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Project-Oriented Design-Based Learning: Aligning Students' Views With Industry Needs*

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This paper focuses on the alignment of students' views on project-oriented design-based learning (PODBL) with today's industrial needs. A Collaborative relationship between academic institutions and industrial expectations is a significant process towards analytical thinking (linking the theory and practice). Improving students' knowledge as well as the students' transition into industry, requires efficient joint ventures by both learning institutions and industry partners. Project-based learning (PBL) is well developed and implemented in most engineering schools and departments around the world. What requires closer attention is the focus on design within this project-based learning framework. Today design projects have been used to motivate and teach science in elementary, middle, and high school classrooms. They are also used to assist students with possible science and engineering careers. For these reasons, design-based learning (DBL) is intended to be an effective approach to learning that is centered on a design problem-solving structure adopted for a problem-oriented project-based education. Based on an industry design forum, which the authors conducted in Melbourne, Australia in 2012, a research study was performed to investigate the industry and academic requirements for students focusing on achieving design skills. To transform the present situation in the academic teaching and learning environment and to fulfill industry needs, this research study also investigated the students' views on design skills.

Keywords: design-based learning; project-based learning; problem-oriented and project-based learning; industry needs

1. Introduction

Learning and Teaching institutions such as universities are considered to be the place of identification for new knowledge and industries are expected to be the environment where knowledge is transferred into practice. In learning and teaching institutions, practicing design is one of the fundamental processes in engineering and all other engineering activities related to it. Accreditation bodies such as the Accreditation Board for Engineering and Technology (ABET), Engineers Australia (EA), as well as the European Accreditation of Engineering Programs (EUR-ACE), all specify in some shape or form that the abilities to identify, formulate, and solve engineering problems are essential skills in an engineering program. When students require the opportunity to apply their knowledge to solve design problems, project-based learning is generally recorded as an innovative method for engineering education. With different learning styles, students are able to express their skills and talents through working with projects in authentic learning environments. However, integrating design and technology tools into science education will provide the students with dynamic learning opportunities to actively investigate and construct innovative design solutions. Hence a design-based learning environment helps a curriculum to practice 21st century skills such as hands-on work, problem solving, collaborative teamwork, innovative and creative designs, active learning, and to engage in real-world assignments.

This paper firstly presents research findings from a quantitative research analysis of student views about design-based learning in engineering. It illustrates the views of over 100 on-campus and off-campus (distance education) undergraduate engineering students from all year levels (year 1 to year 4) in a Bachelor of Engineering degree, and four engineering disciplines including mechanical engineering, civil engineering, electrical and electronics engineering, and Mechatronics and robotic engineering. In addition, a research study was performed through an industry design forum to investigate the industry requirements for students focusing on achieving design skills. The focus of the research is on the alignment of project-oriented design-based learning from a students' point of view with today's industrial requirements.

2. Project-based learning

Project-Based Learning (PBL) is a student-driven, teacher-facilitated approach to learning. The natural curiosity of students practicing by asking questions around their own problem-solving approaches is what makes them active learners. In a project, students develop a question and are guided by the teacher's supervision. Students' choice of developing their own problem or question is a key element in this approach. They can under-

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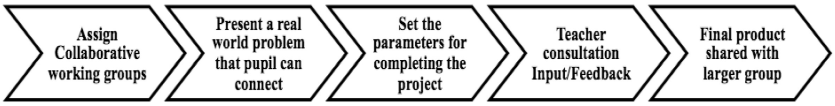

Fig. 1. Project-based learning.

stand, what is the problem or question, how to approach the problem, what are the different solutions to the problem, which is the most suitable approach to that question, discuss and share the ideas with peers in a team environment, share the solution or end result with the classroom to get their feedback, and make appropriate changes and prepare a report as an end product of the project, as illustrated in Fig. 1. Through this approach, students are encouraged to collaborate and communicate effectively, improve individual learning capability, and acquire self-management skills. The outcome of PBL is greater understanding of a topic, deeper learning, higher-level reading, and increased motivation to learn [1].

