

Innovative Problem-based learning approach using on and offline resources in 1st Year Chemical Engineering

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Abstract: *In a first year chemical engineering undergraduate course, the primary learning objectives are: to develop the students' knowledge and understanding of basic chemical process principles, called material balances; and develop their problem solving skills. A Problem Based Learning (PBL) approach was introduced in 2005/06. 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. This represents what Savin-Baden (2000) refers to as "Model I" type PBL with the expectation that students become competent in applying knowledge in the context of problem solving and also learn how to manage their problem solving. The knowledge is fairly certain and the process of learning linear in nature.*

Combining all aspects of the assessment, only 2 students failed on the first attempt in 2006/2007 with student feedback being very positive. However, some students found the group work stressful due to their weakness in core chemical engineering skills. A decision was made to support the development of these skills in the early part of the course through the use of online quizzes. These enable the students to self-assess their weaknesses and strengths in the core chemical engineering principles and enable them to independently practice these skills, so that they come to the PBL group work much more prepared. This paper outlines the lessons learnt from providing both online and offline resources in this PBL approach.

1. introduction

Why introduce problem based learning (PBL) in a chemical engineering curriculum? What advantages can it give compared with traditional didactic presentation of lectures and tutorials? Has the use of PBL since 2005/06 in a first year chemical engineering course been effective in terms of developing the students' knowledge and skills of core chemical engineering principles? Why make the effort of developing and incorporating online resources to support the PBL assignments? How has the addition of these online resources enhanced the students' learning? These are some of the questions to be addressed in this paper.

The paper is organised as follows: section 2 addresses the first three questions above; in section 3 the online resources and their impact on student learning are discussed; and in section 4 the conclusions and suggestions for the engineering community are presented.

2. Why problem based learning approach and is it effective?

2.1 Motivation

We wanted to transform the course from having a student class generally struggling to grasp the key concepts (67% pass rate on first attempt in 2002/2003) to a successful course both in terms of academic performance and student engagement. Students were not making the connection between the academic course content and their future role as Chemical Engineers. Within the Engineering discipline in the UK, a project funded by HEFCE (FDTL) was recently carried out to look into retention and attrition of students in Electrical Engineering. As part of this study Edward (2003) looked at the use of a variant of problem-based learning (design-led learning) to inspire and motivate students so that they could experience “real” engineering. It is in this context that a problem based learning approach was introduced into our first year chemical engineering curriculum. We wanted to expose the students as early as possible to “real” engineering problems through the chemical process principles course CPE1002.

Much has been written about problem based learning and its many variants (enquiry-based learning; inquiry-based learning). In the UK, there are Centres of Excellence for Teaching and Learning (CETLs) such as CILASS (2008) and CEEBLE (2008) which support development and innovation in this area and are useful sources of information on research and case studies. At the time of the early developments within the course, these sources were not available to the authors.

Initially, the transition from traditional delivery to a PBL approach was facilitated with the assistance of a visiting academic from the University of Queensland (UQ), Australia (Associate Professor Paul Lant¹¹) in the Autumn of 2005. The new aspects introduced into our Chemical process principles 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 evaluation, without losing any of the key technical material. 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. The intention was that the additional skills gained by the students throughout the course would transfer positively into their other courses and contribute to producing a well rounded Sheffield Graduate. (Longer term impact evaluation needs to be done to assess if this has occurred and is beyond the scope of this paper). Associate Professor Lant provided many Powerpoint and paper-based teaching and learning resources (referred to here as the *offline* resources for PBL). He had previously used them in his UQ undergraduate teaching.

2.2 Outcome

The delivery of the course had been altered from a conventional University of Sheffield-Chemical Engineering mode of delivery in 2003/04, where the whole year group had lectures and tutorials together, to providing smaller group tutorials (about 25 students) in 2004/05 (see Table 1). This change came about due to student feedback on the course where they requested more tutorial time. This seemed to have an impact on the students' success rate in 2004/05 with a 9% reduction in the failure rate in the summative assessment.

¹¹ Professor Lant had experience of being involved in a whole-of-programme review at UQ to incorporate a variant of PBL (Crosthwaite *et al.*, 2006).

