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ARTICLE

Integrating web-delivered problem-based learning scenarios to the curriculum

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ABSTRACT This article reports on a small-scale research project (n=56) that investigated student educational gain. For the purposes of this study, gain is defined as an increase in the score that students obtain for pre/post intervention tests. Students received authentic exposure to the process via a web-delivered problem-based scenario. The students were randomly allocated to case and control groups. No statistically significant differences in educational gain were recorded between the two groups. However, the research highlights the requirement to fully integrate problem-based learning (PBL) work into a curriculum. It also confirms findings from other research that students engage well with PBL and enjoy the learning process using this methodology.
KEYWORDS: *case-based learning, diagnostic training, plant protection, problem-based learning, scenario-based learning*

Introduction

The effectiveness of problem based learning (PBL) is a major educational issue that continues to be debated because of the confusion over terminology and lack of conclusive evidence to support or reject it (Newman, 2003). Rhem (1998) suggests a PBL definition that emphasizes meaning-making over fact-collecting. He stresses that in PBL problems are contextualized and considered in group situations resulting in better student comprehension, greater learning, better 'knowledge forming skills' and wider social skills. Moust et al. (2005) note that research into PBL has shown that PBL has a positive effect on the process of learning as well as on learning outcomes. Prince (2005) in his review of action learning suggests two views about PBL: firstly, that it is difficult to conclude if it is better or worse than traditional curricula, and secondly, that 'it is generally accepted … that PBL produces positive student attitudes' (2005: 228). Major and Palmer (2001) agree with Prince and conclude their review of PBL literature by stating 'students in PBL courses often report greater satisfaction with their experiences than non-PBL students' (2001: 4). However, a study by Beers (2005) demonstrates no advantage in the use of PBL over more traditional approaches. This sample of existing literature suggests that further studies are needed in order to either support or reject PBL's efficacy.

PBL clearly sits towards the student-focused, learning-orientated end of the conceptions of teaching scale and away from the teacher-centred, content-orientated end (Entwistle, 2000) and as such it can be argued that it facilitates understanding and encourages conceptual change (Bonwell, 2001). The history of PBL and its definitions are covered in detail by Gijbels et al. (2005) and by Prince (2005) amongst others and do not need to be addressed here. However, it is worth reiterating that the key characteristic of PBL, according to Gijbels et al. (2005) is posing a 'concrete problem' to students to initiate the learning process.

PBL has emerged as a 'coherent educational approach' (Moust et al., 2005) that has both benefits, noted above, and some difficulties associated with its use. Kirschner et al. (2006) suggest that PBL ignores human cognitive architecture and places heavy demands on working memory and that it may restrict learning due to the cognitive load it places on students. In addition to these working memory demands, Mackenzie et al. (2003) note that PBL also requires students to assume greater responsibility for what and how they learn. They go on to identify that 'the student's role … includes defining issues, identifying learning needs, drawing on self-directed learning in relation to scenarios provided by clinical and research cases, and organizing and integrating learning material from various sources' (2003: 13). It is this variety of roles that places the cognitive load onto the students. However, Hake (1998) concludes a large review (n=6000) of interactive-engagement compared with traditional teaching by noting that the former method promotes a variety of improvements in a variety of areas. An additional dimension in the use of PBL has been detailed by Kumar and Kogut (2006), who report that students with 'a keener sense of metacognition' (2006: 114) can readily formulate the steps required by problem solving exercises. Conversely, the students (n=25) in their study, who were motivated by extrinsic factors and who required greater teacher input did not cope well with PBL. They note that PBL raises difficulties for students because they need to adjust to the 'learning mechanisms embedded within PBL' (2006: 115). These studies suggest that further research is needed into the process of learning (by the students) using PBL rather than a focus on its use to deliver content.

As PBL has evolved and been recognized as a learning methodology, information and communication technology (ICT) in teaching has also developed. Gibson et al. (2002) note that the most prevalent use of ICT in education is in the creation of static documents from lecture notes. They argue that ICT can readily merge theory and practice. Goeghan (1994, cited in Carlson, 1998: 3) estimates that only five per cent of teachers use ICT in a capacity beyond its ability to replicate a blackboard and overhead projector. Carlson (1998) offers reasons for this: ICT developers do not pay sufficient attention to end user needs; technology in education does not have a sufficiently developed paradigm for its use; and teachers are characterized as resistant to the adoption of ICT in teaching and learning.

