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Polishetty,A, Chandrasekaran,S, Goldberg,M, Littlefair,G, Steinwedel,J and Stojcevski,A 2014, Enhancing student learning outcomes in manufacturing engineering through design based learning, in Proceedings of the Australasian Association for Engineering Education Conference and IEEE International Conference on Teaching, Assessment and Learning for Engineering; AAEE 2014 conference proceedings, Australasian Association for Engineering Education, Palmerston North, NZ, pp. 1-12.

Enhancing student learning outcomes in manufacturing engineering through design based learning

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Structured Abstract

BACKGROUND
The Manufacturing engineering being a unit relying more on transfer of practical over theoretical knowledge. It becomes necessary to give students design based project and expect them to provide open ended solution to the problems within the projects. This paper is focused on enhancing student-learning outcomes in manufacturing engineering using Design Based Learning (DBL). Using design based learning, guiding the student on a step-by-step approach to answer the hypothesis of producing femoral stem using machining or casting.

PURPOSE
The purpose of the paper is to enhance student-learning outcomes in manufacturing engineering through design based learning. The study is to find out whether student centred approach is efficient, advantageous and feasible for economically to manufacture a Titanium 64 biomedical implant through machining rather than relying on the age old technique of casting.

DESIGN
DBL has shown to improve student-learning outcomes. It relies on engaging students in laboratory work through a DBL process. The unit delivery starts by framing a problem statement and supporting the workshop activity through theoretical knowledge imparted during seminars. The learning approach is a combination of project-based learning and design-based learning.

RESULTS
The problem statement is given at the start of the project. The student learning outcomes in manufacturing engineering help students to familiarise with the design problem solving process. A written report explaining the highlights of the open ended solution which includes a design brief, technical aspects, research analysis and Computer Aided Design (CAD) model.

CONCLUSIONS
Design based learning is a self-directed approach in which students initiate their learning by designing creative and innovative practical solutions which fulfil academic and industry expectations. Design based learning helps students to practice the 21st century skills such as practical work, problem solving, collaborative teamwork, innovative creative design, active learning and engagement with real world assignments.

KEYWORDS
Manufacturing engineering, students learning outcomes, design based learning.

Introduction

Engineering education is a combination or integration of solid knowledge on the basis of natural sciences and a good knowledge in some aspect of technology. In undergraduate university courses, projects are believed to be the best way for students to interact with their teacher. Author Elizabeth Godfrey states that (Godfrey, 2009)project work takes place in the first, second, third and final year of all university curriculums because during this four year program there has always been a strong commitment to engineering design. The School of Engineering at Deakin University has always tried to improve its unit delivery method to enrich the student experience and to produce capable job ready engineering graduates. To this end, it has explored new teaching methods to aid in this process. One such method is Design Based Learning (DBL). This paper is focused on enhancing student-learning outcomes in manufacturing engineering using Design Based Learning (DBL). Using design based learning, guiding the student on a step-by-step approach to answer the hypothesis of producing femoral stem using machining or casting.

Hypothesis

The hypothesis for the paper is to assess the suitability of implementing learning and teaching approach in order to enhance student-learning outcomes in manufacturing engineering through design based learning.

Learning and Teaching Approaches

Problem Based Learning

In this type of learning and teaching, students are usually presented with a situation, a case or problem as a starting point. The role of the teacher is to be a supervisor of the learning process. The subject knowledge gained by students is considered to be about the same for problem-based learning as it is for traditional teaching methods, however it does aid in developing creative thinking skills for problem solving. In this approach, students learn how to learn. Using problems or cases from real life in teaching is effective for motivating students and enhancing their learning and development of skills. Students need to learn how to find information when needed as this is an essential skill for professional performance.

Problem solving is a component of the problem-based approach. Problem based learning (PBL) focuses on problem scenarios rather than discrete subjects and the selection of the problem is essential in PBL (Duch, 1995; Graaff E. D, 2003; Julie E. Mills, 2003). The teacher acts to facilitate the learning process rather than to provide knowledge and solving the problem may be part of the process. Here, problem scenarios encourage students to engage in the learning process. The learning process is the central principle, which enhances students' motivation, and is a common element in problem and project-based learning. PBL is an approach to learning that is characterized by flexibility and diversity, which can be implemented in a variety of ways in different subjects and disciplines. Students work on their own learning requirements and teachers support this learning (Gabb & Stojcevski, 2009; Savin Baden & Wilkie, 2004; Savin-Baden, 2000; Stojcevski, Bigger, Gabb, & Dane, 2008).