In 2005/06, the switch to PBL approach occurred and the delivery of the course was radically changed. The lectures became plenary sessions to provide information and content for the course. The tutorials sessions now became PBL sessions where the students worked in groups of 4-5 to complete PBL-based tasks and assignments. The whole focus shifted from the academic staff transmitting the information and the students passively engaging with it to the students directing their own learning and knowledge construction to complete the tasks and assignments. More staff support was required so that the students' learning could be scaffolded and guided. A lot of emphasis was placed on getting the PBL sessions "right" and getting the students to engage with the group tasks and assignments.

Students' feedback about the course (Biggs, 2006) was very positive and seemed to be stimulating their interest in engineering. Those students who didn't engage with the group work suffered badly in the overall assessment as the student feedback showed that the examination (worth 50%) was perceived as difficult. So those who did badly in the coursework, largely through not engaging in the PBL activities, were not able to pass the course overall via making up the marks in the examination. Thus, the failure rate actually went up significantly during the first year of introducing PBL and triggered a need to explain this phenomenon to the Departmental Executive Committee (Biggs, 2006). It was identified that most of those who failed this course also failed other subjects so were not engaging with the programme as a whole.

As a result of the review, further formative feedback was incorporated into the course and the students were alerted to the need to engage with the group work or risk overall failure in the course. In 2005/06, students were given weekly homework tasks but these were not marked, rather only verbal feedback to the whole group about how to tackle the problems was provided. In 2006/07, the decision was taken to mark the homework and give individual written as well as whole group verbal feedback to the students. This had a resource implication and the staff requirement increased by 1. The outcome in 2006/07 was much improved with only 2 students failing the course combining all aspects of the assessment (see Table 1). The students' feedback on the course was also positive and they seemed to be making more of a connection between the academic content and development of their professional skills for being practising engineers in industry.

We had seemingly achieved our goal! Why not just continue with the above strategy and reap the benefits? Peer evaluation by the students showed that the more able students were "carrying" the less able in the group work. Although the use of a Peer Assessment Factor (Lant, 2005) helped to reward those students who did the most work, there remained an underlying problem that the less able students were continuing without the necessary knowledge and skill set to be a professional Chemical Engineer. This could not be allowed to continue as it would have repercussions throughout their degree programme and professional career. Action needed to be taken to develop the skills of these less able students and help them maintain a positive relationship with the rest of their group.

Table 1 – Summary of key components of course delivery changes

Academic Year/ Key Components	2003/04	2004/05	2005/06	2006/07
Staff Resources	Biggs+1	Biggs+1	Biggs+Lant+1	Biggs+Rossiter+2
Student	28	55	66	67

Numbers (SN)				
Lectures per week	2 hours	2 hours	1 hour	1 hour
Tutorials per term; style	3 hours 2 x term Whole group	3 hours 3 x term Small group	2 hours weekly PBL	2 hours weekly PBL
Summative Assessment	80% exam 20% coursework	75% exam 25% coursework	50% exam 50% coursework	50% exam 50% coursework
Failure Rate : Number (% of SN)	7 (25%)	9 (16%)	15 (23%)	1 (2%)

3. online resources and their impact on students' learning

3.1 Strategy adopted and why

We had to consider the best strategy for developing the less able students' core skills. One option was to have remedial tutorials but this had staff resource and timetabling implications as well as potentially not being taken up by those who really needed it. A lot of time had been spent with students in previous years on providing one-to-one support but with the increase in student numbers (see Table 1) this was not in the long term a practical or sustainable solution. Hence, an alternative was sought. One of the authors (Rossiter and Rossiter, 2006) had experience of developing online resources. It was decided that online resources that could provide instant formative feedback to the students to help them assess their own strengths and weaknesses would be ideal. These requirements could be satisfied by creating online quizzes which would be made available in self-assessment mode within the Blackboard Learning System - Vista Enterprise License™ (2008), referred to as MOLE (My Online Learning Environment) at the University of Sheffield. This E-learning platform provides 9 different question types for the quizzes. We created 5 online quizzes using predominantly the following question types: calculated, multiple choice, short answer, matching, fill-in-the-blanks, true-false. These quizzes covered the following core skills for chemical process principles:

- (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 (see Fig 1).

These online quizzes were trialled during the Autumn semester of 2007. Each quiz question has formative feedback for right and wrong answers with general feedback also included linking to the lecture notes and the course textbook (Felder and Rousseau, 2000) (see Fig. 1). It was envisaged that the students would use the online quizzes during the term to develop their core skills. The incentive provided to get them to engage with the resources was 10% of the coursework assessment credit would be available from completing an online test created using the same databank of questions created for quizzes 1-5.