Engineering students require the opportunity to apply their knowledge to solve design problems through project-based learning rather than problem-solving activities that do not provide a real outcome for evaluation [2, 3]. Self-directed study is a big part of a student's responsibility in a project-based learning environment. After the student has engaged in self-directed study, they must collaborate with peers and teachers in a problem resolution stage [4]. Project-based learning has made a tremendous change in students' life in schools. It develops their self-responsibility for their learning processes, raises their self-esteem and self-confidence [5, 6].

3. Problem-oriented and Project-based learning

The implementation of problem-oriented and project-based curricula are due to the fact that the shift from teaching and learning is considered the most important innovative aspect of this educational concept. The task of the teacher is altered from transferring knowledge into facilitating the learning process of the students [7, 8]. This is a student-centered and interdisciplinary approach. Through this approach, students are thinking creatively and communicate clearly, problems are approached from theory to practice, and individual learning capability is transferred to teamwork. The curriculum design of POPBL is based on the PBL principles. The knowledge and competencies achieved through the POPBL approach are problem solving, project management and planning, contextual analysis, technical skills, cross-disciplinary knowledge, collaboration and communication [9, 10].

POPBL is an educational philosophy of creating a constructive learning environment in which students are able to integrate sustainable design into engineering. The project work is considered to be the pathway for students to gain interdisciplinary knowledge and development of skills in order to tackle the sustainable design challenges. Kolmos (author of POPBL) states that most of the engineering institutions in Europe are changing their traditional curriculum due to the expectations of new engineering skills required by the Accreditation of European Engineering Programmes (EUR-ACE). The traditional model is lecture centred; discipline oriented, and based on basic and applied technical knowledge. This particular approach is used to change teaching mode to learning mode, which incorporates interdisciplinary, student-centred, self-directed learning in the new model. Kolmos also states that the task of the teacher is altered from transferring knowledge into facilitating the learning process of the students [7, 11].

4. Design-based learning

Design-based learning (DBL) is a self-directed approach in which student initiates to learn themselves by designing creative and innovative hands on solutions which fulfill academic, society and industry expectations. It is an effective approach to learning that is centered on a design problem-solving structure adopted for the problem-oriented project-based education. It has been implemented for over the past 10 years but it is a concept, which needs further development. When students work under projects, they share their ideas with other team members and they are encouraged by formal and informal classroom activities. The industry is looking for professionals with design knowledge, which is integrated with creative and innovative thinking in interdisciplinary ways. Design projects have been used to motivate and teach science in elementary, middle, and high school classrooms. Integrating design and technology tools into science education provides students with dynamic learning opportunities to actively investigate and construct innovative design solutions [12, 13]. Through DBL, design is driven by qualitative thinking, speculation, ideation, prototyping and specification. It is an innovative approach to initiate students' with design skills as well as teamwork, communication and project management skills [14, 15].

Students are encouraged to study subjects and learn it by doing everyday science and technology projects around them. These opportunities make them build, design and create their own products, solutions and prototypes that came from their prior learning experiences. The important key is the student needs to integrate the knowledge in the design process. The design process is similar to a problem-solving method. Design-based learning (DBL) approach is used to enrich student involvement in learning science and to combine design experience with it. DBL is a type of project-based learning where the problem is solved by student teamwork [16].

In the 21st century to increase the importance of creative and innovative thinking, project and design-based learning is used in secondary school projects. Holistic thinking, understanding, imagination, creativity, visualising problems and solutions are the fundamental skills of a designer [17]. Project and design-based learning approaches are used to transform these skills into active learning and to evaluate student progress in classrooms. Teachers are well prepared to do interdisciplinary teaching and understand the disciplinary content through practising design education. Because of these design concepts and processes, students acquired the potential to mould themselves. The purpose of design education in secondary school is to enhance the learning and teach students to acquire skills needed to become active participants to solve everyday engineering problems around them [18].

5. Newly proposed approach: Project-oriented design-based learning

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 the students to be a problem solver. 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 [19]. The research aim is to find an approach, a method or a framework, which will balance the teaching and learning by incorporating design, creativity, innovation and communication skills in the engineering curriculum.

