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Learning through Projects in Engineering Education

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INTRODUCTION

What is a project? What happens when students engage in projects? are projects really meant to involve students as active learners? In the 21st century, does this project pedagogy help us to learn?

In project-based learning, students work in groups to solve challenging problems that are open-ended, curriculum-based, and often interdisciplinary. Firstly, students decide how to approach a problem and look for a solution based on their prior knowledge. They gather information from a variety of sources and synthesise, analyse, and derive knowledge from it.

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The involvement of adult skills of collaboration and reflection and the connection with a real world problem makes their learning valuable [1].

The main characteristic of a project is to make the learning environment student-centred. Teamwork is regarded as a way to construct knowledge. In each and every project, students develop different skills. The interdisciplinary nature of the problems the student will work on after their graduation is reflected in the content of the projects which are not bound to a specific curriculum area [2]. Students engaged in project-based learning activities "work in groups to solve challenging problems that are realistic, curriculum-based, and often interdisciplinary" [3]. Therefore projects are designed to allow students with a variety of different learning styles to demonstrate their acquired knowledge.

1.1 Project Based Learning

Project Based Learning is perceived to be a student centred approach to learning. It is predominantly task oriented and the project is often set by the facilitator. The students need to produce a solution to solve the problem and are then required to produce an outcome in the form of a report. Teaching is considered as an input directing the learning process. The problem is open ended and the focus is on the application and assimilation of previously acquired knowledge. In a project the production of an end product is the focus of the students.

In general it is an approach that closely reflects the professional behaviour of the engineering discipline. Engineering students require the opportunity to apply their knowledge to solve the design solutions through project-based learning rather than problem solving activities that do not provide a real outcome for evaluation. The dependence on a theory based science model does not prepare students for the 'practice of engineering' is one of the greatest criticisms of traditional engineering pedagogy [4]. Self-directed study is a big part of a student's responsibility. Engineering students need an opportunity to apply their science to resolve design solutions. These can be attained through project based learning modules. After the student have engaged in self-directed study, they must collaborate with peers and teachers in a problem resolution stage [5]. Projects will have varying complexity, but all will relate in some way to the fundamental theories and techniques of an engineering discipline. Small projects may only involve one area of engineering specialisation, but larger projects will be multidisciplinary not only involving engineers from different specialisations but other professional and non-professional personnel and teams. Successful completion of projects in practice requires the integration of all areas of an engineer's undergraduate training [6].

Principles of project based learning in common are as follows:

1. Student's work together in groups and collaborate on project activities.
2. A real world problem that affects the life of the student's is presented for investigation.
3. Student's discuss findings and consult the teacher for guidance, input, and feedback.
4. The maturity level of student's skills determines the degree of guidance provided by the teacher.
5. Final products resulting from project-based learning can be shared with the community-at-large, thus fostering ownership and responsible citizenship in addressing real world problems.

1.2 Design Based Learning

Design Based Learning (DBL) is considered as an educational model in which the aim to learn to design forms a major part of the curriculum and the study programs. It enables students to experience the construction of cognitive concepts as a result of designing and making individual, inventive, and creative projects, to initiate the learning process in accordance to their own preference, learning styles and various skills.



Design based learning is a concept, in which students work co-operatively and actively on multidisciplinary design tasks with the purpose of gaining qualification as a creative professional, capable of integrating all relevant aspects of education, in order to analyse existing technical systems, assess their quality, functionality and cost price and with the purpose of designing new products and systems with increased performance' [9]. In other words, DBL is a form of project-based learning in which students learn what they need to learn by hand's on approach while trying to design something. It provides the opportunity to practise discipline-related design skills as well as more general skills such as project skills, group skills and communication skills.