Project Based Learning

The Project Based Learning is perceived to be a student centered approach to learning. It is predominantly task oriented and facilitators often set the projects. In this scenario, students need to produce a solution to solve the project and are required to produce an outcome in the form of a report guided by the facilitators. Teaching is considered as input directing the learning process. The project is open ended and the focus is on the application and assimilation of previously acquired knowledge.

Engineering students require the opportunity to apply their knowledge to solve problems through project-based learning rather than problem solving activities as those do not provide a real outcome for evaluation (A.Stojcevski, 2008; Solomon, 2003; Vere, 2009). One of the greatest criticisms of traditional engineering pedagogy is that it is a theory based science model that does not prepare students for the 'practice of engineering'. Self-directed study is a large part of a student's responsibility in project based learning modules (A.Stojcevski, 2008; Frank, Lavy, & Elata, 2003; Hadim & Esche, 2002; Hung., 2008)

Design Based Learning

Design based learning (DBL) is one type of project-based learning which involves students engaged in the process of developing, building, and evaluating a product they have designed (Dopplet, 2008). 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 vehicle 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 was implemented more than ten years ago, however it is a concept that still needs further development. With this in mind, it is very important to characterise DBL as an educational concept in higher engineering education. Design-based learning is especially used in scientific and practical disciplines. In engineering science classrooms, DBL opens new possibilities for learning science. The design based learning engages students in complex real-world design challenges, encourages them to solve problems and make decisions, makes students responsible for accessing and managing information, fosters reflection and evaluation as an ongoing process, and creates a learning environment that tolerates error as part of the learning process, while encouraging change. Integrating design and technology tools into engineering science education provides students with dynamic learning opportunities to actively investigate and construct innovative design solutions (Y. Doppelt, 2009; Yaron Doppelt & Schunn, 2008; Dopplet, 2008).

Teaching Manufacturing Engineering through DBL

Problem statement

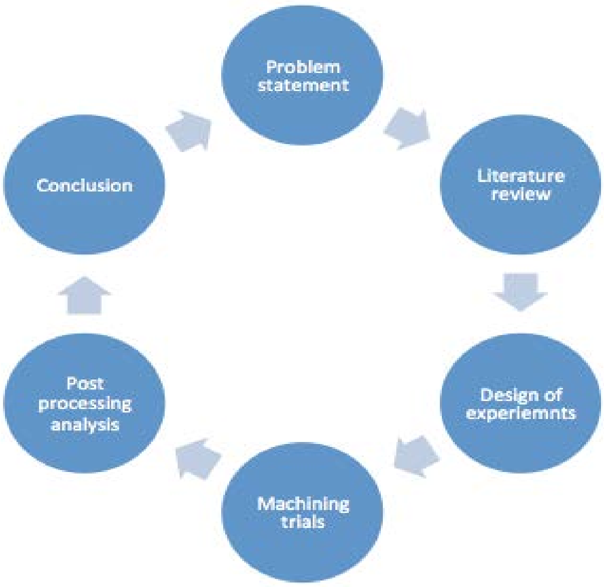

Figure 1: DBL cycle for Manufacturing project

To check the suitability of machined Titanium alloy Ti-6Al-4V for bio-medical/aerospace applications. To evaluate the machinability characteristics of Ti-6Al-4V. Titanium alloy Ti-6Al-4V is the most commonly used titanium alloy in the aerospace and biomedical industries due to its superior properties. An experimental investigation has been carried out to evaluate the machinability of high performance aerospace alloys (Ti-6Al-4V) to determine their in service performance characteristics based on different machining strategies.

DBL is a form of learning in which participants gain knowledge while designing an object or artefact meaningful to them. It involves collecting information, identifying a problem, suggesting ideas to solve it and evaluating the solutions given. Once learners have chosen the problem to focus on, they design an object to solve it and finally, they receive feedback on the effectiveness of their design both from the facilitator and from other participants. This kind of learning is based on the constructivist theory, which stresses the active role participants play in the learning process. Figure 1 shows DBL cycle for manufacturing project.

A theoretical model has been developed based on experimental data tested across a range of cutting conditions conducive with those typically applied in industry. Nearly 80-90% of the titanium used in airframes is Ti-6Al-4V. Therefore, determining their machining characteristics helps to perform machining effectively.

Change in Learning and Teaching Structure

The comparison between the traditional learning approach and DBL approach is given in table.1. According to the table .1, the contact hours are reduced from 30 hours of lecture time to 2 hours weekly meeting with the facilitator; the workload for student is streamlined from 3 assignments to project involving DBL activity, presentation and submission. The teaching method is through cloud learning in case of DBL and laboratory work for on/off campus students.