Learning is conducted in many ways such as discovery learning where student driven and interest based activities are delivered, learning by doing where learning focuses on active, hands-on learning opportunities for students, experimental learning is learning through experience which links thinking and doing, case based learning is done through the use of stories or cases that contain the information or circumstances, the teacher wants the students to learn [20, 21]. Design education aims to enhance the learning of students' to acquire fundamental skills and become active participants in solving every day engineering problems. Holistic thinking, understanding, imagination, creativity, visualising problems and solutions are the fundamental skills of a designer [18, 22].

To produce a curriculum that improves the learning for all students is the important aim of science education and Yaron Dopplet states that we can achieve this by using design-based learning. When

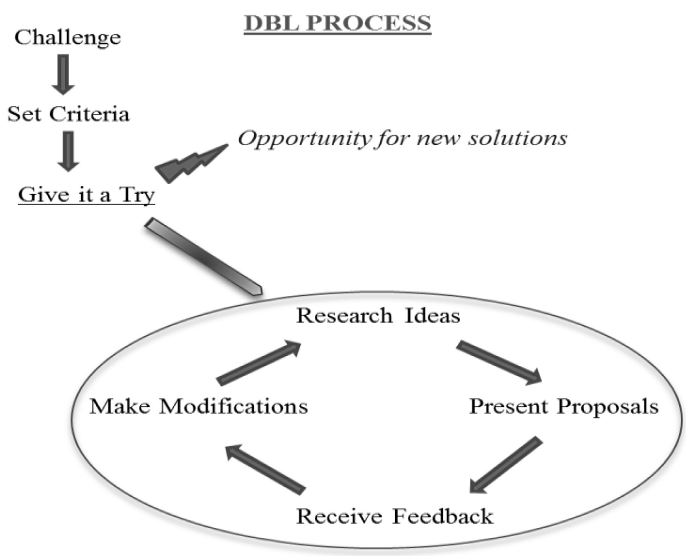

Fig. 2. Design-based learning process.

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. In addition to providing students with a better practise in design and technology, design-based learning involves several advantages such as good design that meets the social, economic and industrial needs. This active learning process, which makes the students to practice and recognize different learning styles that support learning and sharing through cooperative methods [23].

This paper is a foundation work of a research project, which is an innovation in engineering education. More than 120 students from various disciplines in 1st year and senior year participate in a quantitative and qualitative survey to give their own perspectives' on design-based learning in their curriculum. This research paper also looks into industry views collected during an industry design forum conducted in Melbourne, Australia in 2012. By aligning the ongoing study on student perspectives' with the investigated industry views a new framework for our newly proposed approach known as 'Project-oriented design-based learning' (PODBL) will be structured in our curriculum by considering all other affecting factors in the learning and teaching process.

6. Industry perspectives

To increase productivity and to meet competitiveness in the global market, industry needs effective management practices, technical skills and capabilities of a skilled workforce. More productive firms require highly skilled people across all levels. Industry conducting skills assessment, workforce development plans and formal trainings to upgrade the employees' knowledge and vision due to high demands of more advanced projects from clients. They found this should be a continuous process to survive in vast manufacturing targets. So, the industry decided to take part in collaborative arrangements with universities. From a previous research, it shows about 43% of Victorian manufacturing employees do not hold post-school qualifications, because of that there exists many areas of skills shortage in metal trade workers, manufacturing professionals, machine operators, engineers and technicians. Around half of all adult Australians have literacy and numeracy skills below the level considered necessary to function effectively at work [24].

Australian firms recognize that they need to become even more efficient and productive, innovative and attuned to their customers' needs. A previous research on Australian companies' strategies for remaining competitive over the next few years shows about 85% attention is needed for building the employee skills base which is one of the key elements to be considered in future. Australian firms are looking for their employees with higher-level soft skills (willingness to learn, good communication and teamwork skills, problem-solving skills), solid basic skills (numeracy and literacy) and right attitude. A previous research survey work shows companies experienced difficulties in securing skills of the employees in various occupations such as 46% of engineering professionals, 48% of Technicians, 26% of other professionals and 15% of IT professionals are performing their jobs with difficulties in shortage of skills as mentioned above [24]. The exchange of knowledge and experiences between universities and industry, willingness of industry to engage with academics, students and engineering curriculum is a possible way to overcome this situation [25, 26].