2.0 LEARNING THROUGH PROJECTS

Learning is an active process of investigation and creation based on the learner's interest, curiosity and experience and should result in expanded insights, knowledge and skills [10]. Graaff and Kolmos have summarised the main learning principles in three approaches such as learning approach, content approach and social approach. The learning approach as problem and project-based learning means that learning is organised around problems, the content approach concerns especially interdisciplinary learning and the social approach is team based learning [11]. One institution approach to project based learning may possibly look very much similar to another institution with adequate variance in the teaching methods and learning outcomes. According to Kolmos in [11], assignment project appears in the more traditional learning concept but the project or problem is centered around the notion of learning which gives the learner the opportunity to be involve in learning process. From this observation, university projects are mostly discipline projects, which are pigeonholed by subjects chosen beforehand, and industry projects are claiming problem project that determines the self-directed learning process. Establishing a new educational practice requires not only an understanding of new learning principles, but also understanding content-based curriculum issues, students' collaborative-learning process, and the development of new concepts of project based learning knowledge while establishing new organizational and institutional practices [12].

An engineering project activity is carried out either in conjunction with industry or simulates a real engineering work environment, thereby contributing to Work Integrated Learning (Self-directed project based learning in small groups). Many of the characteristics and benefits of project-based learning make it a relevant pedagogical strategy in engineering education where realistic problems can be posed. Design is the vehicle for learning and an inductive mode of teaching can be employed [13]. Project-based learning shifts away from teacher directed learning to a more student centred learning activities that focus on real world issues and practices. Learning through projects, students get opportunities to interact with their colleagues and make new colleagues through cooperative projects [14].

2.1 Projects Types

2.1.1 University Projects

University projects require students to undertake their own fact-finding and analysis, either from library/internet research or from gathering data empirically. The written report that comes from the project is usually in the form of a dissertation, which will contain sections on the project's inception, methods of inquiry, analysis, findings and conclusions. Engineering students have the opportunity to apply the concepts they learn in the classroom to hands-on projects with real-world applications. Students from all engineering majors enjoy the teamwork, problem-solving, and hands-on design that accompanies projects course opportunities from the freshman to the senior year. Projects often focus on creating innovative solutions to real-world problems, and students follow a process that mirrors the way engineers work in industry.



2.1.2 Industry Projects

Industry projects are project-based activities in partnership with an industry organisation. Students complete a research project focused on a given leisure, event or industry issue, problem or opportunity. Students mostly work independently on their selected topics. A teaching and learning approach where individuals conduct work activities (paid or voluntary), including research combined with intentional educational activities. The project involves a substantial research component, which can range from market research such as a questionnaire survey or focus groups, to observation, in-depth interviews or analysis of existing data. Workplaces may be in the private, public or not-for-profit sectors, ranging from multi-nationals, government agencies, small to medium enterprises. The client will receive the final project report detailing appropriate and actionable conclusions and recommendations.

Students work to meet two sets of requirements, those of the industrial client and the University's academic requirements. The scale and scope of the project are managed by the University academic supervisor. Students work on a project individually and if clients are willing to take on more than one student, they can have multiple projects being completed in one year.

2.1.3 Community Projects

Community projects provide a unique opportunity to extend student learning and broaden experiences beyond the academic environment. Students will be working closely with other students from different faculties to develop meaningful projects in support of university departments and disadvantaged groups in the community. It is a teaching and learning approach that combines community based initiatives with intentional educational activities.

These projects provide an opportunity to connect with other students from different faculties and get actively involved in the community. By doing these projects, students will not only be contributing their knowledge and skills towards helping others in the community, but they also gain a range of career related transferable skills such as networking, teamwork, marketing, supervising, coordinating, organizing, public speaking and more.

The key emphasis in community project learning is that of shared benefit and interchange for the student, the University, and the community agency or enterprise. The experience will also provide students with an opportunity to develop useful career networks and gain a broader understanding of the social and cultural needs of various groups in the community.