Practitioners, in any field, encounter many problem situations within their professional lives which are difficult to replicate realistically and bring to life in a lecture format. PBL using ICT aims to enhance students' ability to form structured approaches to deal with issues. When undertaking a PBL exercise students are required to analyse and assess the given situation, make choices as to how they might tackle it and provide recommendations for future action. They can make observations, seek further information from various sources and undertake common diagnostic tests. The use of ICT to deliver a PBL scenario can therefore integrate the theory and the practice of the topic being studied. The literature on PBL also discusses how problems for students should be presented and whether the students should be taught the subject matter prior to the PBL discussion. Bowden and Newton (1996) report a definition formulated by Boud and Feletti (1991) stipulating that PBL starts with the problem and not the earlier presentation of the subject matter in a lecture. The ICT and PBL approach allows students to be presented with a previously unseen problem. But, it can also support the student's learning by offering guidance and therefore reducing some of the cognitive load demands noted earlier.

Although there is material about the use of ICT in PBL courses it often focuses on the potential for the World Wide Web (Watson, 2002) to enhance them. Watson (2002) goes on to say that ICT can promote both the development of problem-solving skills and students' abilities to use information technology, emphasizing an advantage of PBL as a promoter of process as opposed to content objectives. However, there is a lack of empirical evidence for these claims. This suggests that further research is needed into finding out how students learn, as well as their abilities with regard to the use of technology in so doing, that is, a focus on the process of learning, rather than content of a subject. With regard to educational gain in terms of content, Lockhart and Le Doux (2005) found a significant improvement in the content knowledge test score for high school students using PBL for learning about gene therapy. Prior to the PBL exercise 35 (of 97) students knew what gene therapy was and could offer an appropriate definition of it. After the PBL module, 93 students gave a suitable definition and identified a disease for which it would be appropriate to use gene therapy as a treatment. Their study raises an important issue of how to evaluate the success of PBL. Learning methodologies can by evaluated by many means, for example, students' gain in knowledge or change in students' cognitive and/or metacognitive development. For Lockhart and Le Doux (2005) it was simply an increase in the numbers of students who could accurately define the topic.

As noted above, there are conflicting views on the efficacy of PBL as an approach; as Prince (2005) remarks, we need further research evidence to support or reject the view that PBL is better, and in what way(s) than more traditional methods. Whilst the literature cited above makes the point that PBL has primarily been used to deliver content, there is a need to look not at content but instead at process. What is it that students actually do in order to learn? What are their views on both this and the PBL approach itself? Research addressing these questions will inform the debate surrounding the efficacy of PBL. The hypothesis of the study described later in this article was that the PBL intervention using ICT and a software-based scenario would enhance student learning of the processes involved in their practice. In our investigation of student educational gain is defined as an increase in the score students' obtain for pre/post intervention tests which tested student contextual decision making. The unusual aspect of this study is the integration of ICT and a PBL scenario into a learning activity aimed at developing students' process skills rather than their curriculum knowledge.

Methodology

The aim of this study was to investigate the effectiveness of a PBL scenario delivered via web-based technologies. Effectiveness was approached from two perspectives, the students' perceptions of the exercise and from an 'educational gain' viewpoint. A pre/post testing approach was used, although the PBL intervention sat outside the normal structure of the course. The 'educational gain' was defined as an improvement in the pre/post PBL exercise test scores. It was quantified by using the pre/post test scores within a case/control group experimental design. This experimental design approach has also been used in a nurse education context by Beers (2005), who, in a study with a lecture group (n=18) and a PBL group (n=36), sought to evaluate the learning gain associated with each strategy. This approach, a simple pre/post knowledge test, has also been used in a high school context (Lockhart and Le Doux, 2005), although unfortunately, the authors do not report the timing of the post-intervention test.

The problem was developed and presented using PBL Interactive, an authoring and presentation package specifically designed to present problem-based scenarios (Anonymous, 2006). An appropriate contextual scenario, an apple orchard with trees (see Figure 1 below) showing symptoms of unknown disease was presented over the web to the students via a web-browser. In this study, students were not given any prior teaching about disease possibilities or diagnostic methodology.

Students proceeded through the scenario by selecting an action and responding to the displayed results. They could then make a judgement as to whether or not the action had been appropriate and use the additional information to figure out their next step. The pre/post test asked questions about the process (see example in Table 1).

