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The introduction of large class problem-based learning into an undergraduate medical curriculum: an evaluation

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SUMMARY *When considering implementing integrated curriculum models, such as problem-based learning (PBL), concerns may be expressed about the need for increased staff resources required to deliver tutor-led small group PBL. Less staff intensive ways of supporting PBL need to be explored. We compared the outcomes of a PBL module conducted in a large class format within a lecture theatre with a module having the same defined learning outcomes delivered in small group PBL format, both supported by e-learning resources. The pre-existing 27 small groups within the whole class (n = 246) of first year students undertaking a cardiovascular basic science module at Sheffield undergraduate medical school, UK, were randomized to 22 groups undertaking the large class Integrated Learning Activity (ILA) and 5 groups to traditional small group facilitated PBL sessions. Outcome measures were: a pre–post knowledge based test, a student educational effectiveness questionnaire, and assessment of student group work and presentations. There seemed to be no significant differences in learning outcomes between the methods although it is recognized that students would prefer the small group teaching format. Within institutions where resources to support small group PBL are limited, the large group ILA format supported with e-learning techniques may be a useful alternative approach.*

Introduction

In recent years, medical schools have responded in a variety of ways to the challenges of modernizing traditional disciplinary-based courses. The trend has been a move to various integrated curriculum models, including problem-based learning (PBL). PBL has been widely adopted in medical education as an instructional method presenting authentic problems and providing a framework to integrate learning (Davis & Harden, 1999). For schools contemplating the introduction of conventional small group PBL, concerns are often raised about the perceived need for additional staff resources.

The availability of computer-based systems to support curriculum management and the delivery of learning materials (e-learning) (Davis & Harden, 2001), may provide one way of supporting students undertaking PBL without increasing existing teaching loads.

Despite its popularity, there has been little work to objectively compare the costs of a PBL curriculum with a more traditionally delivered one (Nieuwenhuijzen Kruseman *et al.*, 1997). Consequently, this pilot study was conducted to evaluate a less staff intensive method of delivery of PBL within a single institutional context. It compares the outcomes of a PBL module delivered in a large group format with a module having the same defined learning outcomes delivered in small group PBL format, both supported by e-learning resources.

Curriculum development

This initiative was one of several alternative teaching strategies that had been explored and evaluated as part of a major curriculum review at the University of Sheffield (Newble, 2002). At the time of this study, the Sheffield curriculum was fairly conventional. The first two years were largely pre-clinical, focusing on biomedical sciences but taught in an integrated systems-based fashion. The last three years were clinically orientated being predominantly undertaken in teaching hospital settings. The new curriculum, commencing in 2003, was outcome-focussed, highly integrated and organized around body systems. A decision was taken not to adopt a full PBL approach but rather to have a spine of problem, case and patient-based integrated learning activities (ILAs) running throughout the course, each having the basic characteristics of PBL, but delivered in a number of different formats. Their major purpose was to provide a means of vertical integration of basic medical science knowledge and clinical competence throughout the course. In our own institution, many staff, particularly basic scientists, were initially reluctant to implement any form of PBL.

Electronic managed learning environment

The e-learning aspect of the ILAs in the new curriculum is delivered via Minerva, a flexible web-based curriculum management system, which had been developed to the specific requirements of the Sheffield curriculum (Roberts *et al.*, 2003). Minerva has similarities to software systems to support PBL that have been operating at the University of Sydney for some time (Carlile *et al.*, 1998). It was first made available to students in September 2000.