There is also a need to focus on getting some "real-world" industry-sponsored design projects for students, with help from industry volunteers. In addition, surveys of the "student customers" to obtain constant feedback on teaching effectiveness [27].

7. World accreditation requirements of engineering design

Accreditation is a periodic assessment of an education program for any discipline against the accreditation standards. Most higher education institutions identify a list of expected graduate attributes or outcomes that are incorporated in their educational programs to be accredited by an accrediting professional body such as Engineers Australia (EA) in Australia, Accreditation Board of Engineering and Technology (ABET) in America, and the European Accreditation of Engineering Programs (EUR-ACE) in Europe.

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'. It states that one of the important engineering application ability is the application of systematic engineering synthesis and design processes [28]. ABET proposed the 'Criteria for accrediting engineering programs' to assure 'the ability to design' is a most important student outcome that prepare graduates to attain program educational objectives [29]. EUR-ACE 'Framework standards for the accreditation of

Table 1. Questionnaire

Number	Quantitative Questions
1	Are you enrolled full time or part time?
2	What is your mode of study?
3	Do you work while you are studying?
4	Is your work engineering related?
	Qualitative Questions
5	Could you please define "Engineering"?
6	Why did you choose to study Engineering at Deakin?
7	What does "Design Based Learning" mean to you? Please explain.
8	How could the School of Engineering include "Design Based Learning" in your curriculum?
9	How important is DBL to your career?
10	How important is DBL to your final year project?
11	Should DBL take place in teams of students or with individual students?
12	List up to 3 advantages and disadvantages for team DBL and individual DBL

engineering programmes states that 'graduates should be able to realize engineering design consistent with their level of knowledge and understanding' [30].All these three accreditation bodies focus on design processes, ability to design, and engineering design practice as important attributes of the engineering outcomes based education.

8. Methodology

The survey questions are based on quantitative and qualitative analysis. From the quantitative and qualitative analysis performed, the results presented students' perspectives on design-based learning within the curriculum. Qualitative methods are useful for evaluating, developing program goals and for involving participants in the evaluation process to gain their insight and perspective [31]. The questions covered here are designed to determine the students' level of experience from 1st year and senior year. Some other questions involved in the survey are designed to cover the student background, level of experience or understanding in their education. The survey results presented give various views, which include students' knowledge and expectations that in turn can inform the school to implement a design centred education. In line with the ethics approval process and procedures, a third party carried out the paper based research survey. The data collected is anonymous and unidentified. The questions were prepared to identify the challenges in teaching and learning and in particular to investigate the students' perspective on the practice of design-based learning. The survey questions used in the research are shown below in Table 1.

9. Results

9.1 Students' perspectives on design-based learning approach

The students' views on DBL in this research come from 1st year and senior year undergraduate engineering students'. The survey goal is to determine the students' perspective of DBL and how the perspective changes over the years studying the engineering. The way engineering students tackle their university degrees are somewhat very different to the way engineering students carried out their studies few years ago. The tables below show a comparison of 1st year and senior year students' perspectives. As it can be seen from Table 2, 97% studying on campus and 3% studying off campus in 1st year engineering as well as 83% studying on campus, 11% studying off campus and 6% are blended learning in the senior year.

In 1st year of engineering, 71% working part time and only 29% of the students are choose not to work while studying. The students in the senior year of the 78% working, 72% work part time, and 6% work full time. Only 22% of the students in senior year choose not to work while studying. This shows that from the 1st year to senior year, students' got their own responsibility of maintaining their financial situation that adds more value to their education. This is illustrated in Table 3. It is interesting to see Table 5 that only 9% of 1st year and 16% of senior year students' work in jobs related to engineering, which helps them to get more practical experience and knowledge while studying.