3.0 THE AUSTRALIAN ENGINEERING EDUCATION PROJECTS OVERVIEW

The majority of students undertake university studies to become a professional engineer. It is highly likely that students as future engineers will play an important role in addressing the key challenges of the 21st century such as providing water resources, infrastructure and communication, food supplies and health services and the development of a new sustainable energy economy. Research not only in Australia but world-wide shows that engineers should experience a broadly based undergraduate course, and later develop specialist skills by postgraduate study [15]. Author John Webster recommends that engineering courses must be outcome-oriented, and equip graduates for lifelong learning. In first year engineering, most of the time will be spent on the mathematical and scientific basics that underpin all engineering disciplines. The actual projects have been defined and structured by the teachers in the first year for students to obtain the fundamental knowledge. In second and third year, students work in industry and/or community projects, and industry practice should take place in the final year [16]. However, being a professional engineer is much more than the technical



application of these sciences. The research for this paper looked at Australian universities and their alignment to assessment. It was found that there is no examination for most of the engineering units which are based on learning through projects.

It was also found that engineering programs are starting to include different forms of project and problem approaches to learning. Most common implementation of project-based learning in engineering is for capstone design courses [17]. In this research, we looked at the undergraduate engineering units, which have project covering in one or two semesters of a course level. We undertook research for almost every university in Australia to gather information on learning through projects. Based on the teaching methods, learning outcomes and assessment measures, table 1 shows the percentage of project work done in a final year unit of study from various universities in Australia. The purpose of this research was to explore learning through projects and its pedagogical structure. It provides a report on its implementation and impact on project-based learning based on the results of a quantitative review of course units in undergraduate programs. It also summarises the different type of assessment methods undertaken in a university project, industry Project, or a community project. These projects are done by individual work or teamwork based on the structure of particular disciplines.

Table 1: Learning Through Projects – Universities in Australia

University	Project Work (%)	Assessment	Project Type	Project is based on
1	100%	Group Based Work	University Project	Research
2	50%	Group Based Work	University & Industry Projects	Design & Development
3	80%	Group Based Work	University Project	Infrastructure Design
4	100%	Individual Work	Industry Project	Professional project
5	100%	Group Based Work	University Project	Aerospace Design
6	100%	Individual Work	University Project	Research Project
7	100%	Individual Work	Industry Project	Design Project
8	100%	Individual Work	Industry Project	Engineering Project
9	100%	Individual Work	University Project	Engineering Design
10	100%	Individual Work	Industry Project	Integrated workplace
11	55%	Individual Work	University Project	Major Project
12	100%	Individual Work	University Project	Capstone Project
13	100%	Individual Work	University & Industry Projects	Final Year Project
14	80%	Group Based Work	University Project	Design Project
15	100%	Individual Work	University Project	Engineering Project
16	85%	Individual Work	Industry Project	Engineering Project
17	90%	Individual Work	University Project	Research Project
18	100%	Group Based Work	University Project	Group Project
19	100%	Group Based Work	University Project	Integrated Design
20	100%	Individual Work	Industry Project	Industry based
21	100%	Individual Work	University & Industry Projects	Thesis (Major Project)
22	100%	Individual Work	University Project	Project
23	80%	Individual Work	University Project	Major Project
24	80%	Individual Work	University Project	Engineering Project
25	100%	Individual Work	University Project	Engineering Project
26	80%	Individual Work	University & Industry Projects	Project Development



27	100%	Group Based Work	University & Industry Projects	Project
28	90%	Individual Work	University Project	Engineering Project
29	50%	Individual Work	University Project	Engineering design project

Figure 1 illustrates a graphical representation of the overall scenario in Australian universities related to learning through projects.

