Paper

Learning from Problem Based Learning

Alison M Mackenzie[a], Alex H Johnstone[b] and R Iain F Brown[c]

a Department of Adult and Continuing Education, University of Glasgow, Glasgow G3 6LP.
b Centre for Science Education, University of Glasgow
c Department of Psychology, University of Glasgow

e-mail: a.m.mackenzie@educ.gla.ac.uk

There is increased interest in Problem Based Learning (PBL) as a teaching and learning method in the sciences. This paper describes the form of PBL currently in use in a medical school where PBL is the main method for learning the content of the course and for generating self-driven, independent learning and for fostering the skills of organisation and communication. The course has been independently evaluated to discover if the claims for PBL can be substantiated. The PBL technique and the evaluation results are presented here and suggestions are made about how this might be applied to the teaching and learning of the sciences.

Introduction

The term Problem Based Learning (PBL) has recently been appearing in Science Education circles, in conferences and in the literature.[1, 2] Even in casual conversation the title PBL is being applied to what used to be called tutorials, problem solving workshops and group exercises and indeed they all involve some measure of PBL They are problem based, but do they necessarily facilitate learning?

Exercises in chemistry designed to promote discussion and group problem-solving have been around for along time [3, 4, 5, 6, 7] and efforts to evaluate them have generally shown positive gains in skills and improvement in attitudes towards the methods themselves and towards chemistry in general.[8, 9]

However, the idea of PBL as the *main* medium for learning in a discipline, or cluster of cognate disciplines, has been addressed by some of our medical colleagues. This paper will be devoted to the description and evaluation of one form of PBL in the medical school in the University of Glasgow. Implications of this for the teaching of chemistry and other sciences will be explored. We believe that this could stimulate thinking in the sciences about PBL and lead to a wider perspective on the teaching and learning of the sciences. The basic sciences of chemistry, physics, biology and biochemistry are being learned through PBL in medical schools, suggesting the possibility of the transference of PBL into the traditional science structures.

Why did medical schools make such a change in their curriculum? They were responding to pressure from the General Medical Council[10] to devise courses to equip students to be effective, self-directed learners throughout their professional life and also to be good listeners and communicators.

'Traditional' undergraduate courses, although not identical in format, have tended to share certain features, for example, teaching methods which rely heavily on large-group lectures and structured laboratory classes; a heavy assessment load, with a reliance on multiple choice tests, and discipline-based, self-standing courses in the basic sciences (e.g., physics, chemistry, biology) during the initial, pre-clinical years.[11] Recommendations for change have highlighted the need to reduce the factual 'load' in undergraduate courses while developing students' critical thinking skills, such as independent enquiry, awareness of different contexts in which decisions are made, and the evaluation of information on the basis of evidence. The need for course designers to address concerns about integrating knowledge of the basic sciences with their practical application in the clinical setting has also been stressed.[10, 12]

In contrast to this picture, PBL has its own characteristic features.

Students are required to assume far greater responsibility for what and how they learn. The student's role, for instance, includes defining issues, identifying learning needs, drawing on self-directed learning in relation to scenarios provided by clinical and research cases, and organising and

integrating learning material from various sources. The PBL process is thought to be facilitated by small-group work and independent study, with other more traditional activities, such as lectures and labs, playing a much reduced role.[11, 12]

Introduction of problem based learning in Glasgow University's medical course

How was PBL implemented in our medical school? The PBL course was devised by writing teams over a two year period. Staff training was undertaken by the university's Teaching and Learning Service in readiness for the changeover. Rather than changes being phased in gradually, the PBL course completely superseded its predecessor; in one academic year, new medical students entered the first year of the traditional course; the next year, new students entered the first year of the PBL course. Small group work was the major method for students to acquire course content in PBL and in the first year they worked in groups of eight. In deliberate contrast to the heavy reliance in the traditional curriculum on frequent class exams and lab reports, the first year in the new curriculum included assessment of independent learning, an objective, structured, clinical examination and a written examination. Course assignments also contributed to final assessment.

A week in the life of a PBL student

Monday: PBL (2 hours). A group of eight students work with a facilitator. The first hour is devoted to discussion of the outcomes of the previous Thursday's tasks. The second hour is for the introduction and analysis of a new scenario and the selection of tasks to be undertaken.
Tuesday and Wednesday: Students work independently on the tasks arising from Monday. There are laboratories, workshops and larger group discussions.
Thursday: PBL (2 hours) as for Monday
Friday: As for Tuesday and Wednesday.

Occasionally (not weekly) there would be a lecture to integrate the work of the previous scenarios or to prepare the context for the forthcoming scenarios.
Almost half the week was earmarked for private study, library work and report writing.

How was a PBL session organised?