As part of the process towards identifying what

Table 2. Students' Studying ON/OFF campus

Study Mode	1st Year (%)	Senior Year (%)
On campus	97	83
Off campus	3	11
Blended Learning	0	6

Table 3. Students' who work and study

Work Mode	1st Year (%)	Senior Year (%)
Full time	0	6
Part time	71	72
No work	29	22

DBL means to students, it was important to find out how students define engineering and why they decided to study engineering. Fig. 3 show that most of the students in 1st year are having a basic idea about engineering. In 1st year (19%) and senior year (22%) defines engineering is a process of creat-

Table 4. Students' studying full time and part-time

Enrolled at Deakin Engineering	1st Year (%)	Senior Year (%)
Part time	0	6
Full time	100	94

Table 5. Students' Work related to Engineering

Engineering jobs	1st Year (%)	Senior Year (%)
No	62	84
Yes	9	16

ing new things. 20% of 1st year and 22% of senior year students defines engineering is solving problem and critical thinking. only 2% of 1st year and 11% of senior year defines it is a profession of acquiring and applying scientific, science skills'. 18% of 1st year and 34% of senior year defines engineering as the use of science and technology that benefits to society' and 9% of 1st year, 11% of senior year defines engineering as creates complex structures or machines. The overall results show that most senior year students' are involved and experienced many aspects of engineering and the students' in 1st year are eager to learn and practice engineering.

Figure 4 shows students' perspective on design-based learning, DBL in their curriculum and DBL in their future career. It looks interesting that 15% of 1st year and 45% of senior year defined it is the practical 'learning by doing' approach. About 7% 1st year and 17% of senior year defined it is Getting involved with practical application of engineering. Only 22% of senior year defined it is Project-based learning and learning through projects and 60% of students in 1st year mentioned that they don't have an idea about DBL. These results show us that current curriculum need to concentrate more on design skill programs from the year 1 to the year 4. Integrating design education within or outside curriculum will improve teaching and learning that prepare the teachers, students to design-based learning approach [32]. In today's classroom to achieve the goal of education development, design educators should provide practical strategies that exhibit the pedagogy of design education and problem-solving processes. The goal of the design approach is not changing the whole curriculum of art education but through design activities students can develop the ability to enhance and transform ideas through visualization, manipulation and application of data to problem solving [33].

When students' are asked about practicing DBL in their curriculum, 17% of students in senior year recommended DBL through ilectures, video lectures (tools and tech), 18% of 1st year and 34% of senior year wanted DBL by hand's on learning, Demos in classes and practicals. Only 5% of stu-