At the end of the exercise, students were informed what the problem was (Phytophthora crown rot) and how and why an expert would have approached the scenario to reach a diagnosis. The learning outcome envisaged for the students was that by completing this 'walkthrough' they would be better able to explain their approach to plant pathology problem diagnosis and the processes involved 'in the field'.

In previous courses at another institution, similar exercises were run as assessable assignments, after the students were taught diagnostic methodologies by more traditional means (that is, lectures and laboratory classes) (Stewart and Galea, 2006).

Data from the students, assessing their learning of plant protection processes, was obtained via a twenty item online test that was administered to both the exposure (case) group and the non-exposure (control) group. Figure 2 illustrates the timing of the online test for the case and control

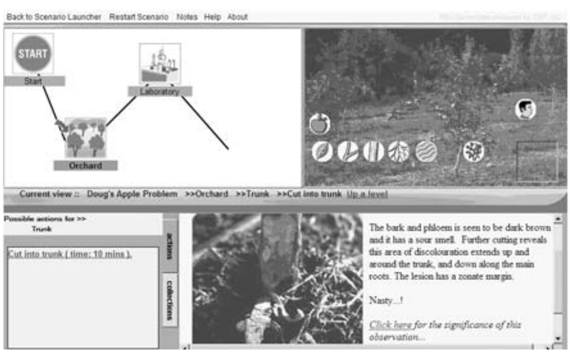

Figure 1 **Screenshot of apple orchard PBL scenario**

Table 1 **Example question**

Q. 19	You are a consultant, called in by a farmer about a problem in his wheat plants. At first glance, they appear to be suffering from a nitrogen deficiency – older leaves are turning chlorotic and plants are stunted. What should you do FIRST to further investigate this problem? (a) Dig up some roots to check, in case it is actually a root problem (2) (b) Investigate nutrient management in the orchard and see if there seems to be a problem there? (1) (c) Send leaf samples off to a diagnostic lab to see if the leaves are low in nitrogen (0) (d) Send samples off to the lab to test for cereal yellow-dwarf virus (0) (e) Recommend an application of urea (0)

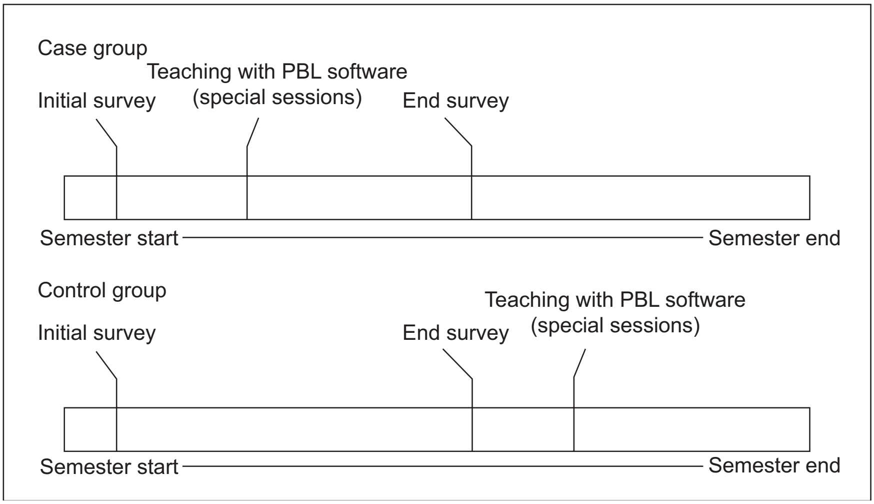

Figure 2 **Timelines for the project**

groups and shows how both groups were given the PBL experience prior to their final examinations for the paper. The online test was administered both before and after the PBL work. Two classes of students were included in the research. One class were second year undergraduate plant protection students (n = 10) and the other class were third year undergraduate plant protection students (n = 22). The participants (n = 32, 11 female and 21 male) from each class were randomly allocated to the case or the control group. The control group (n = 19) experienced their normal teaching throughout the semester (which included a lecture on the process of problem diagnosis), whilst the case group (n = 13) experienced the normal teaching plus teaching using the PBL web-based scenario.