The facilitator (a member of staff, drawn from medicine or science, trained to ask questions rather than to provide answers) met with the group of eight students. One student was appointed as chairperson and another as scribe. (These 'posts' were rotated round the group from time to time.) Each student was presented with the scenario on about half a page of A4. This consisted of a description of a situation, part of which might be familiar from previous work. The facilitator would explain any unfamiliar terms and then the students, under the chairperson, had to decide on the main issues about which they required knowledge. The scribe recorded the ideas on a board in the form of a mind map to show linkages between the issues and to arrive at an agreed analysis of the problems. The facilitator could help with emphasis on main concerns and help to deflect students from pursuing unprofitable lines. The students then left with a short list of about six issues to be pursued. They were obliged to search in textbooks, library texts, papers and computer resources. At the next PBL session, the first hour was devoted to the students' reporting back. They had to communicate their findings, compare them and resolve any conflicts. They also had to report on their information sources. From this interaction, students compiled their response to the scenario along with some input from the facilitator. The second hour of PBL was spent opening up the next scenario.

The method was clearly designed to develop communication skills, independent learning, source seeking and integration of knowledge. The laboratories were closely linked with the scenarios so that some of the issues raised in the PBL session could be answered in the laboratory thus giving added importance and point to them.

This major innovation in PBL had, on the face of it, all the ingredients needed to foster the skills and attitudes thought to be desirable in students and future professionals. However, Rosenthal and Ogden[13] argued that "proponents for change in medical education appear to have given little consideration to the attitudes of students themselves either to the present curricula or to the proposed changes". The innovative changes in the Glasgow curriculum created an opportunity for such an evaluation because the last cohort of the 'traditional' course and the first of the PBL course were available for comparison. The authors, one psychologist (RIFB), one psychologist and specialist in adult education (AMM) and one chemist (AHJ) were invited to carry out an evaluation study, which will make up the remainder of this paper.

Conceptual framework for the present study: Perry's[14] scheme of intellectual and ethical development.

The GMC's document[10] *'Tomorrow's Doctors'*, emphasised the attributes that were required for medical graduates in the twenty-first century: the ability to apply theoretical knowledge in a range of clinical contexts; good communication skills for working with patients and colleagues alike; and the capacity for self-directed, lifelong learning for

continuing professional development. These attributes are similar to those described by Perry[14] as being at the higher levels in his proposed scheme of intellectual development – reflecting a critical, self-directed student, capable of evaluating information and evidence, and wanting scope to demonstrate understanding of the complexities of a field of study. Also relevant to our study, Perry's developmental scheme has been used to describe how students view their own role and that of their teachers[15, 16, 17].

Perry's[14] initial, longitudinal study investigated changes in thinking among undergraduates and the ways in which they made sense of their educational experience. The outcome of his research was an outline of intellectual and ethical development in which he described a series of nine 'Positions' or stages, together with their associated transitions, in the individual's developmental journey. Each Position reflected the person's way of thinking about the world and self, as well as knowledge and how learning takes place. Perry conceptualised the Positions as representing a hierarchical sequence in which individuals moved from relatively simple ways of thinking to highly complex ways of perceiving and evaluating knowledge and the world. At one extreme ('Dualism') are students who see knowledge consisting of 'right answers', 'taught' by the lecturer, and whose responsibility is to return memorised 'facts' in assessments. At the other extreme ('Contextual Relativism') are students who are analytical, independent learners, who see their task as demonstrating that they can evaluate possible solutions to problems on the basis of evidence. 'Knowledge' is seen as not absolute, and the student copes with this uncertainty by taking into account the settings in which decisions are made. The lecturer is expected to provide knowledge within a context and to demonstrate evidence for a decision or opinion. Within the scheme, the individual's 'ways of seeing the world' are reorganised as the person confronts social and intellectual challenges, either by chance through social situations, or by design through an educational programme.[18]

There have been criticisms of the scheme and Perry's research methodology. For instance, it has been claimed[18] that one Position should not be regarded as 'better' than another. However, it is difficult to view 'Dualist' and 'Contextual Relativist' Positions as equally desirable for students in higher education. Indeed, much of the 'Perry' research in educational settings[17] seemingly has tried to determine how best to challenge students to encourage them to move to 'higher' Positions. Also, participants in Perry's initial study were Harvard undergraduates, not necessarily representative of students in general, with major analyses based on male interviewees, although a quarter of participants were women.

Despite such criticisms, there seems to be agreement in the literature about Perry's important contribution to understanding learning from the student's perspective,[19] and his work has generated copious research in diverse areas of post-school education, including medicine, law, engineering, science and teacher training.[20]

Later researchers have reduced the number of Positions to three or four.[21, 22] We utilised a three stage version of Perry's scheme;[17] 'A' Position or 'Dualism' (representing Perry's Positions 1 and 2); 'B' Position or 'Multiplicity' (representing Positions 3 and 4); 'C' Position, or 'Contextual Relativism' (representing Positions 5-9). Johnstone[23] has summarised these three Positions in relation to students' perceptions of four elements of the learning environment (Table 1).

Method

Two cohorts of medical undergraduates at Glasgow University were invited to take part: *(i)* the final intake of students to the first year in the traditional course (n=237) and *(ii)* in the subsequent year, the first intake of students to the first year in the PBL course (n=235). All students were asked to complete a questionnaire about their learning experience on two occasions – near the *beginning* of first year (five weeks after the course began) and near the *end* of first year (five weeks before the course finished).