Table 1. Comparison between traditional and DBL approach

	Traditional Approach	**DBL Approach**
Contact Hours	30 hours lecture	2 hours weekly meeting with facilitator
Workload	3 Assignments	1Project involving DBL activity, presentation and report submission
Teaching Method	Lectures	Cloud learning/laboratory work
Team Work	-	Project work in teams of 4 or 5 students
Assessment	Writing reports	Presentation/report/model

Tools

5-Axis Machining center, Ti-6Al-4V workpiece, cutting tools, cutting force dynamometer, surface roughness (Ra) measurement device and chip morphology study.

Table 2: Chemical Composition of Ti-6Al-4V

Work material	Chemical Compositions (wt %)						
Ti-6Al-4V	V	Al	Sn	Zr	Mo	C	Si
	4.22	5.48	0.0625	0.0028	0.005	0.369	0.0222

Work material	Chemical Compositions (wt %)						
Ti-6Al-4V	Cr	Ni	Fe	Cu	Nb	Ti	Mn
	0.0099	<0.0010	0.112	<0.002	0.0386	90.0	<0.002

Table 3: Mechanical properties of tested Ti-6Al-4V

Work material	Ti-6Al-4V
Ultimate tensile Strength (mpa)	887
Modulus of elasticity (x10^6mpa)	11.3
Hardness (HRC/ 12mm/ 150 Kgf)	28-32

Table 4: Milling parameters of Ti-6Al-4V

Milling Trial No	DOC (mm)	Speed(m/min)	Coolant
1	3	60	Off
2	2	60	Off
3	1	60	Off
4	3	100	Off
5	2	100	Off
6	1	100	Off
7	3	60	On
8	2	60	On
9	1	60	On
10	3	100	On
11	2	100	On
12	1	100	On

The experimental design consist of face milling Ti-6Al-4V at 12 different combinations of cutting parameters consisting of Depth Of Cut (DOC)- 1, 2 and 3 mm; speeds- 60 and 100 m/min; coolant on/off and at constant feed rate of 0.04mm/tooth(as shown in Table 4). The experimental design consists of two parts. First is the material characterisation and the final part involves machining trials. Material characterisation includes spectrometry analysis, tensile test, bulk hardness test of Ti-6Al-4V. Post machining analysis includes surface roughness test, chip morphology and microstructure analysis of machined alloy.

The various elements present and the chemical compositions of the Ti-6Al-4V (in wt %) examined by spectroscopic analysis are given in the Table 2. Measured mechanical properties such as bulk hardness, tensile strength of the Ti-6Al-4V alloy are shown in Table 3.

Results and Discussion

The measured cutting forces during machining of Ti-6Al-4V alloy are plotted in form of a graph as shown in Figure 2. The highest force was measured during wet machining operation with the large DOC and low feed rate. From the experiment it has been concluded that the tool wear is more in case of low speed machining compared with high speeds. The stress on cutting edge also increases with the increase of cutting speeds due to the decrease of contact length and shear angle. These fluctuations make the tool to vibrate which would result in early tool failure. The fluctuations in cutting forces are evident more when the DOC is large and high cutting speed. One such graph obtained for 60m/min speed, 3mm DOC, dry machining is shown below in the Figure 2.

