THE TRIALS AND TRIBULATIONS OF IMPLEMENTING A PROBLEM BASED LEARNING APPROACH IN THE FRESHMAN YEAR OF UNDERGRADUATE CHEMICAL ENGINEERING

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Abstract

Chemical Process Principles I (CPE1002) is a core and compulsory course taken by approximately 70 students in the freshman year of a Chemical Engineering undergraduate degree at The University of Sheffield, UK. The primary learning objective of this module is to develop the students' knowledge and understanding of material balances. Here we will present the progression of improvements in CPE1002 over the past 3 to 4 years, including the adoption of a problem based learning approach.

New aspects introduced into the course were group work, industrial visits and assignments incorporating industrially relevant processes. The course was extended to cover key personal and transferable skills such as group work, communication skills, independent and self-directed learning and peer assessment, without losing any of the key technical material. In addition, online resources were provided via WebCT Vista (managed learning environment) [1] to enable the students to self-assess their weaknesses and strengths in the core chemical engineering principles and practice these skills so that they were able to come to the group work more prepared.

Through the changes in the course, we were able to expose the students to the way process engineers work, think and communicate their ideas as well as introducing them to the processing/chemicals industry. These changes transformed the course from a problem module with the class generally struggling to grasp the key concepts to a successful module with positive student feedback.

Introduction

The core learning content of the Chemical Process Principles I course looks at material balances for single unit operations, such as mixers, splitters, separators and reactors, and then various combinations of these single units in series. This allows for purges and recycles to also be considered. A lot of our students were finding the learning content challenging and were struggling to make the connection between the mathematical manipulations required and what a practicing Chemical Engineer does. As a result of this feedback, it was decided to adopt a different style of course delivery to try and engage the students more effectively with the learning content and its application.

The new course delivery mode selected was a type of Problem Based Learning (PBL). Our primary reason for this choice of change in module delivery was that our department had good links with Chemical Engineering at the University of Queensland, in particular Professor Paul Lant. They had had considerable success with their students adopting a project centred curriculum [2] and as part of his sabbatical at Sheffield, Professor Lant was willing to assist with its introduction within our course. At Queensland, this approach has been implemented programme-wide whereas we were looking initially to introduce it for one course. Professor Lant visited in the academic year 2005/06 and brought all his learning resources relating to his syllabus for material and energy balances. This was the start of a major transformation for our course and change within our department.

This extended abstract will provide details of the chronological developments of the course including the issues that were addressed; feedback from the students and lessons learnt by staff. Then, some conclusions will be provided.

Course Developments

The developments have occurred over a number of years with the initial transition being from traditional didactic delivery in the academic year 2003/04 (see Table 1), when students numbers were relatively low, to two-hour weekly “problem solving” workshops with a one-hour weekly supporting lecture from 2005/06 onwards. The idea was to shift the emphasis from the lecturer being the “sage on the stage to the guide on the side” [3] with the students being given tasks that required them to seek out information from the resources and supports provided, and construct their own knowledge.

Looking at the review by Newman [4], this aligns with his definition of Problem Based Learning i.e. “a conception of learning as an integrated process of cognitive, metacognitive and personal development”. This concept has been introduced successfully into many professional fields of study including engineering. (For anyone wishing to development a PBL course this review provides very good guidance on curriculum design.)

Table 1. Chronological Course Delivery Developments

Academic Year	**2003/04**	**2004/05**	**2005/06**	**2006/07**	**2007/08**
Student Numbers (SN)	28	55	66	67	70
Lectures (per week)	2 hours	2 hours	1 hour	1 hour	1 hour
Tutorials	2 per term 3 hours each Large group	3 per term 3 hours each Small group	weekly 2 hours each PBL-style	weekly 2 hours each PBL-style	weekly 2 hours each PBL-style
Assessment	80% exam 20% coursework	75% exam 25% coursework	50% exam 50% assignments and test	50% exam 50% assignments and test	50% exam 40% assignments 10% online test

From Table 1, it can be seen that the evolution of the course has coincided with an almost 3 fold increase in student numbers from 2003 to 2007. Traditionally, the University of Sheffield has been fortunate to attract very able students to its Chemical Engineering programmes who exhibited higher order learning skills. This type of student was able to cope with limited tutorial support (pre- 2003/04). However as various changes have occurred such as the British government's widening participation agenda for higher education and changes to the 16-18 curricula in science and mathematics [5], although the entry criteria have remained high, the students entering into Year 1 appear in several cases to lack the higher order learning skills required for independent learning. Hence, the change of the course delivery to include weekly PBL-style tutorials has provided more scaffolding of the students' learning.