Questionnaire to investigate students' learning perceptions

One problematic area in Perry's scheme is the measurement of an individual's Position within it. Originally, Perry used unstructured interviews, as did early follow-up studies. Subsequently other instruments were developed, such as structured interviews, paraphrasing and restatement tasks, and semi-structured essays.[24] Although these produce extremely rich data, many are inappropriate for large groups. Therefore we devised a questionnaire incorporating sentence stems and 'agree/disagree' statements of the kind used in previous Perry-related research,[22, 24] and which had been developed to measure the 'A', 'B', and 'C' positions shown in Table 1.[25, 26] (See the Appendix for sentence stems).

A student in Position 'A' ('Dualist'), for example, might be expected to agree with views about the nature of knowledge and the roles of lecturer and student described in Table 1, column 2. Conversely, a student in Position 'C' ('Contextual Relativist') might be expected to disagree with such views.

Table 1
Description of 'Positions' in three-stage version of Perry's scheme of intellectual development (Johnstone[23])

Perceptions of:	Student in Position 'A'	Student in Position 'B'	Student in Position 'C'
Student's role	Passively accepts	Realises that some responsibility rests with the student. But what? And how?	Sees student as source of knowledge or is confident of finding it. Discusses, and makes own decisions
Role of lecturer / member of staff	Authority, giving facts and know-how	Authority. Where there are controversies, wants guidance as to which view is favoured by staff	Authority among authorities. Values views of peers. Member of staff as facilitator
Nature of knowledge	Factual; black and white; clear objectives; non-controversial; exceptions unwelcome	Admits 'black-and-white' approach not always appropriate. Feels insecure in the uncertainties this creates	Wants to explore contexts; seeks interconnections; enjoys creativity; scholarly work
Student's task in examinations / assessments	Regurgitation of 'facts'. Exams are objective. Hard work will be rewarded	Quantity is more important than quality. Wants to demonstrate maximum knowledge	Quality is more important than quantity. Wants room to express own ideas and views.

Questionnaire drafts were discussed with student representatives and staff, and then finalised after piloting. Four sentence stems referred to the four elements of learning. In each stem, students were asked to choose one answer from the three provided (representing 'A', 'B' and 'C' positions). Each set of three answers was presented, not in order of progression in the Perry scheme, but randomly. Additionally, in the first term questionnaire, students were asked to respond to each sentence stem as they might have done *prior* to university. It can be argued[27] that retrospective accounts such as these are less valid than concurrent ones, but since students were being asked to reflect on a lengthy period of schooling which, for most, had ended only about four months beforehand, we considered that such retrospective impressions would still be informative.

Clearly it was important for meaningful comparison of students' responses, that the two questionnaires be as similar as possible. Thus, the first term questionnaires were identical. However, about 10% of respondents in the PBL course provided written feedback, emphasising the need for minor re-wording of several items to take into account more explicitly the nature of their course. The amended wording in the third term questionnaire is also shown in the Appendix.

Results and Discussion

Questionnaire response rates

Although Term 1 and Term 3 response rates were high in both cohorts, it was to be expected that they would be lower for questionnaires returned on *both* occasions (Table 2). These were still acceptable in the context of survey research. The results described below are based on the questionnaires returned on both occasions.

Table 2
Response rates associated with questionnaire on learning perceptions

Time of questionnaire returns	Number returned		Response rate	
	Traditional course	PBL course	Traditional course	PBL course
(*Year 1: Middle of Term 1)*	*(169)*	*(192)*	*(71% of 237)*	*(82% of 235)*
(Year 1: Middle of Term 3)	*(176)*	*(166)*	*(74% of 237)*	*(71% of 235)*
Returned on both occasions	126	134	53% of 237	57% of 235

Table 3

Percentage of undergraduates endorsing 'A', 'B' and 'C' responses to the four sentence stems: Comparison of undergraduates in traditional (n=126) and PBL (n=134) courses