Students in both the case and control groups for both classes were given an opportunity to complete the online test. The software used for the test administration allowed the questions and their answers to be shuffled to minimize any score gain that might have occurred through familiarity with the questions. The online test consisted of twenty questions, each with five answer options, one of which was correct and worth two marks, and one of which was partially correct and worth one mark. The remaining three options were all incorrect and were not worth any marks. During the administration of the test it was made very clear to the students that the marks recorded did not form any part of the formal assessment of their paper. After the pre and post tests had been undertaken the answers were provided to the students for revision purposes. An example question is included in Table 1.

The students' views about learning using PBL software were obtained after they had all participated in the web-based scenario. Sixteen questions were asked and a mixture of Likert scale responses and open questions was used.

Results

In both this section and the analysis section the data are addressed in the following order:

(i) the online test results;
(ii) the evaluative questionnaire – scaled responses to the statements; and
(iii) the evaluative questionnaire – responses to the open questions.

The graph (Figure 3) illustrates the results from the case and control groups, pre and post experiencing the scenario. The mean score for the case group increased from 60.5 per cent to 63 per cent (up 2.4%) and from 59.2 per cent to 62.5 per cent (up 3.4%) for the control group.

The data from the evaluative questionnaire Likert responses are presented below (Figure 4). In all cases, a five point 'strongly agree' to 'strongly disagree' scale was used. Points on the scale were allocated values with a mid-point value of three. For the seven questions reported here, all average scores were positive and higher (or lower depending upon the phrasing of the statement) than the mid-point value. For example, Question 9 asks students to agree or disagree with the statement, 'the scenario made me think about the diagnostic process', and recorded a mean score above 3, whilst the statement in question 16, 'I would have learnt more from readings on the subject', recorded a mean score below three. Both cases can be interpreted as positive responses supporting the use of PBL as a learning method. The earlier questions (Qs 1–8) asked the students about the practicalities of using the PBL interactive software and are not reported here.

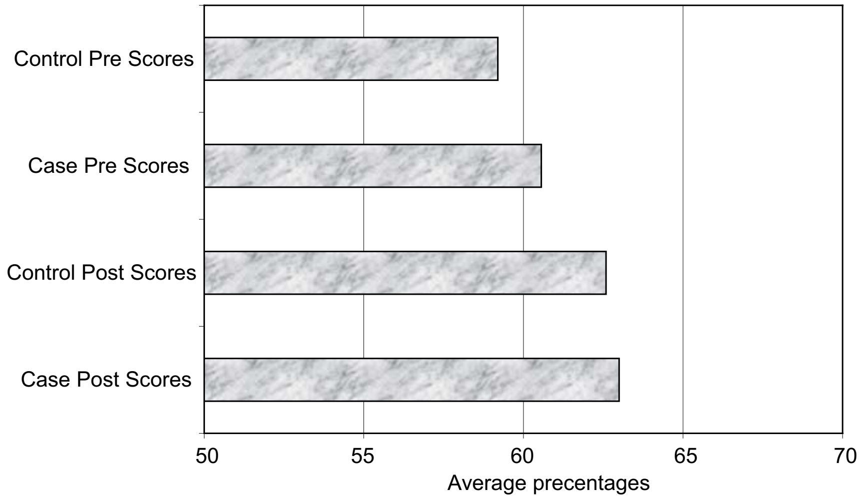

Figure 3 **Case and control group mean test scores**

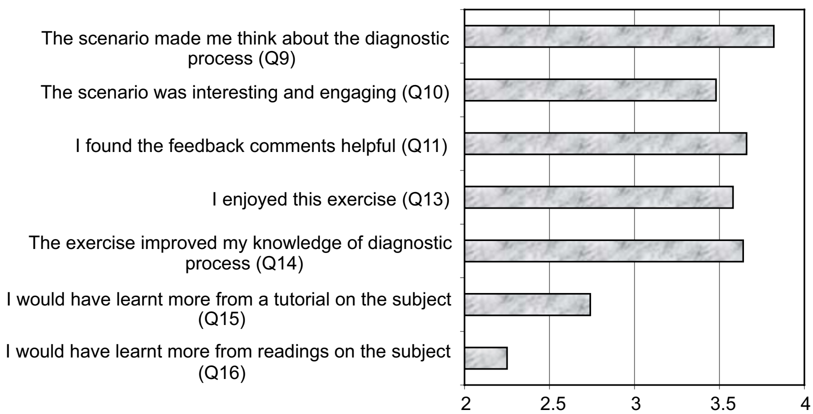

Figure 4 **Evaluative questions mean scores (scale range: strongly disagree=1, strongly agree=5)**

From the open answer questions on the evaluative questionnaire (n=39), categories of responses were identified using content analysis (Cohen and Manion, 1994).