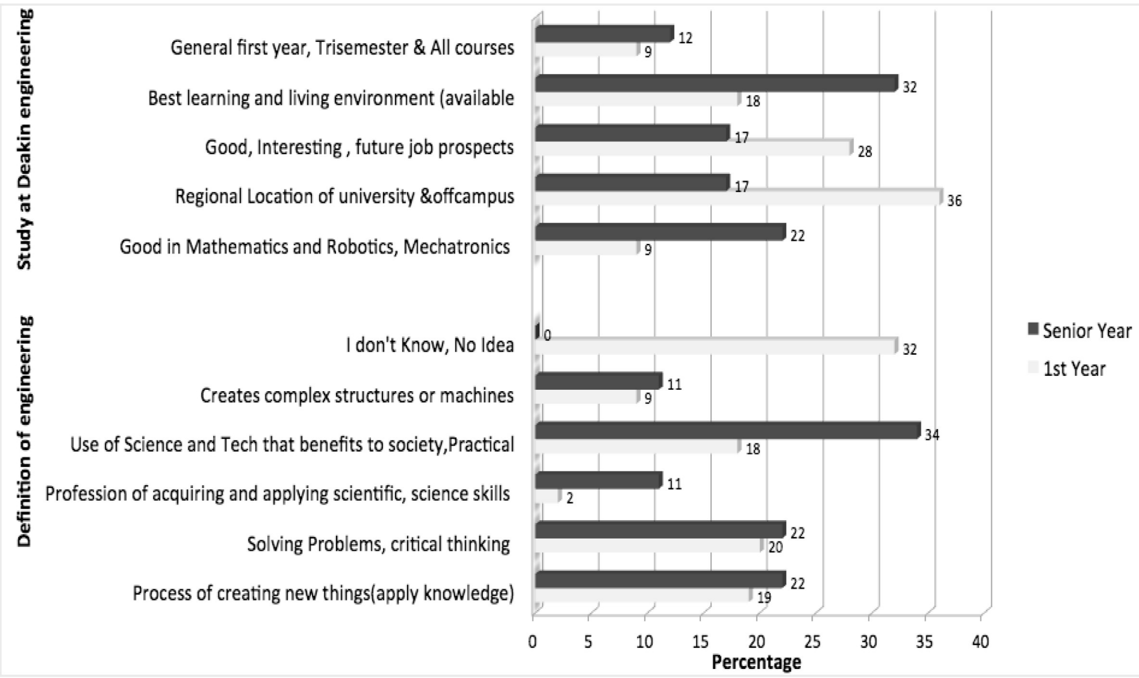

Fig. 3. 1st year and senior year students' views about Engineering.