Type of response given to sentence stem concerning	Before coming to university (gauged retrospectively)		Middle of first term, first year (5 weeks after course started)		Middle of third term, first year (5 weeks before course ended)	
	Trad. Course %	PBL course %	Trad. Course %	PBL course %	Trad. Course %	PBL course %
1. Student role:						
A	27.8	32.1	0.8	-	4.8	0.8
B	38.1	25.4	41.3	15.7	34.1	17.2
C	28.6	35.8	54.0	83.6	61.1	80.6
Mixed response	-	-	-	-	-	0.8
No response	5.6	6.7	4.0	0.8	-	0.8
Significance level	***$\chi^2 = 4.93$, $df = 3$, *NS*		*$\chi^2 = 24.08$, $df = 1$, $p \leq .001$		* $\chi^2 = 13.62$, $df = 1$, $p \leq .001$	
2. Staff role:						
A	24.6	34.3	5.6	3.0	7.9	0.8
B	28.6	19.4	11.1	3.7	27.0	8.2
C	39.7	38.8	81.0	88.8	65.1	89.6
Mixed response	0.8	-	-	-	-	0.8
No response	6.3	7.5	2.4	4.5	-	0.8
Significance level	***$\chi^2 = 4.49$, $df = 3$, *NS*		**$\chi^2 = 6.29$, $df = 2$, $p \leq .05$		**$\chi^2 = 26.14$, $df = 2$, $p \leq .001$	
3. Nature of knowledge:						
A	23.0	20.9	5.6	0.8	8.7	2.2
B	25.4	27.6	27.8	28.4	35.7	28.4
C	45.2	44.0	61.1	70.2	54.8	67.2
Mixed response	-	-	1.6	-	-	0.8
No response	6.3	7.5	4.0	0.8	0.8	1.5
Significance level	***$\chi^2 = 0.39$, $df = 3$, *NS*		*$\chi^2 = 1.03$, $df = 1$, *NS*		**$\chi^2 = 7.80$, $df = 2$, $p \leq .05$	
4. Exams/assessment						
A	49.2	46.3	42.9	26.1	44.4	18.7
B	21.4	26.9	22.2	26.1	31.0	18.7
C	23.8	20.2	31.0	44.0	24.6	60.4
Mixed response	-	-	1.6	0.8	-	0.8
No response	5.6	6.7	2.4	3.0	-	1.5
Significance level	***$\chi^2 = 1.45$, $df = 3$, *NS*		**$\chi^2 = 8.67$, $df = 2$, $p \leq .01$		**$\chi^2 = 31.38$, $df = 2$, $p \leq .001$	
*Chi-square analyses based on: *A &B combined, C: **A, B, C; ***A,B,C, No response*						

Sentence stem responses: Comparison of students in traditional and PBL courses at three points in time.

Table 3 shows the types of sentence stem responses given by students in the traditional and PBL courses at each of three points in time: *(i)* 'pre-university' (students gauging retrospectively what their responses might have been before university); (*ii)* five weeks after the course began (middle of Term 1); and *(iii)* five weeks before first year ended (middle of Term 3). 'Pre-university', both cohorts reported similar perceptions of all four elements. However, even as early as halfway through the first term of first year, differences between the two cohorts existed in all elements except nature of knowledge. By the end of first year, their perceptions differed significantly in all four elements and, excepting knowledge, were highly significant.

'Pre-university' perceptions.

In both cohorts, views about student and staff roles were fairly evenly spread across 'A', 'B' and 'C' perspectives. The great majority of students in both courses had recently left school and had had no previous experience of higher education. In contrast, perceptions of the nature of knowledge and assessment-related tasks were slightly more polarised in the 'C' and 'A' positions respectively. The two groups showed no significant differences in any of the four elements.

Perceptions early in first year (mid-Term 1).

Although the retrospective reports did not distinguish between the two cohorts, significant differences were demonstrated in three elements after five weeks' experience of undergraduate life. The direction of the differences – 'C' type responses reported by higher proportions of 'PBL' students – might be expected to be more closely associated with a PBL curriculum than a traditional, lecture-based one, especially in terms of the extent to which students see themselves as more independent, analytical learners ('C' position) rather than passive, unquestioning recipients of 'handed down' information ('A' position).

Differences between the two cohorts were especially marked in perceptions of the student role. Most 'PBL' students (83.6%) considered they should take a critical approach to their subjects, check out information from various sources and take responsibility for what and how they learned ('C' position). While this approach was also reported by just over half the students in the traditional course (54.0%), a sizeable proportion (41.3%) were uncertain about what or how they should learn, while accepting that some responsibility for learning lay with them ('B' position). There were also significant differences between the cohorts in perceptions of staff roles. Here, significantly more 'A' and 'B' responses were given by 'traditional' students, and significantly more 'C' by 'PBL' students.

Similarly, the two cohorts differed significantly in what they thought was expected of them in exams/assessments. 'A' perspectives were more prominent among 'traditional' students (42.9%, compared with only 26.1% of 'PBL' students). Conversely, 'C' type views were more evident among 'PBL' students (44.0%, compared with 31.0% of 'traditional' students). Only in the fourth element – the nature of knowledge – were there no significant differences between the two cohorts. Most students regarded knowledge from a 'C' perspective; almost all the remainder endorsed 'B' type views. Very few students in either course supported 'A' type views.

Perceptions towards the end of first year (mid-Term 3).

At this stage, perceptions of the two cohorts differed significantly in relation to all four elements. A considerable majority of 'PBL' students reported 'C' perceptions of both student and staff roles (80.6% and 89.6% respectively), compared with 61.1% and 65.1% respectively in the traditional course. Even in their perceptions of exams/assessments, a majority of 'PBL' students (60.4%) now reported a 'C' position, considerably higher than the proportion of 'traditional' students (24.6%). In contrast, a relatively high proportion of traditional students (44.4%) reported 'A' type views about assessments, compared with a much lower proportion of 'PBL' students (18.7%).