For the questions asking students about the presentation of the scenario using information technology the following frequencies (see Table 2) were recorded.

The students identified a range of positive educational benefits from using the ICT based PBL scenario (Table 2). 'Ease of use' and 'enjoyable' are perhaps

Table 2 **Content analysis – PBL using information technology**

Categories	*+ve responses*	*Categories*	*−ve response*
Quality / quantity of explanation (instant feedback)	7	Lack of instructions / not intuitive	6
Ease of use	14	Too simple	3
Allowed reflection on actions / interactivity	5	More scenarios required	5
Incorporation of pictures	5	Computer issues (crashed)	4
Enjoyable	5	Others (educational)	5
Real world scenario	4		

of little use as educational comments, although they may well contribute to a supportive learning environment. However, the identification of 'instant feedback', the 'incorporation of pictures' and the 'interactivity' (students could easily see the consequences of their choices) as well as the 'real world scenario' clearly indicate that students recognize some of the ways in which they learn effectively. The negatives illustrate the same point from a different perspective. Students are clearly frustrated by a 'lack of clarity of task', or 'too simple' tasks, or 'limited scenarios'. The four who identified the limited number of scenarios might, arguably, have gone on to work through others, had they been available.

Among the 'other' negative comments some rather instrumental statements were made, 'no correct answers', 'too much reading' and 'having to do the test when it was not assessed' are three examples.

Table 3 presents the results of the final question which allowed 'other comments' to be made. These were also revealing, although the actual number of responses was low (Table 3).

Examples of negative responses included: 'too rushed to be effective I needed more time to engage with the concept'; and 'too many examples unrelated to viticulture'. The first negative comment reveals that the student did not realize that they could access the scenario over the internet and therefore had as much time as required and not just the allocated class time. The second comment is more problematic for a teacher since it suggests that the student does not recognize the transferability of the diagnosis process from one context (the orchard) to another (a vineyard).

Examples of positive responses included 'useful, would do it again and encourage its development' and 'the software put the diagnostic techniques in their place, in the process of coming to a conclusion rather than teaching

Table 3 **Content analysis – 'other comments regarding learning through the scenario'**

Categories	
Positive responses	5
Negative responses	4

a hell of a lot about each one'. The second positive statement illustrates that, for at least one student, the teaching technique achieved its aim. One student correctly identified the key objective of the PBL exercise and summed it up with the following statement: 'I felt you did not really learn about the actual pest, it was more learning about what steps you would take to identify the problem'.

Analysis and discussion

A paired t-test was conducted on the pre and post online test scores for the case (n=14) and control (n=19) groups and no significant difference between the means was found. A two sample t-test for all the case (n=30) and control (n=22) group results was also conducted but not found to be significant.

Chi-square tests on these data show significant relationships between Q9/Q10, Q13/Q14, Q14/Q15 and Q14/Q16 (see Table 4).

The results obtained seem to suggest three things. One, students think that greater engagement with a task (created by the PBL scenario) promotes more thinking about the diagnostic process. Two, greater enjoyment of the PBL (using ICT) exercise promotes more knowledge gain about the plant pathology diagnostic process. Three, knowledge improvement is greater using a PBL teaching approach than using a tutorial or guided reading approach.

The written comments illustrate the problems associated with learner characteristics and dispositions (Kumar and Kogut, 2006). The student who states that there are 'no correct answers' reveals a great deal about their disposition. The statement is also clearly indicative of a student who holds a dualistic (received) view of knowledge (Perry, 1979). A rather better situation would be one in which students held a 'contextural relativism' position (Perry, 1979) where they recognized the need to evaluate alternative solution to problems. A student's response to PBL may provide a way to ascertain their level of cognitive and metacognitive development. The learning outcomes for this PBL scenario were summed up in the student statement 'it was more learning about what steps you would take to identify the problem'. The higher order metacognitive thinking in applying that

Table 4 **PBL using information technology**

H_0	*Chi-square statistic*	*Decision 95%*
Q9/Q10: There is no difference between students' opinion about their thinking about the diagnostic process and their views on their degree of engagement with the scenario.	30.49	Reject H_0
Q13/Q14: There is no difference between students' opinion about the enjoyment of the exercise and it improving, in their view, their knowledge of the diagnostic process.	20.51	Reject H_0
Q14/Q15: There is no difference between students' opinion about their view of their knowledge improvement due to the PBL exercise and possible knowledge improvement from a tutorial.	22.26	Reject H_0
Q14/Q16: There is no difference between students' opinion about their view of their knowledge improvement due to the PBL exercise and possible knowledge improvement from directed readings.	17.86	Reject H_0

process learning to future scenarios could provide an alternative testing benchmark for PBL.