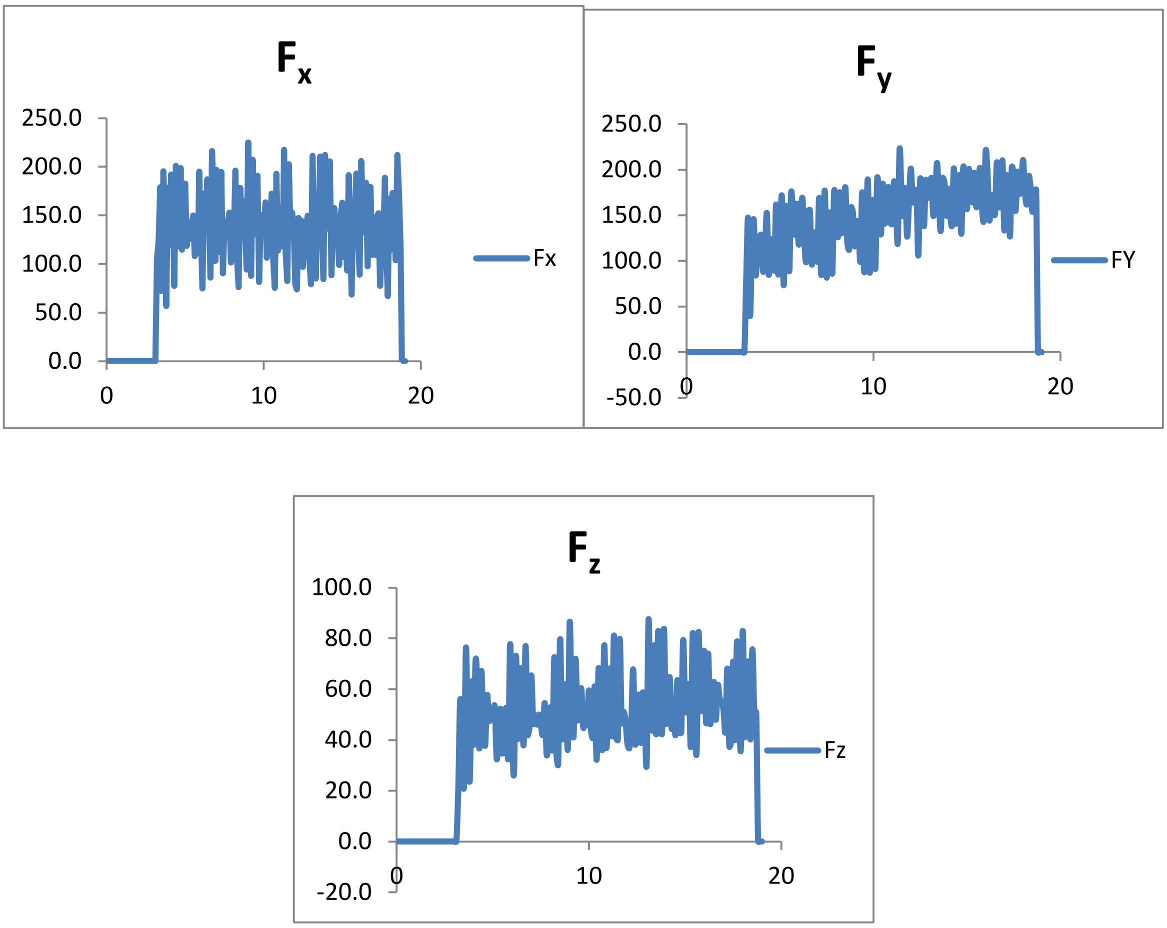

Figure 2: Cutting force in x, y and z axis for 3mm DOC, 60 m/min cutting speed

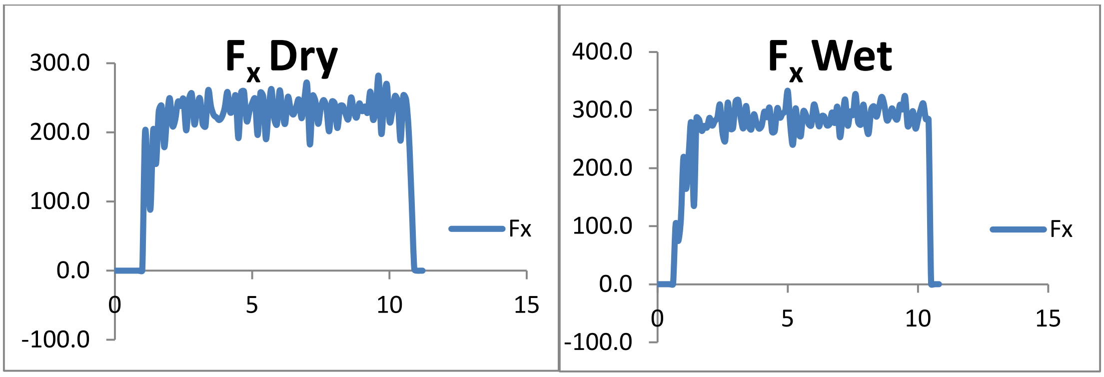

Figure 3: Cutting forces in x axis for 3mm DOC, 100 m/min

Higher forces were recorded in case of wet machining when compared to dry machining; this is because of retardation of thermal softening of the workpiece by the action of coolant. Cutting forces in x axis direction for dry and wet machining is shown in the figure 3.

Surface roughness for 60m/min and 100m/min, dry machining is shown in the figure 4. Surface roughness (R_a) value for 100m/min speed, dry machining is lower when compared to 60m/min, dry machining. That is the high speed has better surface finish comparatively to low speed machining. Surface roughness values were compared between dry and wet machining operations as shown in the figure 5.