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Development of the electronically supported ILA

The basic format of the ILA had been pilot tested in the first two years of the old course, within a fortnightly cycle. The full class of students (approx. 250) attended the first session in a lecture theatre and sat in prearranged tutorial groups (size 8–11 students). They viewed a short video of a patient as the trigger for commencing the PBL process with two to four tutors (often including a clinician and a basic scientist) facilitating this from the front of the lecture theatre. The process is adapted from the Maastricht 'seven jump approach' (Schmidt, 1983). These steps are:

1. Clarify and agree working definitions and unclear terms and concepts;
2. Define the problems, and agree which phenomena require explanation;
3. Analyse the problem (brainstorm);
4. Arrange possible explanations and working hypotheses;
5. Generate and prioritize learning objectives;
6. Research the learning objectives; and
7. Report back, synthesize explanations, apply newly acquired information to the problem, identify further learning needs.

The groups initially worked independently on steps 1–5, with the opportunity to ask the tutors questions and then share their conclusions with the whole class. All groups worked towards an agreed set of learning objectives. Students then had a period of several days to work with their groups independently before reporting back at another large group ILA session where they then worked with their groups and tutors to complete step 7.

Various ways of supporting students during step 6 have been explored at Sheffield. One of these has been the provision of a tutor for a small group session to check progress. Another, which is a subject of this article, had been to supply e-learning support through Minerva. This gave guidance on refining the learning objectives, provided a number of learning resources, supported discussion groups and enabled group work to be submitted electronically to the tutor.

Research aims

Our study aimed to answer specific questions about the instructional method we had developed, with a view to enhancing and implementing the model more widely in the new curriculum:

1. Are student learning outcomes for large class ILAs any different in terms of student satisfaction, assessment data and student learning activity than with conventional small group PBL sessions?
2. How can the feasibility of large class ILAs be enhanced in terms of educational effectiveness?
3. Can resources to support students' independent learning to meet their identified learning objectives generated in PBL steps 1–5 be effectively provided electronically?

The ILA case

This study evaluated first year medical students ($n = 246$) undertaking a module in the cardio-respiratory system in the old curriculum. The focus of the module was predominantly basic medical sciences, but included relevant aspects of clinical competence, clinical sciences, population health sciences and behavioural sciences. The main evaluation data was collected from a case entitled 'Edna—a pain in the legs', which was based around peripheral vascular disease and conducted over a two-week period. A short video introduced the case of a middle-aged woman who had to stop walking because of pain in her legs (due to intermittent claudication). The video also saw her explaining her symptoms to the vascular surgeon. Students had previous experience of an ILA in the musculoskeletal system in an earlier module. The underpinning science objectives for the learning activity were drawn from the medical school's outcomes database. They were to:

- Know the basic anatomy of the vasculature of the lower limb;
- Outline the pathology of atheroma;
- Describe the principles of the physiology of exercise as applied to the scenario (largely about understanding oxygen debt);
- Evaluate the influence of lifestyle factors in cardiovascular disease, e.g. smoking cessation; and to
- Be able to locate and palpate the pulses in the lower limb.

Experimental design

A flow diagram illustrating the study design is presented in Figure 1.

The full class ($n = 246$) was divided into 27 groups of approximately the same size. The students had worked in these groups previously in anatomy practical classes. Groups were randomized by the Course Director (who was not otherwise engaged in this study) into 22 groups to work within the lecture theatre, and five groups who would undertake conventional tutor facilitated PBL in seminar rooms. To be sensitive to ethical concerns about using students as research subjects (Henry & Wright, 2001), students were informed about the purpose of the study by the Course Director prior to an ordinary lecture and by e-mail. The one student who did not consent was asked to attend the large group learning activity. Sessions for both formats were timetabled to be of the same length.

The control group (PBL group)

The five conventional PBL groups (range: 8–11) were shown the video of the problem case as a trigger and worked towards achieving their learning objectives (PBL steps 1–5) with their tutor. A student-only meeting was timetabled to enable students to check progress. In the final PBL session the groups were encouraged to give presentations to evidence their research of the learning objectives to the tutor, who provided the assessment of group work. All tutors had undertaken PBL training conducted by two of the authors (CR and ML).