"Traditional" Problem Based Learning Approach (2005-2007)

The key to successful PBL approach is the use of authentic problems to engage the students whilst developing their core technical skills. Professor Lant provided several case studies relating to industrial processes and the students were required to work in groups to carry out the weekly assigned formative tasks. We also introduced an industrial visit to a pulp and paper mill and summative assignments incorporating industrially relevant processes. The course content was extended to cover key personal and transferable skills such as group work, communication skills, independent and self-directed learning and peer assessment, without losing any of the original key technical material! Students were also encouraged to do weekly homework problems to support their learning.

When the changes were first introduced in 2005/06, feedback from the students was extremely positive. However, 23% of the students failed the summative assessment compared with 16% the year before! A review was carried out by Biggs [6] and showed that those students who didn't engage with the PBL group work were not engaging overall with the whole programme. Suggesting it wasn't necessarily the PBL style of delivery that had impacted but their general lack of motivation and involvement.

However the following year 2006/07, two additional changes were made: (1) emphasis on the need to engage with the group PBL tasks and assignments to ensure success in the course and (2) the weekly homework was marked so that the students got regular formative feedback. This had the desired effect of improving the overall summative assessment results (only 2% failed the course).

The introduction of weekly homework marking and the size of the class meant 2 members of academic staff and 2 teaching assistants were now involved with the course delivery and marking compared with the usual 1 member of academic staff on other traditionally delivered courses within the department. This has had an impact on the running cost of the course and it is not practical for all courses to be delivered in this way without a major increase in the departmental teaching budget which is unlikely to occur in the short term.

Also accommodating up to 70 students at the same time in a learning and teaching space suitable for a PBL-style tutorial proved a challenge. (Due to timetabling constraints it was not possible to split the cohort into say two smaller groups.) Although the University of Sheffield has had a major investment into Inquiry Based Learning (IBL) flexible learning and teaching spaces (see CiLASS [7] website) the largest collaboratory only accommodates up to 48 students. Alternative venues had to be sought which had a flat floor with moveable tables. These proved to be very limited in number. We also wanted to be able to present information using Powerpoint and/or overhead projector slides so it was also essential that the students could see the wall from any where in the space where this information was to be projected. These issues may seem trivial but for PBL-style tutorials to be successful it is very important that the students are able to "huddle" in their groups and exchange ideas and information. This is the essence of the communication and collaboration for PBL to take place.

The new course delivery style of PBL was deemed a "success" by the end of 2006/07 and a new phase of developments started. Initially, it had been envisaged that further developments would involve rolling out the same course format across other courses. However, the combined impact of the running costs and infrastructure limitations meant that this type of widespread roll out was not an option. However, lessons learnt from this course on how to deliver a PBL-style tutorial have been transferred to other small group teaching such as being carried out in the process design strand of teaching throughout Year 1 to 3 (beyond the scope of this paper). So the developments continued to focus on the same course with internal learning and teaching grant from CiLASS.

Blended Learning PBL Approach (2007-onwards)

Despite good student feedback on the whole, for the PBL-style of delivery, there was evidence from the peer evaluation data that some students were being "carried" by the members of their groups. There was a danger that because the summative assessment was 50% group assignments and 50% individual examination that students could succeed on the course but not have the core technical skills required for later courses in their undergraduate programme. These concerns needed to be addressed but constraints on staff time and increasing students numbers (see Table 1) meant that providing additional remedial group tutorials and/or one-to-one support were not practical options to support weaker students. It was necessary to find an alternative approach that would "blend" with the PBL approach.

The strategy adopted was to incorporate online formative quizzes that the students could use to self-test their strengths and weaknesses prior to participating in the PBL group tasks and assignments. We wanted the students to get instant feedback which was possible using computer aided assessment tool. These quizzes cover five core technical skills:

(1) unit conversions using the unity brackets approach;
(2) mass to mole conversions;
(3) calculations and definitions relating to material balances;
(4) material balance calculations without reactions; and
(5) material balances with reactions.

They were delivered within WebCT Vista [1] managed learning environment although some of the development work was carried out within a 3rd party tool for creating online assessments called Respondus [8]. (For detailed discussion of the development of the online quizzes see Rossiter and Biggs [9].)