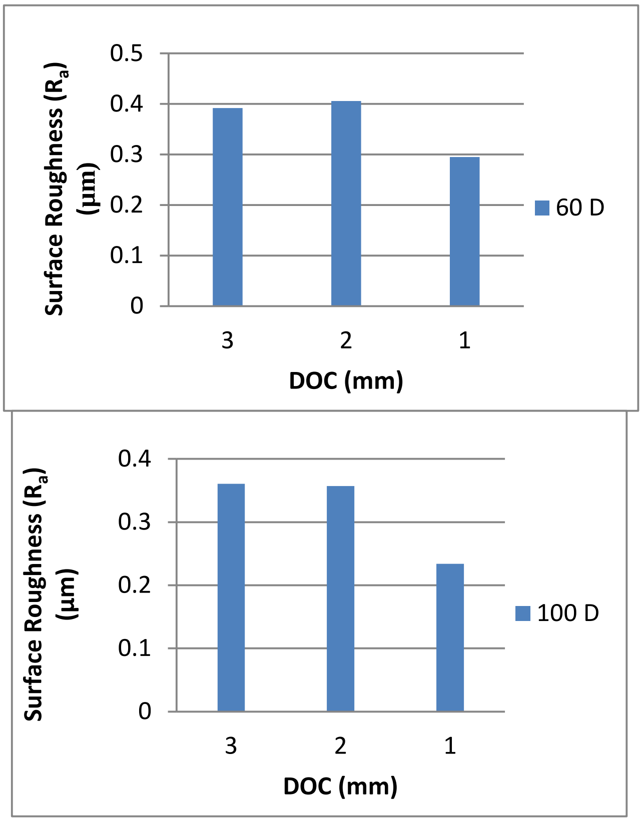

Figure 4: Surface roughness for 60m/min and 100m/min cutting speeds, dry machining

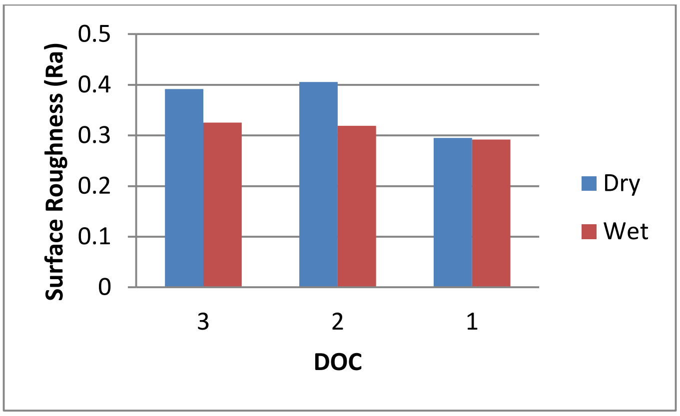

Figure 5: Surface roughness comparison between dry and wet machining for 100m/min cutting speed

Machined Ti-6Al-4V alloy has been examined in SEM for the microstructure analysis. A picture of a Ti-6Al-4V sample examined after machining under SEM is shown in the figure 6. The SEM test was undergone for the sample machined at a speed of 100m/min and 1 mm DOC, dry machining. When comparing the SEM microstructure with the original alloy microstructure, phase transformation of beta and alpha alloy is seen. It states that the Ti-6Al-4V alloy likely to be tempered after machining. Lamellar type light coloured alpha phase with dark coloured beta phase in between can be seen from the SEM microstructure of the machined sample. The mechanism of phase transformation in titanium during milling has to be studied in depth to improve the productivity in machining.