The experimental group (ILA group)

The students undertaking the large group ILA format ($n = 194$) were given a short explanation of how the ILA

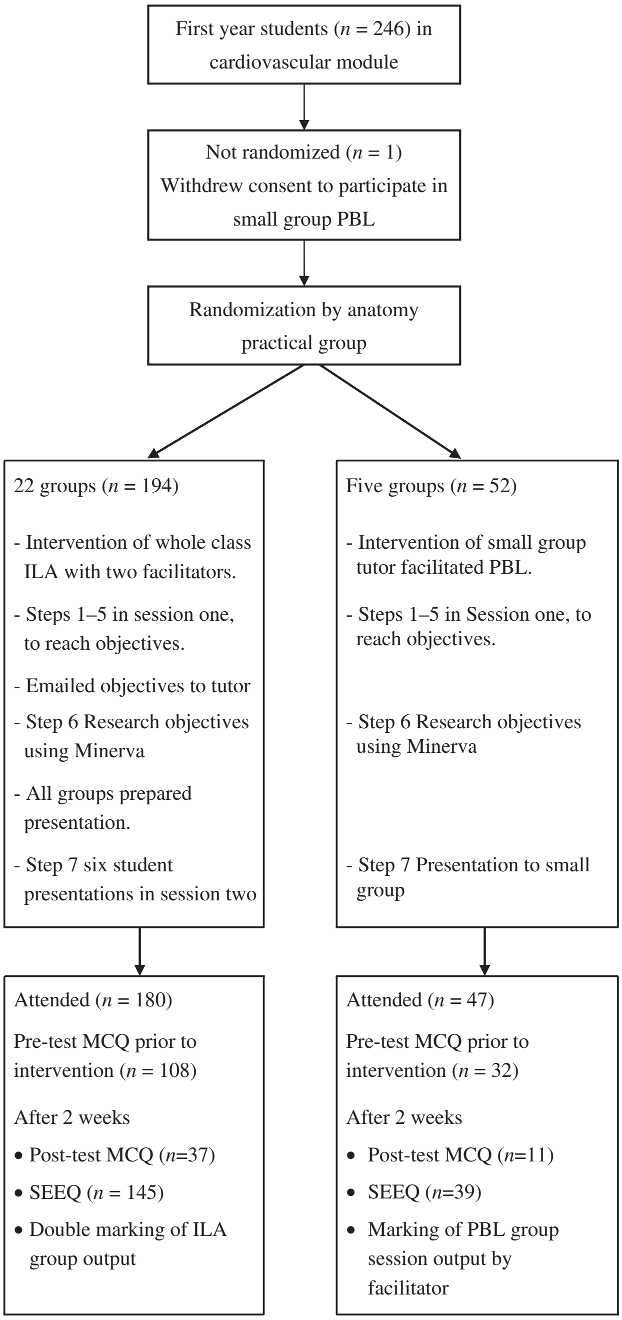

Figure 1. Flow diagram illustrating the study design.

would proceed. Each group was instructed to nominate a group leader and worked in their predesignated groups within the lecture theatre, guided by the two facilitators (one of whom was an educator, the other a clinical scientist and content expert) to identify their learning objectives (PBL steps 1–5) having watched the video. The facilitators ensured that the students had determined appropriate learning objectives by the end of the first session. A student-only meeting was also timetabled at the end of the first week to enable students to check progress. Subsequently the group leaders e-mailed their own groups' learning objectives and summary of group work to one of the facilitators. From the 22 group submissions, the facilitators selected six, so as to achieve full coverage of the learning objectives. They were presented by the student groups in the last ILA session to the whole class in the lecture theatre with a facilitated discussion as a way of demonstrating their learning (PBL step 7) and identifying any further learning needs.

Learning resources

To support their learning objectives (PBL step 6), students in both the large group ILA and small group PBL format were encouraged to use Minerva to point them to a number of prepared multimedia learning resources. These included radiological imaging of the lower limb vasculature to demonstrate functional anatomy, a short animation demonstrating the physiology of "oxygen debt" and a range of text-based information that covered the core material required for the case.