As part of the CiLASS funded learning and teaching project during 2007-08, a detailed evaluation study was carried out to assess the impact of the developments on students, academic staff, their department, the University and the wider community. This evaluation study provided a rich source of data. The data was collected via focus group with students, interview with academic project staff and questionnaire to all students involved with the course. Some of this data is discussed in the following sections.

What did the students say?

The students were asked in the questionnaire and the focus group about all aspects of the course including the PBL-style tutorials and their use of the online quizzes. Here are some comments made:

Table 2. Extract from student feedback at focus group[1]

Interviewer: Do you think the module (CPE1002) changed the way you approach learning or problem solving activities?
Student: "In the first semester, we were learning things and **I could see why we were learning** them because I could see how to apply them. This semester, we're learning a lot, but I'm not always sure why. I wish we had more practical group assignments throughout the course."
Interviewer: If you had your choice between the group format and what you're getting now (predominantly lectures), which would you prefer?
Student: "Last semester, I really liked visiting the paper mill site. Now we know about industry." Student: "You **actually felt like an engineer** when you were doing the group assignments. Now **I just feel like a student**, learning a lot of things"

These comments suggest that by working on the PBL group tasks and assignments the students were seeing the connection between chemical engineering practice and what they were learning on the course. This was reinforced by comments in the personal statements that they included with their PBL group assignments and also the questionnaire data[2] where:

- 93% of respondents found the PBL activities enjoyable and motivating.
- 98% of respondents found their experience of PBL helped them to at least some extent to develop confidence and skills in working collaboratively. (Team working is an essential skill for chemical engineers.)
- 96% of respondents found their experience of PBL helped them to at least some extent to develop confidence and skills in problem solving. (Problem solving is an essential skill for chemical engineers.)

In relation to the online quizzes, the students were equally positive i.e. 81.5% of students who responded said quizzes had helped to some extent in developing their technical core skills. The rest either didn't use the quizzes, didn't know or didn't respond.

The immediate feedback from the quizzes was also found to be beneficial:

[1] Eight students were present at the focus group. – Interviewer R. Petrulis (CiLASS) on 3rd March 2008

[2] Questionnaire, End of Semester 1 Feedback by Year 1 students, 15th Feb 2008, 54 responses out of 69.

Student: “They (Quizzes) were beneficial because of the immediate feedback**.** With the homework, it took a week or so. The online quizzes also referred you to the book and page for more information. If you just get a grade, that’s meaningless.”
Student: “The online self test quizzes gave INSTANT feedback. So if you didn’t get the question right, I understood why and did not do the same mistake again. The quizzes were unlimited and this helped me practice.”

What do staff say?

Overall, blending online formative quizzes with offline PBL-style tutorials has proved successful for this course. This has helped to provide a mechanism with instant feedback for the less able students to get help in developing their core technical skills in preparation for the PBL group tasks and assignments. Thus, helping all students to more actively engage in the group work.

For the first time in the academic year 2007-08, the examination for the course was held at the end of Semester 2 whereas the lectures and tutorials were held in Semester 1. This meant that the online quizzes were also available throughout the year to assist students with their revision prior to the examination. Providing these online quizzes did involve significant development time however it has been offset by a reduction in remedial one-to-one support being required. Some time was also gained through some of the coursework (an online test worth 10%) being automatically marked online. Also, the homework sheets were modified as some of the questions formed the basis of the online quizzes. Hence, this led to some reduction in the weekly homework marking load.

The major benefit though has been the observed awakening of the students when taking ownership for their own learning. The students are clearly more motivated when engaging in PBL group work than passively listening to lectures. The PBL-style tutorial sessions have a “buzz” about them!

Conclusions

There have been several major challenges to be addressed relating to this first year chemical engineering course such as: increased student numbers in some cases with reduced independent learning ability, constraints on provision of additional academic staff, and adequate learning spaces for Problem Based Learning style tutorials.

Creative solutions have had to be found to deal with these challenges and this paper has outlined the blended learning approach adopted for course delivery and support. The initial provision of the PBL content and training from Professor Lant of the University of Queensland was invaluable for starting a major process of change within our department. Back in 2005, it was envisaged that this change would lead to major programme change in favour of PBL style approach but this has not occurred to the extent originally imagined. Although, the process design strand of the programmes have been influenced by the PBL approach as we, the authors, have both been involved in design project supervision. However, an unexpected outcome has occurred in that an alternative mechanism for face-to-face support of the weaker students has been developed through the provision of the online formative quizzes so taking the course towards a so-called blended learning approach i.e. providing both online and offline learning resources and supports.

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