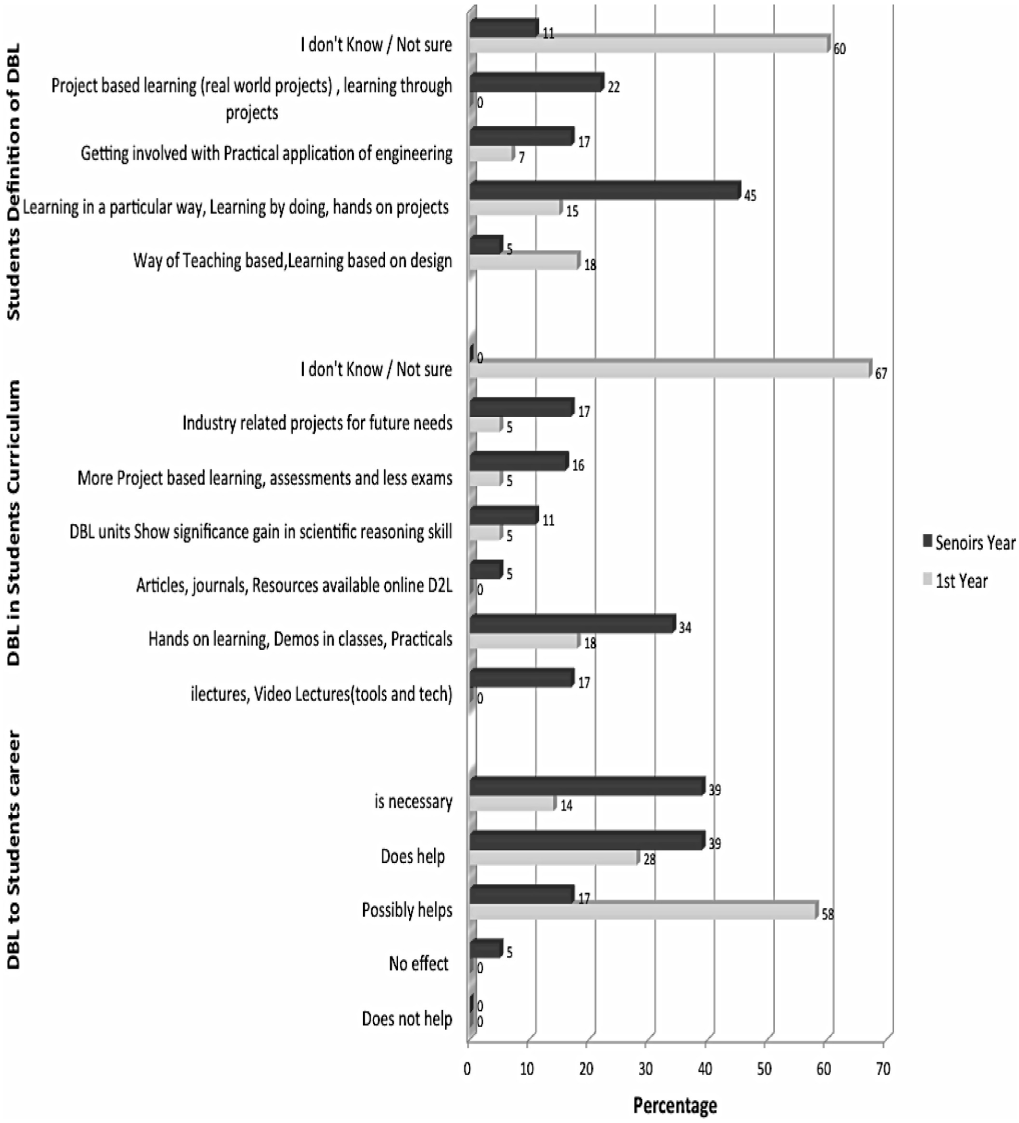

Fig. 4. 1st year and senior year student's views on Design based learning

dents in 1st year and 11% of students in senior year mentioned that DBL units show significance gain in scientific reasoning skill, which is a positive sign for the school of engineering to go forward to proceed with DBL approach. When compared to 1st year students, most of the senior year students responded in higher percentage about DBL in their curriculum and DBL in future career. It is illustrated in Fig. 4, most of the senior students said that DBL should take place more in project-based learning, assessments with fewer exams and they want industry related projects for future needs. From the survey results, it shows that the students in senior level are mostly successful in studying DBL based unit. The students' expectation of DBL that helps in their future career is illustrated in Fig. 4 shows 14% of 1st year and 39% of senior year insists that DBL is necessary, 28% of 1st year and 39% of senior level accepts that DBL does help for their future jobs, 58% of 1st year and 17% of senior level mentioned DBL possibly helps.

The students were also asked about the influence of design-based learning in their final year project. Fig. 4 and Table 6 shows majority of the students' believe that DBL is necessary and it will assist them in their professional careers as well as in their final year project. Table 7 illustrates that students' prefer design-based learning to take place in both modes, at the individual level as well as team based. The

Table 6. Importance of DBL in final year project

DBL in Final year project	1st Year (%)	Senior Year (%)
Does not help	0	0
No effect	0	11
Possibly helps	58	27
Does help	21	34
Is necessary	21	28

Table 7. Modes of DBL preferred

DBL mode	1st Year (%)	Senior Year (%)
All individuals	5	17
Mostly individuals	19	22
Half teams and half individuals	45	61
Mostly teams	8	0
All teams	4	0

majority of the students' in 1st year (45%) and in senior year (61%) preferred DBL in half teams and half individuals' mode.

Figure 5 shows the advantages of teamwork in design-based learning, which includes real world experience and interaction. Students' in 1st year (52%) mentioned that they don't have an idea about the teamwork DBL experience. This shows that the present curriculum needs a change in teaching by implementing the DBL units in 1st year engineering programs. Students' in 1st year (18%) and senior year (28%) says through teamwork DBL, they acquire interactive knowledge, 5% of 1st year and 17% of senior year mentioned that it develops collaborative skill, management skill and social skill. Only 2% of 1st year and 17% of senior year says that they get the opportunity of doing large projects through real world problems with industrial experiences. Overall students' views resembles that most of the essential graduate abilities are attained through teamwork DBL mode.

9.2 Australian industry needs for engineering design

In an industry forum conducted in Melbourne Australia in 2012, a research study was performed to investigate the industry and academia requirements from students' focusing on achieving design skills. The majority of the participants' who took place were design engineers, designers, architects, industrial design practitioners, project team leaders, teachers, lecturers, entrepreneurs from different disciplines and participants' from Engineers Australia (Australia's Engineering Accreditation Body).

The findings from the research performed by the industry indicate learning is a combined source of students' initiation to social, global responsibility and the expected skills from the industry.

The industry is looking for graduates who are ready to practice and perform the essential competences such as practical knowledge, problem solving, teamwork, and innovative and creative designing of real-world projects. In addition, both educators and industry representatives stated that students lack motivation in most cases due to the learning and teaching style they are exposed to. Thus academes must focus on teaching engineering science rather than engineering and should undergo practice rather than theory in the classroom. In learning and teaching institutions, practicing design is one of the fundamental processes and activities in engineering and all other engineering activities related to it [34].

Results indicate that the following key skills are essential elements required for a successful project-oriented design-based learning curriculum. They include creative & innovative skills, successful industry engagement, and awareness of design skills in the early years of engineering. A summary of findings is illustrated in Fig. 6.