Development of outcome measures

Changes in student learning outcomes were evaluated using three measures:

A test of knowledge. Assessment of learning outcomes in this study assumed that students were following a 'guided discovery approach' where specific learning objectives have been identified by curriculum planners and thus testing is considered appropriate (Swanson *et al*., 1991). A knowledge test was constructed from the intended learning outcomes for basic science of the cardiovascular system focussed on peripheral vascular disease. The test was composed of a mixture of one–from–five type multiple-choice, true/false and extended-matching questions. Once prepared in a written format, items were transferred into Minerva ready for time-released, computer-based administration. The feasibility of the web-based assessment was established by pilot testing on a small cohort of ten volunteer staff and students.

The final test consisted of 26 items containing 11 true/false multiple choice questions (marked out of 5), 12 single best answer multiple-choice questions (marked 1 or 0) and three extended matching questions providing 13 stems (marked 1 or 0). Total test marks available were 80. The test was made available to all students for 48 hours at the end of the first ILA session. Questions were marked electronically and the test score totalled, to produce the pre-test scores. Individual feedback for wrong answers was generated automatically. Students were requested (with electronic reminders) to repeat the test two weeks later (up to 48 hours from the end of the last ILA session) to provide post-test scores.

Presentation of student group work. We were interested in the quality of students' learning activities as evidenced by their group work. A short proforma, using a checklist and global rating approach, was used to collect data on the extent to which the tutor felt the group as a whole covered the learning objectives for the case. For the PBL groups the tutor marked their own group's presentations. For the lecture theatre-based format, two independent tutors marked presentations.

Questionnaire of educational effectiveness. A questionnaire was administered to evaluate the students' perceptions of the quality of their learning based on a modification of the Students' Evaluation of Educational Quality (SEEQ)

(Marsh, 1982). Psychometric characteristics of SEEQ have been well established. It has a high degree of internal consistency ($r = 0.88$ to 0.97) and it has reasonable levels of validity in that scale scores correlate significantly with a wide range of measures of learning outcome (Coffey & Gibbs, 2001). Our questionnaire consisted of a series of statements on aspects of educational effectiveness including perceptions of the academic value of the exercise, tutor factors, group interaction, e-learning support issues, organizational considerations and workload. The nine-point Likert scale ranged from strongly disagree (1) through neutral (5) to strongly agree (9). In the interests of a high response rate data was collected anonymously using a paper-based questionnaire.

Results

Data analysis was carried out using SPSS v 11.00, and confidence interval analysis was done using Confidence Interval Analysis (CIA) software (Bryant, 2002). A power calculation showed that to have an 80% chance of significance with a moderate difference we needed to have 62 cases in the ILA group and 16 cases in the PBL group. The attendance for the small PBL sessions was 91% (47/52) and 92% (180/194) for the large class ILA. The analytic approach throughout is non-parametric to maintain a consistent approach due to the small number of respondents ($n = 11$) from the PBL groups for the post-test marks.

Pre- and post-knowledge test

The pre-test knowledge test was completed by 57% (140/246) of students. Reliability (internal consistency) of the pre-test knowledge test was 0.76 (Cronbach's alpha), for the 36 items of the test. Data were analysed to see whether the change in scores between the students in the ILA groups and the PBL groups were different. The results (see Table 1) showed no significant difference between the two groups (Mann–Whitney U = 96.50, $p = 0.13$).

Educational effectiveness questionnaire

The SEEQ questionnaire was completed by 75% (184/246) of students. The overall internal consistency of the questionnaire was 0.89 (Cronbach's alpha). Reliability of sub domains was also high. Medians were calculated for each Likert scale item in the questionnaire with 95% confidence intervals. Table 2 gives the overall score for each aspect of educational effectiveness that we tested. Missing data were handled by excluding the case if more than two values were absent. Differences between the ILA groups and the PBL groups were determined using the Mann–Whitney test.