For the first time, significant differences between the two cohorts were evident in views about the nature of knowledge, the one area where students had shown greatest similarity at earlier stages. Here, more of the 'PBL' students reflected a 'C' stance (67.2%, compared with 54.8% in the traditional course). Conversely, more of the 'traditional' students (44.4% *vs.* 30.6% in the PBL course) gave 'A' and, especially, 'B' perspectives.

From Table 3 it can be seen that, with the exception of the 'traditional' students' response to exams/assessments, more than half in each course reported 'C' perspectives at the end of first year. This was more marked among 'PBL' students, especially in terms of how they saw their own role, as well as that of the staff. However, the largest divergence between the two cohorts related to exams/assessments, where substantially fewer in the traditional course saw them as 'open-ended', allowing scope for their own thinking. Certainly 'pre-university' views about this element indicated that many students in both cohorts had further to

'travel' to reach a 'C' position at the end of first year. The following questionnaire comments may cast some light on possible reasons for the findings:

'Traditional' students:

" used to prefer the open long questions but after what I have experienced during the academic year, I know I prefer clear-cut answers/questions."

"There is no room for thought – all you do is ... regurgitate ... I don't feel that [this] response is what I would like but this appears to be what is expected of me. I don't necessarily agree with the lecturer but I answer exams with his opinion as he will be responsible for the marking scheme."

"Objectives should be provided in all subjects for all sections of the course so students can clearly see what material is examinable and essential. This way there will be no problem with lecturers introducing extra material into lectures."

'PBL' students:

"...much of what we learn makes sense when we stand back and think about the reasoning behind it. It is easy to become overloaded with facts; it is not possible to learn everything but rather get an overview and grasp the basics."

"I enjoy getting to grips with so many different angles and creating my own personal way of understanding."

"The beauty and enjoyment of science lies in the fact that there are many ways to look at things and many options to explore."

Comments from the 'traditional' students embodied a more restricted, syllabus-bound approach to learning, with exams very much regarded as the end towards which they were working. This 'A' stance might be closely associated with perceptions of school exams, and indeed was reflected in 'pre-university' views of many students in both courses. The (relatively) more familiar teaching/learning environment of the traditional course was likely to reinforce this way of thinking about exams. Possibly, many school leavers would find difficulty envisaging alternative forms of 'exams' or assessments. It can be argued, of course, that this was a sound and realistic approach for the 'traditional' students to adopt, and one that had perhaps been validated already by their first year experience. It was also clear from their questionnaire comments that they felt pressure from the numerous exams during the year, that the workload had been heavy, and that it was often difficult to identify what was 'needed' for exams. By the third term, they had had considerable 'first hand' experience of university exams and many had obviously drawn their own conclusions about what was wanted in exam answers.

The 'PBL' students were also facing their first 'professional' exams soon after completing the Term 3 questionnaire but it was clear from their comments that many felt the course assessments during the year gave inadequate preparation. Two 'PBL' students stated:

"It's right that we take responsibility for our own learning and not be spoon-fed by staff but when push comes to shove, we still have to pass exams so we need SOME idea of what we need to know for the exam."

"It's all very well giving assessments which allow students the opportunity to 'show they have ideas of their own' but the marking of these assessments must reflect this in order for these to be worthwhile."

It was quite apparent, therefore, from sentence stem responses and comments that exams/assessments were areas that students in both courses found especially difficult. In particular, their frequency in the traditional course and their infrequency in the PBL course were mentioned as sources of disquiet.

Maintenance/change in individuals' responses between Terms 1 and 3.

We were interested not only in students' perceptions of the four elements at different points in time but, in particular, whether individual students differed significantly in their patterns of change in perceptions during first year. Table 4 shows, for each sentence stem, the percentages of students in each course who, during first year, moved 'forward', 'back' or showed 'no change' in response. Small expected cell frequencies in the chi-square analyses necessitated the combining of sub-categories under 'No change', 'Moving forward' or 'Moving back'.

Table 4

Maintenance/change in individuals' sentence stem responses by end of first year: Comparison of undergraduates in traditional (n=126) and PBL (n=134) courses