3.2 Outcome

Interim qualitative feedback from the students, via their reflective statements submitted with their first PBL assignment, revealed that students who had engaged

with the online self-assessment quizzes had benefited from having access to them. Some students commented that they liked having the formative feedback to guide them and help them detect their errors. Others liked the general feedback from calculated questions where the generic approach was outlined. Here are some quotes from students:

#1 "The online quizzes were really helpful because whenever I got stuck, I refer back to them and it never failed".

#2 "The online quizzes were also useful in a way that they provided the basics to start off calculations."

These early findings suggest that the online quizzes are providing exactly the type of support for students' learning that we had hoped for. A more detailed evaluation study is currently being carried out with the assistance of staff from CILASS (see below) and further findings will be reported at the conference.

4. conclusions/suggestions

The PBL approach using the *offline* resources (2006/2007) was successful in its second year of delivery in reducing the failure rate for the course and engaging the students in the course content. However, the students' feedback from their peer evaluations of their group members revealed that some students were not obtaining the necessary core skills and competency required of them. The addition of the *online* quizzes during this current academic year seems to be going some way to address this problem by giving the students a mechanism for self-directed learning. The final examination for this course now takes place at the end of the summer term (June 2008) so we await the results with interest and will report the outcome at the conference.

A key observation that can be made is that expert support was required to initiate the transition (Associate Professor Lant, University of Queensland) and support further developments (CILASS, The University of Sheffield). Without access to these "experts", our progress would have taken a lot longer and also a certain amount of "reinventing the wheel" would have occurred. The *offline* resources and training provided by Associate Professor Lant were crucial in translating the course content from a traditional perspective to providing a problem-based constructivist perspective. Making this switch without access to these exemplars would require a significant amount of educational research and development time for an academic, especially if they had no prior experience of PBL. Similarly with the development of the *online* quizzes, prior experience of the functionality of the e-learning platform and how this could be used to satisfy the educational requirement was valuable.

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Fig. 1 Self-assessment Online Quiz Question - Material Balance Reaction - Component A

Using the nomenclature in the diagram shown, which of the following material balances is correct for component A (assuming steady state and there is a reaction occurring)?

The diagram shows a reactor with the following parameters and reaction:

- Input flow: F (mol/s) containing $n_{A,F}$ (mol/s) and $n_{B,F}$ (mol/s)
- Output flow: P (mol/s) containing $n_{A,P}$ (mol/s), $n_{B,P}$ (mol/s), and $n_{C,P}$ (mol/s)
- Reaction: $A + B \rightarrow 2C$

The multiple-choice options are:

- a. $n_{A,F} + n_{A,P} - R = 0$
- b. $n_{A,F} - n_{A,P} - R = 0$
- c. $n_{A,F} - n_{A,P} - 2R = 0$
- d. $n_{A,F} + n_{B,F} - n_{C,P} - R = 0$

The interface includes a 'Check Answer' button and a 'Question Status' panel on the right showing a progress indicator for 10 questions.

The feedback shown in brackets would not be visible unless the student selected this answer.

Student Response	Value	Correct Answer	Feedback
A. $n_{A,F} + n_{A,P} - R = 0$	0%		(Incorrect, P is an output stream so should be subtracted not added.)
<input checked="" type="checkbox"/> B. $n_{A,F} - n_{A,P} - R = 0$	100%	<input checked="" type="checkbox"/>	Correct, stoichiometric coefficient $v_A = -1$
C. $n_{A,F} - n_{A,P} - 2R = 0$	0%		(Incorrect, there is only 1 mol of A so the stoichiometric coefficient $v_A = -1$)
D. $n_{A,F} + n_{B,F} - n_{C,P} - R = 0$	0%		(Incorrect, only component A needs to be considered.)
Score:	100%		

General Feedback: See Lecture Notes on reactions. Felder & Rousseau (2000) uses extent of reaction in the same way, see p.130 section 4.7e. Assuming steady state the material balance with chemical reactions is:

$$\text{INPUT} - \text{OUTPUT} + v_i R = 0$$

where R is the net Rate of reaction and v_i are the stoichiometric coefficients for the molecular species with the sign convention where coefficients for products are positive and negative for reactants.