USE OF PROBLEM BASED LEARNING IN BIOMATERIALS EDUCATION

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Abstract: Problem Based Learning (PBL), also know as project based learning, student centred learning (SCL) and design centred learning (DCL), is a pedagogical technique. The concept is that groups of students are presented with a problem to solve. The students have to divide the problem into its constituent parts and divide the effort between the members of the group. Regular meetings are held to present the information gathered by the individual members of the group, consider the progress in solving the problem. Finally the solution developed is presented in some manner dependant on the type of problem under consideration.

This approach was used with a group of students with a range of backgrounds including Medicine, Biomaterials, Biology and Engineering for the project, entitled 'Design Study for Biomedical Applications'. The students had three weeks in which to complete the project and present it in a form of a 5 page report and 10 minute presentation. Since the introduction of PBL the average degree and project marks have increased gradually in the Department of Materials The students who have gone through PBL have found project work easier and have produced higher quality projects.

Introduction

Problem-based learning (PBL) is a pedagogical strategy for posing significant, contextualized, real world situations, and providing resources, guidance, and instruction to learners as they develop content knowledge and problem-solving skills [1]. PBL is also known as project based learning, student centred learning and design centred learning (DCL). PBL is a form of experiential learning. This method of learning from experience is best described by Kolb [2]. The Kolb learning cycle requires 4 stages of learning abilities to be met if the learning is to be successful; Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation. This theory is clearly reflected in PBL based teaching.

The students are presented with a case study or scenario, they then analyse the problem, enter into a role playing state, hold brainstorming session to reflect on the problem, and then they devise a plan for experiments or a strategy to address the problem. These scenarios are often left open ended or have multiple solutions, as the idea is to reinforce the learning process, and all learning of new knowledge is done within the context of the problems [2].

This method of teaching was first pioneered at Case Reserve University in the early 1950's. It now serves as part of the curriculum at many Universities worldwide. Unfortunately, memorisation is a common occurance in traditional programmes [3], even though the majority of students retain and use little of what they memorise in lecture room situations. PBL attempts to break this form of learning by encouraging interaction and engagement of students by presenting them with problems related to real life scenarios. Although problem based learning tends to reduce initial levels of learning, it improves long term retention [4].

PBL was introduced in the Department of Materials in September 2000. As used in the Department of Materials PBL is conceived as a method of reinforcing the traditional lecture based process of delivering academic content, and it is not designed as a substitute. It is primarily a problem solving programme that seeks to provide students, by the end of year 2, with a checklist of transferable skills and underpinning subject-specific knowledge for more detailed project/research work and further study/application in subsequent years [5].

Students are provided with a handbook called 'Learning Materials in a Problem Based Course' [5]. The handbook clearly explains the process of PBL and the manner in which it should be carried out. The roles of the teaching staff can be defined in 2 ways:

1. The Facilitator – who works with the group
2. The Champion – who creates a specific case study exercise.

The leader of a PBL group acts as a facilitator rather than a teacher, using their expertise not primarily to transmit facts, but to provide encouragement and guidance as the participants tackle the problems they have identified [6].

The skill of PBL facilitation is that of knowing when to provide assistance to the group, be it suggesting useful resources they might like to consider or interjecting with though provoking comments to guide the breadth and depth of learning, without necessarily imparting facts [7].

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A skeletal structure is provided to the students allowing them a form of guidance to tackle their problem. Thus, a 7-step project plan is introduced to students:

- Step 1: Explain unknown wording, statements and concepts
- Step 2: Define the problem(s)
- Step 3: Brainstorm – analyse/try to explain the problem(s)
- Step 4: Make a systematic inventory of explanations
- Step 5: Formulate self-study assignments
- Step 6: Perfom self-study assignments
- Step 7: Report and evaluate on self-study. After each group meeting, the group formulates the next stage of self-study assignments.

There are four specific roles within a group: Chair, Minutes-Secretary, Scribe and General Member of the group: Each role serves its own purpose enabling the students to gain several different skills. The chair leads the group through the 7-step plan, ensuring equal participation of the group, also keeping time and maintaining good group dynamics. The chair's role also involves ensuring the group sticks to the task at hand and to check if the scribe records the points raised in the discussion. The role of Minutes-Secretary is crucial to the organisation of the group, as the Secretary records the minutes of the meeting by structuring points written down by the scribe and distributing them to all members of the group and the facilitator. The Scribe records the points raised in the discussion by the group and helps the group order their thoughts, as well as participating in the group discussion.