The students responded positively to the exercise overall. However, there were a number of significant differences between the perceptions of students in the ILA groups and the PBL groups.

Academic value

Compared with those in the ILA groups, students in the PBL groups found the learning activity of more academic value ($p < 0.01$).

Tutor factors

PBL groups rated tutor related factors more highly than did the ILA groups. Significant differences ($p < 0.01$) were found in favour of the PBL groups for a number of these, e.g. rapport, which included friendliness, interest and encouraging seeking advice, and humour.

Group interaction

Additionally there were differences in favour of the PBL groups in items exploring group interaction ($p = < 0.01$), that is students feeling able to: participate, share ideas, ask questions and express themselves.

Table 1. Comparison of median scores for pre- and post-test knowledge test.

	No. tested pre- (post-)	Median of difference in score	95% CI	Mann–Whitney U	Exact Sig. (2-tailed)
ILA group	108 (37)	11	(8, 16)	96.500	0.130
PBL group	32 (11)	6.5	(−4, 15)		

Table 2. Tables of medians with their confidence intervals for items of teaching student satisfaction questionnaire.

	Large group			Small group			Mann–Whitney U Scores	Exact Sig (2-tailed)	Subscale reliability
	Median	Lower CI	Upper CI	Median	Lower CI	Upper CI			
Academic value	5.75	(5.50	6.00)	6.75	(6.25	7.00)	1793.50	0.00*	0.83
Tutor factors	5.50	(5.25	5.75)	6.88	(5.38	7.88)	1746.00	0.00*	0.92
Group Interaction	5.75	(5.00	6.00)	7.25	(6.75	8.00)	1089.50	0.00*	0.90
e-learning support	5.50	(5.25	6.00)	4.38	(3.50	5.00)	1787.00	0.00*	0.88
Organizational factors	4.50	(4.00	5.00)	5.50	(4.50	6.25)	2204.50	0.04*	0.95
Workload considerations	5.33	(5.00	5.33)	5.33	(5.00	5.67)	2491.50	0.31	0.64
Personal study time/hours	3.00	(3.00	4.00)	2.00	(2.00	3.00)	2002.00	0.03*	n/a
No. of learning resources used	4.00	(3.00	5.00)	3.00	(2.00	4.00)	1915.50	0.01*	n/a

*denotes significant at the 95% confidence level.

E-learning support

The e-learning support was appreciated more by the ILA groups than the PBL. In particular significant differences were found in favour of the ILA group for the appreciation of the content ($p < 0.01$) and usability of the electronic learning resources ($p < 0.01$).

Organization of teaching

There was some negativity expressed by ILA students for organizational aspects of the exercise. They found the explanation of the exercise harder to understand than did those in PBL groups ($p = 0.02$).

Workload factors

There were no differences in perceptions of workload, which included subject difficulty, and the pace of the work required. ILA students spent longer (median = 3 hours) in personal study time and used more learning resources (median = 4 resources) than those in the PBL groups (medians = 2 and 3 respectively).

Marking group work

The pass mark for the group work using a borderline method was 47.7%. Three of the ILA groups were deemed to have been below standard. There was no significant difference in group marks between ILA and PBL groups (Mann–Whitney U = 1, $p = 0.11$).

Discussion

Decisions related to areas of curriculum reform are complex and rarely one-dimensional. In this study we have attempted to objectively evaluate an educational delivery method taking into consideration a number of different components. Our findings suggest that students engaged in a large class ILA are equivalent to students in a small group learning setting in terms of their basic science knowledge outcomes as evidenced by both their knowledge gain and their groupwork. However, they do not score as highly as small group PBL students in important areas of educational effectiveness characteristic of PBL, e.g. group interaction, and perceived academic value. This mirrors the evidence from reviews of other comparisons between PBL and other instructional methods (Colliver, 2000).