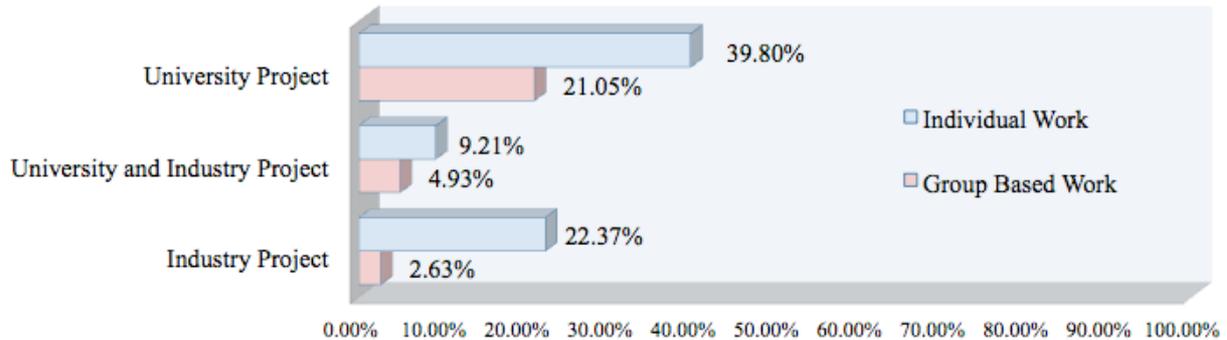


Fig. 1. Learning through projects in Australian Universities

4.0 ENGINEERING PROJECTS AT DEAKIN UNIVERSITY

Deakin University practices a trimester system in undergraduate engineering education, which is a unique structured program creating options for students to accelerate their degree or at commence at a convenient time of year. These trimesters run from March to June, July to October and November to February. Here in this curriculum, all courses have a built-in work placement component for academic recognition and for student's career opportunities. In these programs, students have the opportunity to take part in real industry experiences related to their studies through capstone projects offered in the first and second trimester of the final year. A project includes a number of skills gained during the course of study and is a reflection of what they can anticipate when entering employment as a graduate engineer. Projects have a research element, which may not necessarily be research based but rather industry specific. The learning style is predominantly student-led with direction from a supervisor through face-to-face or online meetings. This may be a virtual prototype of a product or a process. The final thesis is an intellectual piece of work documenting the major findings of the research project and reflecting on the progress and outcomes against some pre-agreed deliverables.

4.1 Learning Principles

On the basis of previous recommendations by the Engineers Australia as well as national and international research, it is very important and critical that a framework is defined and is unique to Engineering projects. Based on Engineers Australia Stage 1 competencies it is proposed here that fundamental knowledge base, engineering ability, and professional attributes are the key elements of competency and part of the integrative learning principle for a project approach.

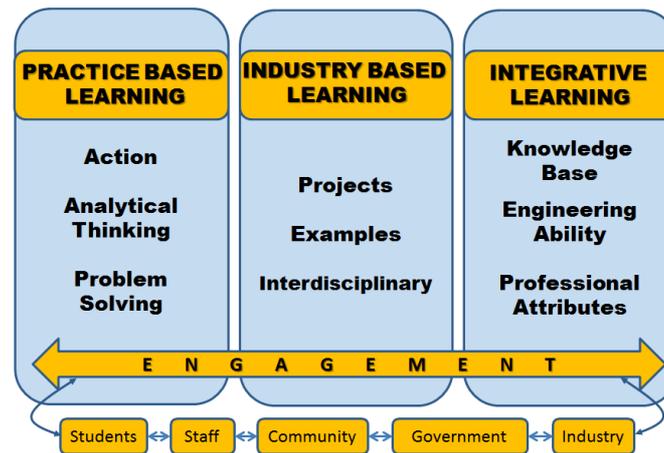


Fig. 2. Project approach learning principles

The other key learning principles forming part of the proposed model are practice based learning which includes action based learning, analytical thinking and problem solving, and industry based learning which is based on project learning and interdisciplinary learning. These three learning principles are all constructively aligned and are underpinned by constant engagement between students, staff, community, industry, and the government. This is illustrated in Figure 2.

5.0 CONCLUSIONS

Learning through projects has a positive effect on student content knowledge and the development of skills such as collaboration, critical thinking, and problem solving which increases their motivation and engagement. It is a challenging task for academic staff to implement a project-based approach and integrate technology into projects in meaningful ways. We recommend that learning through projects is considered as a way of interactive learning. It benefits all the stakeholders such as students, industry, community, and of course the university. It provides a framework for embedding experiential and rich learning activities, integrated with discipline-based curriculum that improves employment and career outcomes. The benefits of learning through projects include enhanced students' participation in the learning process (active learning and self-learning), enhanced communication skills, addressing of a wider set of learning styles, and promotion of critical and proactive thinking skills.

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