By engaging the industry with the Academe,

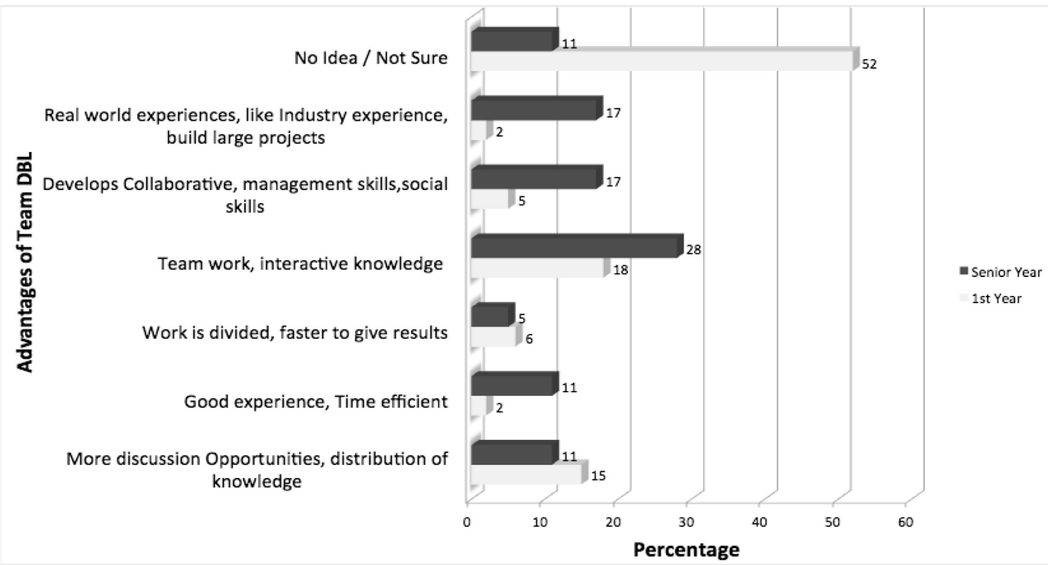

Fig. 5. 1st year and senior year views on advantages of teamwork in DBL.

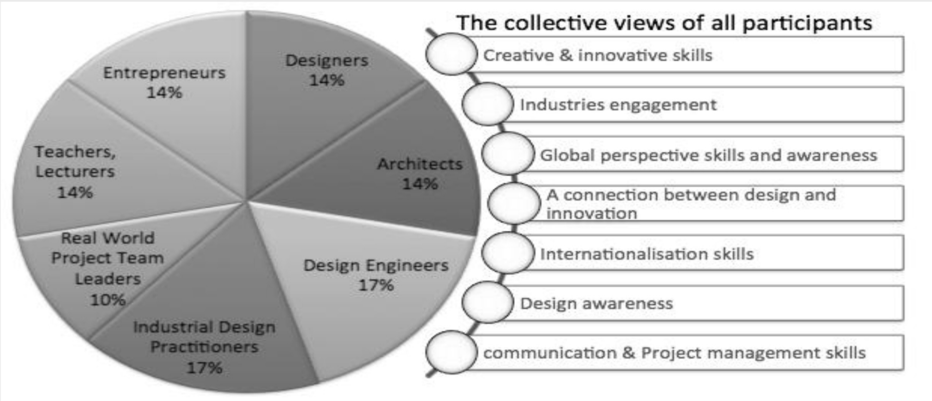

Fig. 6. Industry and academia view on design discussion.

students will acquire global perspectives and knowledge about the core attributes expected in future engineering jobs. In today's large-scale industrial market, companies tend to prefer graduates with design skills attained through project approach. Thus universities should open their doors and accept the challenges of interacting students with industrial experiences and expectations.

10. Conclusion

The students in 1st year have a broad understanding of design-based learning through projects. The survey results show clearly that students are interested to learn by doing hands on projects and getting involved with practical application of engineering design. The senior year students' who are currently practicing engineering have an understanding of DBL and are fully engaged in it during their studies. Project-oriented design-based learning is applicable to motivate the students and also to teach engineering science in classrooms to get more practical experience that fulfil the industry needs. Project-oriented design-based learning 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 their motivation and engagement. It is an interesting task for academics to implement a PODBL approach and integrate design and technology into projects in meaningful ways.

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