Type of change in sentence stem responses between first and third terms in first year:	1. Student Role		2. Staff Role		3. Nature of Knowledge		4. Exams/Assessments	
	Traditional Course %	PBL Course %	Traditional Course %	PBL Course %	Traditional Course %	PBL Course %	Traditional Course %	PBL Course %
No change – stayed at:	**57.9**	**76.1**	**65.1**	**84.3**	**58.7**	**72.4**	**45.2**	**52.2**
A	0	0	1.6	0.8	3.2	0	24.6	11.2
B	19.8	5.2	6.4	1.5	14.3	15.7	11.1	7.5
C	38.1	70.9	57.1	82.1	41.3	56.7	9.5	33.6
Moved 'forward':	**20.6**	**9.7**	**7.9**	**4.5**	**12.7**	**10.4**	**23.0**	**29.1**
A ⇒ B	0	0	1.6	0.8	2.4	0	10.3	3.0
A ⇒ C	0.8	0	2.4	1.5	0	0.8	7.9	11.9
B ⇒ C	19.8	9.7	4.0	2.2	10.3	9.7	4.8	14.2
Moved 'back':	**17.5.**	**12.7**	**24.6**	**5.2**	**22.2**	**14.2**	**27.8**	**13.4**
B ⇒ A	1.6	0	0.8	0	2.4	1.5	6.4	3.7
C ⇒ A	3.2	0.8	5.6	0	3.2	0.8	12.7	3.0
C ⇒ B	12.7	11.9	18.2	5.2	16.7	11.9	8.7	6.7
Mixed/no responses given	**4.0**	**1.5**	**2.4**	**6.0**	**6.4**	**3.0**	**4.0**	**5.2**
Significance level	*$^{*}\chi^2 = 30.6$, df=3, $p \leq 0.001$*		*$^{**}\chi^2 = 21.0$, df=2, $p \leq 0.001$*		*$^{***}\chi^2 = 10.0$, df=4, $p \leq 0.05$*		*$\chi^2 = 46.2$, df=8, $p \leq 0.001$*	
Chi-square analysis based on:	* "No change: B", "No change: C", "Moved 'forward' ", "Moved 'back' " ** "No change", "Moved 'forward' ", "Moved 'back' " *** "No change: A", "No change: B", "No change: C", "Moved 'forward' ", "Moved 'back' "							

'Maintenance'.

Table 4 highlights the extent to which individuals in each cohort were characterised, not by *change* during first year, but by *maintenance* of their first term perceptions. In all four elements of the learning environment, a higher percentage of 'PBL' students reported 'C' perceptions at mid-first term of first year and maintained these into the third term. Perceptions of the student's role over the year showed a highly significant difference between the two cohorts (χ^2 = 30.6, df = 3, p< 0.001) especially in maintaining 'C' positions: of those in the PBL course 70.9% maintained this position, compared with just over a third in the traditional course (38.1%). Only a very small proportion of 'PBL' students (5.2%) held 'B' views over the year, compared with a much larger proportion in the traditional course (19.8%). In relation to the role of staff, the difference between the cohorts was also highly significant (χ^2=21.0, *df*=2, $p \leq 0.001$), with 82.1% of 'PBL' students maintaining a 'C' position throughout the year, compared with 57.1% of 'traditional' students. Perceptions of the nature of knowledge, also differed significantly (χ^2=10.0, *df*=4, $p \leq 0.05$), with 56.7% of 'PBL' students and 41.3% 'traditional' students maintaining a 'C' position. Finally, the difference in response to exams/assessments was highly significant (χ^2=46.2, *df*=8, $p \leq 0.001$): 33.6% of 'PBL' students compared with 9.5% of the 'traditional' students remained in a 'C' position throughout the year; twice as many 'traditional' students (24.6%) as 'PBL' students (11.2%) maintained an 'A position.

'Changes'.

Changes in individuals' perceptions that could be interpreted as representing 'backward' movement during first year tended to be reported by more students in the traditional course, mostly to a 'B' position. For instance, with reference to the role of staff, 24.6% of the 'traditional' students appeared to move 'back' compared with 5.2% of 'PBL' students. In the case of exams/assessments, 27.8% of the 'traditional' students appeared to move 'back' (mostly towards 'A'), compared with 13.4% of 'PBL' students (half of whom moved 'back' to 'A').

There was also evidence of what could be described as 'forward' movement for individuals in both cohorts. In their views of the student's role, twice as many in the traditional course as in 'PBL' (20.6% *vs.* 9.7%) reported moving 'forward', and this was towards a 'C' position. Also worth noting was the proportion of students in both courses reporting 'forward' movement in their perceptions of exams/assessments (23.0% of 'traditional' and 29.1% of 'PBL' students). Of these, about half the 'traditional' students (12.7%) moved to 'C' while almost all 'PBL' students (26.1%) did so.

Confidence and uncertainty

The questionnaires, whose results are discussed above, were accompanied by open-ended sections to obtain student views more informally. Analysis of these responses exposed aspects of confidence and uncertainty, which supported and amplified the findings of the main questionnaire.

By the end of first year, there seemed to be some evidence among 'PBL' students of less confidence and more uncertainty about the depth and breadth of course content and about the 'appropriate' approach to take to given topics, and this was more pronounced than for those in the traditional course. Evidence came from 'PBL' students' comments:

"Sometimes it can be scary to do all this work on your own in case what you learn is wrong."

"When you are trying to work independently, this can lead to ... an inability to see the wood for the trees."

"It is difficult to work out what is right or most feasible, as an uneducated student, without guidance from staff. Difficult to evaluate when students' knowledge is not enough to make an informed decision on the relevance of information."

Some 'PBL' students requested some lecture sessions, not in a desire for 'spoon-feeding', it seemed, but as an organisational framework for what they had discovered through their own independent learning:

"More backup lectures to supplement rather than replace PBL would be very helpful."

"I strongly believe there needs to be an increase in 'reinforcement lectures' to consolidate and aid in our understanding of core topics (e.g., coagulation, immunology, neurology)."