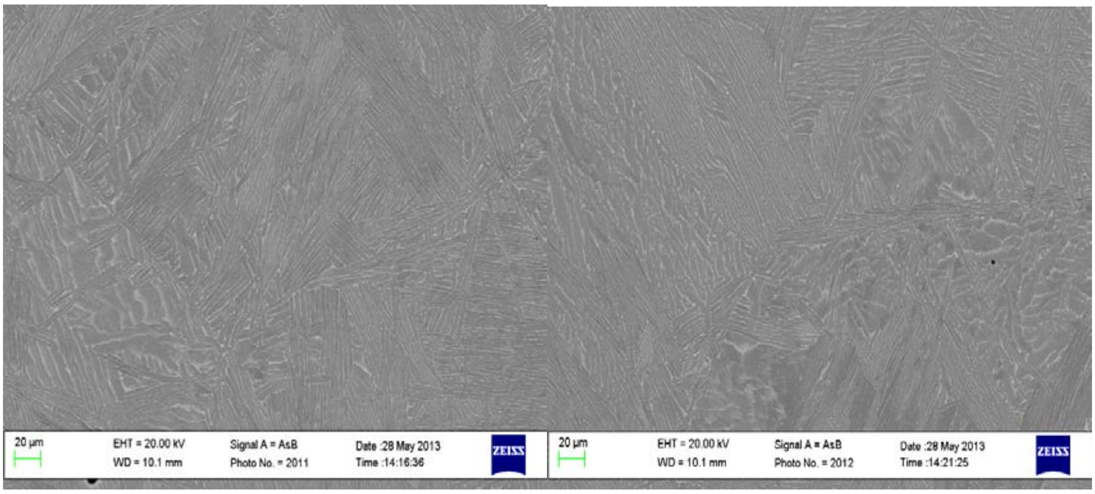

Figure 6: SEM microstructure of machined Ti-6Al-4V alloy

Student engagement

The class strength consists of 25 students divided in groups. Each group consists of 4-5 students. Each students in a group is assigned an individual task related to the project and all results from each student is heard in the group meeting and finally, different views from each group is considered to be multiple solutions for the problem statement.

Staff facilitation

The staff ensures all the required resources are available to the students. The staff is responsible for dividing the student in to groups and provide checks in order ensure that team work prevails in each groups. The staff is one of the platform for the students to lodge a complaint and for providing a decision in case of problems among the group especially arising out of indiscipline, work attitude and dedication. The theoretical knowledge required for successfully completion of the project is imparted through lectures by the staff.

The staff also is the final judge in selecting the best solution to the problem. The best solution is chosen out of the various solution arising out of groups.

Learning outcome

To impart knowledge on fundamentals of manufacturing engineering. To make students gain a specialised (machinability) knowledge in the field of manufacturing.

Student Feedback

At the end of the study period, student feedback was collected. Out of the total strength of the unit (25), 21 did respond to the feedback. The feedback was a valuable tool in order to know the effectiveness of the teaching method and to look for areas of improvement in unit delivery. The student satisfaction for the unit was reasonably satisfactory taking the consideration the novelty of the learning approach and implementation for the first time. The feedback form provided consisted of ten core questions and responses were recorded. Figure 7-16 show the student responses for the 10 core questions.