Group members form the fundamental basis of the group, they share information and ideas with each other, as well as researching all the learning objectives independantly. They are encouraged by the chair to follow the 7-step plan and actively participate in the group discussion. During group meetings students are expected to rotate their roles to ensure they gain experience of all four roles.

Methods

One Case study titled 'Design Study for Biomedical Applications' was introduced at Queen Mary, University of London October 2004. Students from several departments were involved including; Medicine, Engineering, Biomaterials and Biology. Students were encouraged to work together from multi-disciplinary areas, by splitting them up into groups of 10. One Academic designed this study and split it into six subjects; Articular Cartilage, Skin Tissue, Rib Cage, Vertebral Column, Heart Muscle and Device for Interverebral Fusion. Teaching assistants acted as facilitators. They were provided with suitable training in PBL, either in the form of a Certificate in Learning and Teaching (CILT) or a Postgraduate Certificate in Academic Practice. Teaching assistants were employed to facilitate PBL in parallel to their PhD studies.

The aim was for students to consider alternative materials and/or implants and examine each in detail in term of functionality, mechanical properties, chemistry, processibility, sterilisability and conclude which was the most ideal candidate system. Finally, outlining the production and testing programme that would be used to design and test the prototype system.

One such example of the case study that was presented to the students as part of their project was Articular Cartilage, where the students were provided with the brief:

Example 1

"Articular Cartilage:

"Osteoarthritis is a major degenerative joint problem affecting a large proportion of the population. It affects both the young and the old. The present treatment of mosaicplasty, osteotomy or joint replacement is not entirely satisfactory, particularly for the younger or more active patients. It is your task to consider the anatomy and function of natural articular cartilage and attempt to design an equivalent to replace or regenerate the cartilage of the knee of a young and active patient. The implantable device must be insertable by a surgeon and it must be able to be manufactured under aseptic conditions or sterilisable. Outline all the properties required in a cartilage replacement and then propose as many suggestions as you can that would confer these properties. Having noted a number of alternative materials and/or treatments, you should then examine each in detail in terms of functionality, mechanical properties, chemistry, processibility, sterilisability, etc., and conclude which the most ideal candidate system for cartilage replacement would be in this young and active patient. Finally, outline the production and testing programme that you would design to test your prototype system" [8].

The case study was presented during an introductory session. The academic, who is also the Champion, presented the scenario to the students. Students were organised into groups with a mixture of backgrounds and asked to sit in their groups.

Facilitators meet by academic during a briefing session before the case study begins. Facilitators also attended the introductory session, to allow the students to familiarise themselves with their facilitator. Each facilitator was advised to meet with their group at least once a week and keep a record of attendance and contribution. The students were given 3 weeks to complete the study. The students were encouraged to meet more often but it was not made compulsory.

During a case study the group is typically expected to produce one or more of the following at the end of each project poster, report, oral presentation, html web page, or to design and build device. In this case study students were expected to produce a 15 page maximum report and a 10 minute presentation with 5 minutes of discussion.

The individual's mark was moderated by peer assessment. In addition to the mak allocated by the champion for each group. The students are expected to complete a peer assessment form and return to their

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facilitator. The facilitator was responsible for moderating the individual scaling factors generated from the peer review forms. Some suggections were provided on the forms for scaling factors:

- Non-participation – 0.0
- Poor – 0.75
- Average – 1.0
- Good – 1.1
- Excellent – 1.25

The facilitator's generated a weighting factor for the student without altering the average mark obtained by the whole group. Thus the average of the multipliers was maintained at 1.00. For this case study the individual mark was derived from:

[(report + presentation)/2] x individual scaling factor

The feedback session was designed to allow an immediate form of formative assessment, so that students felt they were rewarded for their work relatively quickly. During the feedback session the Champion highlighted the areas where students performed well and areas where the students performed poorly. As the case was designed open-endedly, no answer was incorrect, but the Champion still provided an overview of a more suitable solution, including comments on the most recent research and commercial developments.