[These problems have since been addressed, by the issue of clear objectives for each five-week block of work.]

'Traditional' students, in their unstructured comments, also referred to uncertainty about what was expected of them, especially in knowing what was 'essential' for exams rather than 'merely interesting'. However, this was far less prominent than among 'PBL' students.

Those aspects which 'PBL' students found problematic are identical to those revealed in other studies. Their greater concerns about breadth and depth of knowledge required and ability to identify 'core' information were referred to by Albanese &

Mitchell[11] in their meta-analysis of studies of PBL in medicine. The fulfillment of pre-course fears about gaps in 'necessary' knowledge and about incorrect information being reinforced by fellow students and 'naïve' (i.e., non-specialist) staff were highlighted by Bernstein *et al*.[28] Uncertainty about how to tackle preparation for examinations was reported by Birgegård & Lindquist.[29] Uncertainty about what was expected of medical students and a perceived lack of feedback on progress was noted by Kaufman *et al*,[30] and these were also reported as sources of stress in Moffat et al.'s [31] Glasgow study of the PBL cohort which followed the one in the current study.

Effects of the different courses on students' perceptions

If features associated with a 'C' stance are the qualities desired in medical graduates, it was encouraging to find that, at the end of their first year, more than half the students in each course reported 'C' perspectives in the sentence stems concerning knowledge and the roles of students and staff. 'C' type responses from both cohorts emphasised the importance of setting decisions in appropriate contexts, referring to ethical issues, the complexity of human beings, and the suitability of different treatments for different patients. One 'traditional' student said:

"I think the scientific facts have to be put in the context of treating the patient. Often logic is not applicable and the human body requires individual assessment."

One of the 'PBL' students commented that

"Very few things in medicine are clear cut: drugs have various side effects and many body mechanisms are not known. Ethics are certainly not clear cut ... Few things in medicine are clear cut, if you think about them."

However, more striking were the significant differences in the views reported by the two cohorts about their first year learning experience. These were generally in a consistent direction: to a greater extent, 'PBL' students reported views associated with more critical, self-directed learning, i.e., a 'C' type stance.

The question is whether this resulted directly from the PBL format. It is impossible to say with certainty what produced the differences between the two cohorts, given the likely range of individual differences, even in this highly selected student body. These comprise intrinsic factors, such as motivation, confidence, academic ability and personality, and extrinsic factors likely to impinge on students in their first year, for example, the transition from school, and often living away from home. The research design did not permit conclusions about cause-and-effect. However, statistically significant perceptions were found to be associated with students enrolled in the two different courses.

It could be argued that 'traditional' and 'PBL' students entered first year from different starting-points – that more of the 'PBL' students held a 'C' perspective before they even began university – and this was the source of the significant differences. However, students' retrospective evaluations of how they viewed learning prior to university lent support to the idea that the two cohorts had started from essentially similar baselines. Recall of 'pre-university' study would have to be consistently faulty across both cohorts to produce no significant differences between them. Very importantly, too, admission requirements had not been altered. The same criteria, based on academic qualifications and interview, applied to students in both cohorts, lending further support to their apparent initial similarity.

Prior knowledge about the forthcoming change in curriculum might have been a source of bias, with advance information about the new PBL course attracting more potentially 'C' type students. Questionnaire comments from 'PBL' students suggested this was unlikely – they reported extremely vague (and, in the event, inaccurate) expectations, 'pre-university', about what PBL would entail. Many, expecting 'group work' akin to school seminars, had been unprepared for the radically different format.

It is impossible to claim that the two cohorts definitely started from similar baselines in their 'pre-university' perceptions. However, it seems likely, from the above, that they were more similar than dissimilar. At least, they were similar in the perceptions they thought they had before university.

Distributing the first questionnaire in mid-first term should have allowed for initial settling-in without substantial adaptation to the new learning environment. Therefore, it was surprising to find significant differences between the cohorts appearing so soon. Obviously, by then the PBL students had experienced the new format in practice, they had observed how staff behaved and they were learning what was expected of them, as students, in this new learning environment – all very different from school. The school to university transition, especially during the first few weeks, can be expected to have an impact on most undergraduates and, indeed, at this early stage, more students in both courses endorsed a 'C' stance

than had done in the 'pre-university' reports. Apparently, however, in their first few weeks, 'PBL' students encountered a course so different from their expectations or previous experience that it had an even greater impact on them than the traditional course had on its students.

Tracing the ways in which individual students changed or did not change during first year demonstrated that, in both cohorts, end-of-year 'C' positions represented largely, not a movement to 'C', but maintenance of a 'C' stance from first term. Thus, whatever movement to 'C' had occurred seemed to be associated with the first few weeks of the new academic session. This does not mean there was no movement at all by individual students. There was evidence of change both 'forward' and 'back' within each cohort, though change 'back' was more clearly, but not exclusively, associated with students in the traditional course.