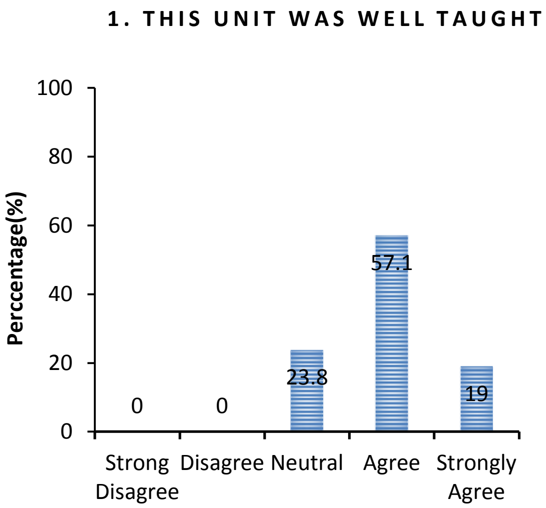

Figure 7: Core Question 1

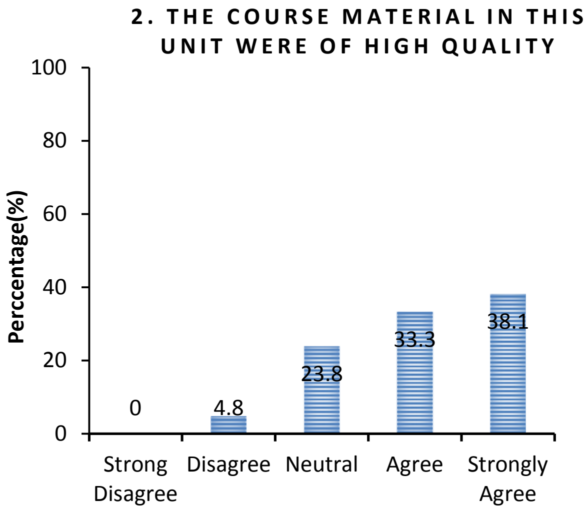

Figure 8: Core Question 2

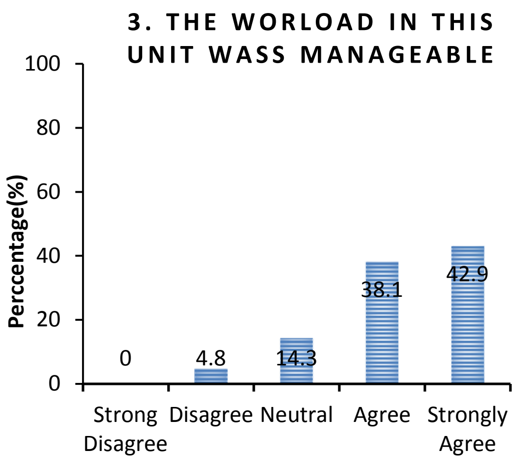

Figure 9: Core Question 3

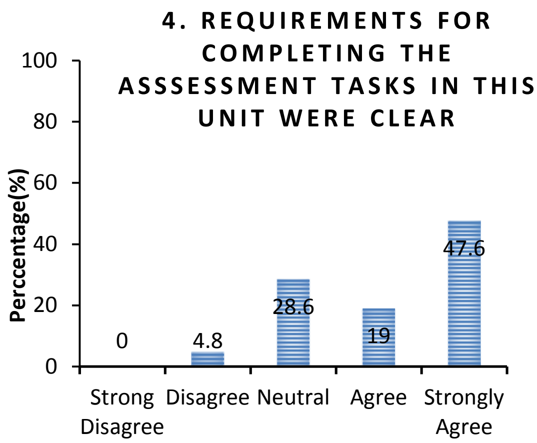

Figure10: Core Question 4

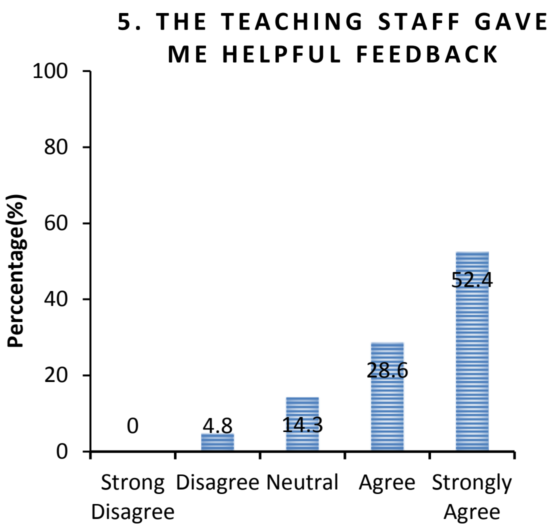

Figure 11: Core Question 5

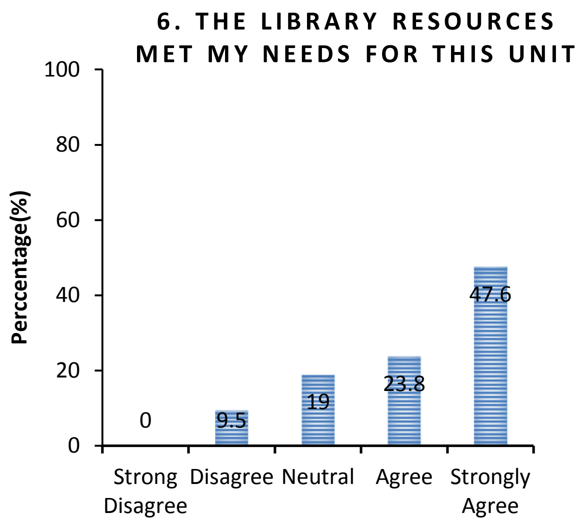

Figure12: Core Question 6

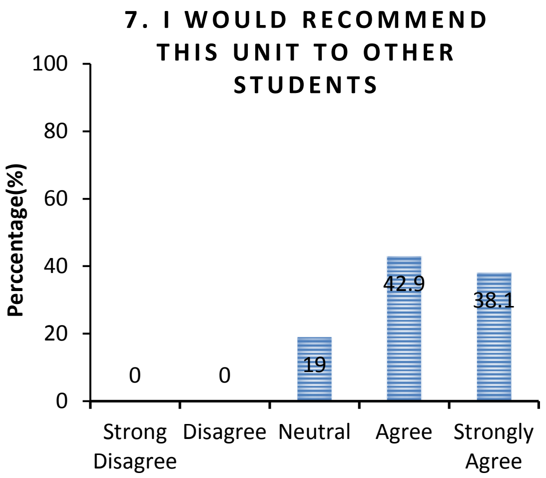

Figure 13: Core Question 7

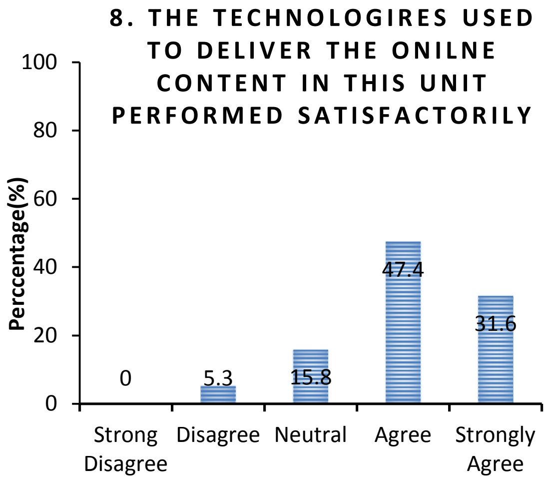

Figure14: Core Question 8

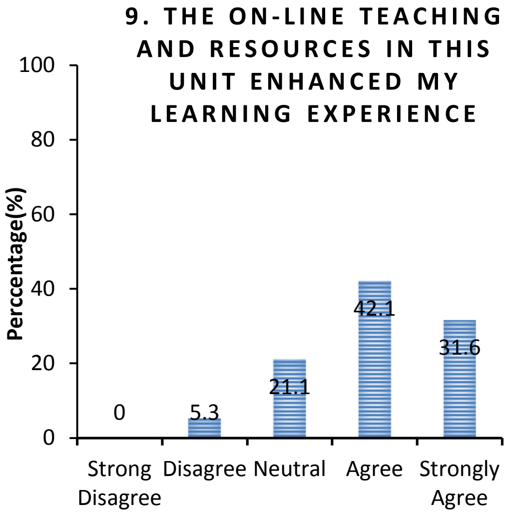

Figure 15: Core Question 9

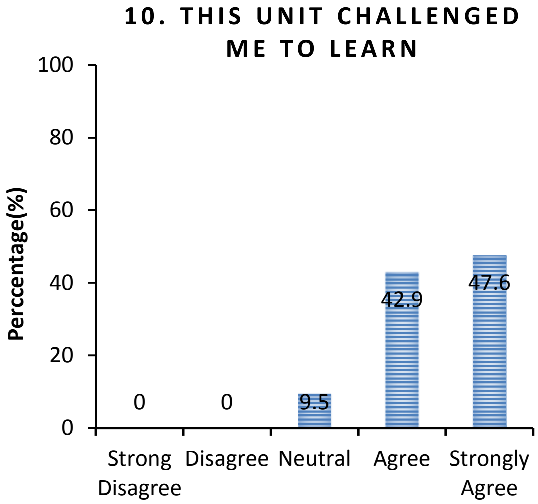

Figure 16: Core Question 10

Conclusion

Design based learning is practiced as a self-directed approach at Deakin University, where students initiate their learning by designing creative and innovative practical solutions which fulfil academic and industry expectations. Design based learning helps students to practice the 21st century skills such as practical work, problem solving, collaborative teamwork, innovative creative design, active learning and engagement with real world assignments. The focus of the paper concludes that Design based learning process gives students the freedom to apply their design skills as they think best. DBL not only looks at the end product but also at the underlying process in creating that product.

The ultimate tensile strength and yield strength of the machined femoral stem are higher so that they can withstand high tensile forces acting on them. Titanium alloy Ti-6Al-4V has high UTS and yield strength as compared to other biomaterials like stainless steel, Co-Cr etc. Hence, titanium