Results

An average was taken of the final year research project and degree marks from 1999 to 2005. The research projects of this degree programme are all based on an individual project, always on biomaterials and generally experimentally based. The marks compiled were taken from students studying towards a three year Batchelor of Engineering (BEng) degree in Biomedical Materials Science and Engineering.

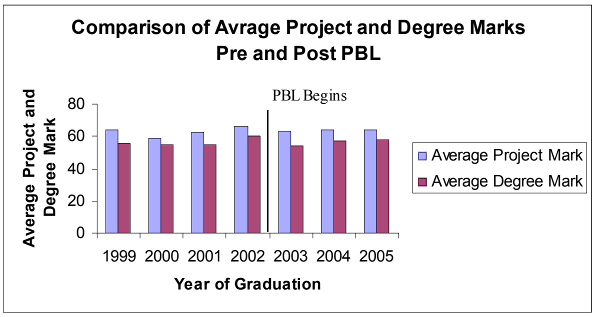

Figure 1: Comparison of average project and degree marks Pre and Post PBL

Figure 1 shows a gradual increase in average project and degree marks after PBL was introduced.

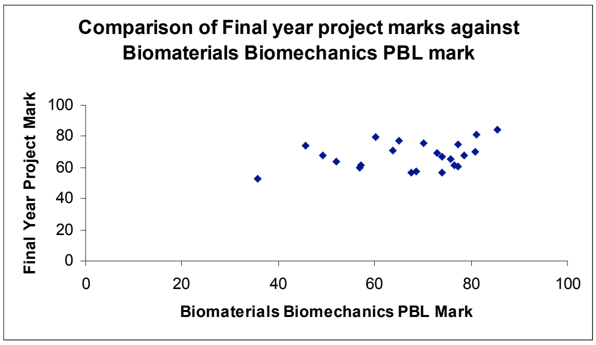

Figure 2: Comparison of Final Year Research Project marks against Biomaterials and Biomechanics PBL Mark.

Discussion

Students performing well in PBL generally performed better in their final year projects. Since the introduction of PBL in the Department of Materials, the average final year project mark and average degree mark has increased gradually and steadily. The average project marks were 63, 64 and 64 for 2003, 2004 and 2005, respectively. The average degree marks for 2003, 2004 and 2005 were 54, 57 and 58, respectively.

Although the average project and degree mark was higher in 2002, the last year of graduates before PBL was introduced, in this graduation year fewer students transferring onto the four year enhanced Master of Engineering (MEng) degree programme. Hence, the 2002 graduates included several students who would normally transfer onto the MEng leading to an anomaly.

The slight drop in average marks in 2002 was also due to the new process and changing of the entire curriculum, as PBL replaced all traditional Coursework. This change in curriculum required a period of adjustment. Each PBL project requires 120-160 hours to construct, field-test, and revise [9].

PBL helped develop key and transferable skills. Students develop time management and project management skills, hence producing higher quality final year projects. Their ability to function and participate through student interaction and teamwork in Problem Based Learning enables them to enhance their interpersonal skills, thus increasing their understanding of working in interdisciplinary areas. PBL requires students to use self-selected resources such as journals, on-line searches, textbooks and other library resources. Prior to the introduction of PBL, most traditional students would only use such resources during the final year of their degree. PBL has required the use of such resources at a much earlier stage of their degree hence students became more competent in information-seeking, data analysis and presentation skills.

This methodology of teaching promoted self-motivation and peer to peer learning. Students found themselves encouraging each other to perform well, as assessment was provided in two forms, a group mark moderated by a peer mark. PBL was initially a time consuming method to set up and implement. Staff had to be trained suitably and the curriculum adapted to suit PBL.

Academic staff initially found PBL very demanding with their time, hence the introduction of recent graduates as teaching assistants proved to be essential. Students performed exceptionally well during the Design Case Study and interacted with students from other disciplines to produce high quality multidisciplinary reports and well presented presentations.

Conclusions

Students who performed well in PBL also produced high quality research projects in their final year. The introduction of teaching assistants resulted in highly trained facilitators and is essential to the development process of PBL. Since 2003 the average research project and degree marks for graduates have increased steadily.

Acknowledgements

The authors would like to thank Sandra Wells for her assistance in collating the data presented.

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