Possible reasons for moving 'back' or maintaining 'A'/'B' positions emerged from questionnaire comments. For 'traditional' students, these included the much more onerous workload; the perceived irrelevance of studying the basic sciences, accompanied by decreasing motivation and pressures from frequent exams throughout the first year. For 'PBL' students, likely factors derived largely from the novel nature of the PBL course, such as decreasing confidence and increasing confusion about appropriate depth and breadth of learning material – what constituted 'core' knowledge – and feelings of a lack of preparedness for the forthcoming first 'professional' exams. Indeed, the lowest proportion of 'PBL' students in an end-of-year 'C' position was found in the exam/assessment element. This suggested that changes in assessment formats (or, at least, students' perceptions of assessment demands) were perhaps not keeping pace with the PBL thrust in other aspects of the students' learning environment. The problem of devising appropriate assessments in PBL has been acknowledged elsewhere.[32]

Conclusion

Our findings from this relatively short-term study of the learning experience of first year medical undergraduates provided some evidence that PBL, as implemented here, was fulfilling, with certain qualifications, the General Medical Council's recommendations for change. Compared with the traditional course, the new curriculum seemed to be associated overall with a more critical, self-directed approach to learning among students entering under identical admission criteria and holding similar 'pre-university' perceptions of learning.

Possibilities for the sciences

It could be argued that what is an appropriate teaching and learning experience for highly intelligent and motivated medical students would not be suitable for science students. However, the positive responses obtained from science students participating in limited PBL experiences mentioned at the beginning of this paper might encourage us to go further. If we want the desirable skills and attitudes, which are so often aired in the literature, to develop in our students, we may have something to learn from our medical colleagues.

It might also be argued that the kind of scenarios used in medicine where science, medicine and social problems can be personalised in a 'living' situation, would be difficult to find in the sciences. However the 'case studies' that have been used in chemistry to link academic and industrial and environmental situations are exactly parallel to those in medicine. The laboratory could easily provide the scenario. Wham[33] devised such a situation when he had students analyse water samples taken at different points on the River Kelvin for phosphate and then work in groups to explain the results. The brainstorming raised issues such as: "Where was the phosphate coming from? Who used it and for what? Why did the phosphate concentration rise suddenly at some points and then diminish? Has anyone got a map? What industries are on the tributaries?" This is exactly analogous to the type of scenarios used by our medical colleagues.

Many examples must exist which could be shared within the chemical and inter-science community and so enable us to see new possibilities for the development of the skills of our students and even to gain the bonus of enthusiastic and co-operative learning of chemistry.

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Appendix Sentence stems

[The associated 'Perry' Position is shown for each response (Positions were not indicated in the actual questionnaires). The amended wording in the Term 3 questionnaire for students in the PBL course is shown in italics in brackets.]

The statements below are about your views of knowledge and learning. In each case, choose ONE statement which best fits your view at present.

1 My job as a student is:

To accept the information given to me by the lecturer without question and to learn it. *(To accept the information given to me without question and to learn it.)* **Position 'A'**

To accept that some responsibility rests on me for learning but I am not sure what is expected of me about what or how to learn. **Position 'B'**

To accept what is given but to think about it critically, to check other sources for myself and to take responsibility for what and how I learn. **Position 'C'**

2 I think that the lecturer's job *(the job of members of staff)* is:

To give me all I need to know for the exams but where there is more than one way of looking at things the lecturer should indicate clearly which way s/he prefers. *(To give me all I need to know but where there is more than one way of looking at things, it should be indicated clearly which way is preferred.)* **Position 'B'**

To provide me with information but I realise that the lecturer is *(members of staff are)* not the only source of information and that I can find things out for myself to supplement what the lecturer has *(they have)* given. **Position 'C'**

To give me all I need to know for the exams *(To give me all I need to know)* and to avoid any extra non-examinable material. **Position 'A'**

3 I think that knowledge is:

A collection of unchangeable facts which are either right or wrong. I dislike uncertainties and vague statements. I am uncomfortable if I am asked to think for myself. I prefer to be given the facts. **Position 'A'**

Complex and by no means all black and white but I find this exciting and stimulating. It makes me want to explore things for myself. **Position 'C'**

Not just a collection of black and white facts but that there are shades of grey. Things may be right or wrong depending on circumstances and context. This uncertainty makes me feel uncomfortable. **Position 'B'**

4 My job in my exam *(assessments and exams)* is:

To give back the facts I have learned as accurately as possible. I prefer questions with single clear-cut answers rather than open long questions. **Position 'A'**

To answer the questions, including what I have been taught and what I have found out for myself from reading or other sources. I dislike questions which force me into a fixed answer (such as multiple choice) and prefer open questions in which I have room to show my own thinking. **Position 'C'**

> To give back all I know about the topic and leave the examiner *(marker)* to give me credit for the relevant bits. I quite like open-ended questions, which allow me to show how much I know.
>
> **Position 'B'**

In the first term, in a separate section of the questionnaire, students were also asked (see below) to say what they thought their answers to each sentence stem might have been prior to entering university.

Before you came to university, you may have held different views from those you hold now. In each case, choose ONE statement which best represents your views then.