alloy Ti-6Al-4V is the best choice of biomaterial for medical implants. The surface roughness of the femoral stem decreases as the cutting speed is increased. The surface roughness of the machined titanium alloy is low as compared to the casted titanium alloy. The surface texture of the machined femoral stem is fine as that of a bone. It can withstand high stresses from the adjacent bones. The machined titanium alloy is harder than the normal titanium alloy. The hardness of the titanium alloy Ti-6Al-4V is 29 HRC which is harder than the bone. It has the capacity to withstand high stresses from the adjacent bones. The obtained material removal rate is low for a machining process but it is effective to machine a component with a thickness of 3mm. The time taken to manufacture a femoral stem is short in machining process as compared to casting process.

The student feedback to the ten core question relevant to the unit delivery/learning and teaching method was noted. The effectiveness of the teaching method and to look for areas of improvement in unit delivery were some inferences to be taken from the student survey. The student satisfaction for the unit was reasonably satisfactory taking the consideration the novelty of the learning approach and implementation for the first time.

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Acknowledgements

I would like to thank my friend Dr. Siva Chandrasekaran without him it would not be possible to write this paper. I would like to thank Prof. Alex Stojcevski for his valuable suggestion. Finally, I would like to thank Prof. Guy Littlefair, who has agreed to present his paper at the conference putting aside his busy schedule.