The distinction between learning about process and content has also been noted (Savery and Duffy, 1995). Students are frequently conditioned by their educational experiences into thinking that they are required to learn 'correct' content. Any teaching that has a different objective, such as learning about process, has this obstacle to overcome. The study attempted to overcome some of these process and content issues by asking questions about plant pathology diagnostic processes in the online test. However, the results reported were inconclusive. The PBL exercise aimed to promote learning about the plant pathology diagnostic process but was seen by students as a problem with one correct solution. The use of the online test may have reinforced the view some students had of knowledge being polarized as correct or incorrect.

Conclusions and implications for practice

This study has highlighted some of the issues involved with the implementation of new learning methodology. Any new methodology must be clearly explained to the students in order to ensure that their learning matches the intended outcomes. Students must also clearly understand the reasons why they are attempting a learning task and the PBL scenario needs to be carefully set and managed to promote the desired learning outcome.

The students' approach to the ICT delivered problem scenario highlights some of this study's limitations. The presentation of the scenario in a normally timetabled but noticeably different session may have enhanced the students' view of having a problem to solve. It would be better to evaluate ICT and PBL when students are not aware that they are undertaking something different. In addition, the nature of the subject for the scenario may have led students towards thinking that there was one correct diagnosis. The difficulties in constructing correct, partly correct and incorrect multiple choice questions about a process also need to be noted. Further work in this area could lead to a refinement of this technique. The number of paired responses (n=32) for the t-tests also limits the generalizability of the study. Replicating it with larger numbers of students across a variety of courses will provide more evidence to support PBL effectiveness claims.

One of the elements of problem-based learning is that the 'teaching and learning stems from, and comes after, exposure to a scenario or trigger (the "problem") which is presented without prior detailed teaching of the material involved' (Fry et al., 2003: 376). In this scenario, the exposure of students to the problem prior to any teaching presented a particular issue. The students tended to consider the learning to be about the issue (i.e. what was happening to the plants in the orchard), rather than the approach to be adopted for confronting a generic problem (i.e. how to approach and diagnose plant pathology problems in the field). The aim was to create a situation where the students learnt how to think like plant pathologists and to reflect upon such metacognitive processes. However, because of the way the work was presented outside the formal lesson sequence and with a rather limited introduction, many of the students simply searched for a solution to the scenario. It is perhaps a response to years of formal teaching that when given a problem the first inclination of a student is to search for a correct answer. This might be overcome with integration of the scenario into the formal sessions of class teaching.

The research replicated Beer's (2005) results with no statistically significant change in pre/post test scores recorded. It also supports Prince's (2005) view that PBL engenders positive student attitudes. This was particularly the case when PBL was compared with reading as a learning method. Although the students in this study were not asked about their degree of satisfaction with their experiences, the positive responses to questions 10, 13 and 14 (see Figure 3) suggest agreement with Major and Palmer's (2001) views about PBL and student satisfaction.

PBL in this study does not seem to significantly improve students' learning of 'content'. However, PBL using ICT, as undertaken in this study, does promote greater engagement with the subject. Further research might be able to draw more conclusive arguments for the use of PBL because of the greater engagement it engenders. It seems logical to suggest that students might learn more if they are more engaged with the process. A study might compare two concurrent papers, one using PBL and one using more 'traditional' methods. However, the problem of how to measure the educational 'output' remains. Problem-based learning and the development of generic thinking and cognition skills can be seen to be at odds with content coverage and knowledge retention. Another productive direction for research could be to investigate what effect the use of PBL has on student metacognition. Perhaps this could be achieved by mapping students against Perry's (1979) developmental stages before and after a course using PBL as the teaching methodology. Again, comparisons with 'traditional' courses could be made.

PBL clearly offers a viable alternative to 'traditional' course delivery although its knowledge gain claims in comparison to other methodologies are still open to debate. This study does provide further evidence to support the notion that students derive greater satisfaction from PBL compared with other 'traditional' methodologies.

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Biographical notes

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