au/sites/default/files/shado/Education/Program Accreditation/110318 Stage 1 Professional Engineer.pdf

ENAEE, (2008). EUR-ACE Framework standards for the accreditation of engineering programmes European Network for Accreditation of Engineering Education. http://enaee.eu/eur-ace-system

Gómez Puente, S. M., Van Eijck, M., and Jochems, W., (2011). Towards characterising design-based learning in engineering education: a review of the literature. *European Journal of Engineering Education*. 36(2), 137-149.

Kolmos, A., Graaff, E. De. (2007). Management of Change: *Sense Publisher.*

Kolmos, A., Graaff, E. De. (2003). Characteristics of Problem-Based Learning. *Journal of Engineering Education*. 19(5), 657-662.

Liu, Z., and Shonwette, D. J., (2004). Teaching creativity in engineering. *International Journal of Engineering education*. 20(5), 801-808.

Treffinger, D. J., Isaksen, S. G., and Dorval, K. B. (1994). Creative problem solving: an overview. Ablex Norwood, NJ.

Wijnen, W.H.F.W. (1999). Towards Design-Based Learning *Educational Service Centre*: Technische Universiteit Eindhoven.