Limitations of the study

The strength of this study is that we conducted a randomized controlled trial in an educational setting. Whilst this has strengths in terms of objectivity, we acknowledge the many problems we encountered and the criticisms of this style of research (Norman, 2003). Of most concern was incomplete data collection for the assessment exercise. Whereas 60% of ILA students and 68% of PBL group students took the pre-test, nearly two-thirds of the sample was lost for the post-test, leaving the study underpowered for student competence claims. The students need to be offered some educational gain for doing the test twice. This could happen through provision of detailed feedback to the students completing the post-test. Another way would be to use an equivalent test of similar items. Whilst the pre-test and post-test were done formatively, students were encouraged to do tests to the best of their own ability, and not discuss their answers. Students from both study groups are likely to have discussed the ILA with each other, potentially biasing results. However, we believe the results are still useful in that they provide some of the answers to our research questions (Prideaux & Bligh, 2002) from a pilot study conducted naturalistically as part of curriculum reform.

Implications

This study suggests that where resources to support conventional PBL are lacking the large group ILA might be a practical alternative instructional approach. We acknowledge our students would prefer small group PBL were this possible. It is feasible for two facilitators to guide groups of students through the steps of PBL in a lecture theatre, using a well-prepared problem case, supported by e-learning resources. Such large class ILAs are acceptable to students who are prepared to put in the necessary work to achieve identified learning objectives. The economies of scale are noteworthy. Excluding preparation and assessment of the case, the small group PBL model would have required 27 tutors to deliver this ILA with an average contact time of 3 hours, totalling 81 tutor hours over a two-week period. In contrast, the large group ILA delivered equivalent learning outcomes using 6 tutor hours over the same time-period. However, for the large group ILA tutors, the onus is on excellent organizational and tutoring skills to be able to manage the degree of interaction needed within a large group.

The amount of support students need is related to their prior experience of PBL (Davis & Harden, 1999). The opening ILA session must be well organized and in an appropriate venue. Students must be sitting in their pre-arranged groups, and well prepared to undertake the PBL process. A clear plan for the session must be given to the students, which outlines the group work tasks, the timings of the session, and the role of the tutors. Student group leaders need to ensure they understand the requirements both for electronic submission of their groups' learning objectives and the requirements for submitting group work.

Although we used a video to introduce the problem case, other methods for presenting the case could be used, for example presenting a text-based scenario or enacting a short scenario using a simulated patient. Student groups are largely happy to publicly address the facilitators and sharing ideas amongst groups may confer some educational advantage to the large group format compared to conventional PBL. Facilitators must be skilled at ensuring that the derived learning objectives of the students relate to those developed for the problem case, and check the progress of several groups of students, by moving around the lecture theatre. Staff training is required for this role (Davis & Harden, 1999).

Formative assessment of ILA learning objectives using a computer-based testing approach is appropriate given our outcome focussed summative assessment strategy. Whilst this pilot demonstrated the feasibility of testing, we acknowledge the need for better formats (Case & Swanson, 2001).

The advantage of well-written Extended Matching Questions is that they can test problem solving, not just simple recall of facts (Coderre *et al*., 2004) and are machine markable. Some consideration within the assessment strategy needs to be given to student groups who produce unsatisfactory work or who do not attend learning activities.

The e-learning support in this study was restricted to providing resources to support the research of learning objectives (PBL step 6), as well as providing a framework for curriculum management of a spine of ILAs. Students in the large class ILA relied more on learning resources, including those within Minerva, to support them in researching their learning objectives. Preparing high quality multimedia learning resources is labour intensive and an added initial cost that has to be balanced against the ongoing savings in PBL tutor support. However, such resources are likely to be re-usable for future years and this is an important consideration in managing the learning resources required for implementing a spine of ILAs throughout the curriculum (Harden & Hart, 2002). Students engaging in a programme of ILAs must have a level of competency in information technology that allows them to use curriculum management and delivery systems such as Minerva (Ellaway *et al*., 2003).

Curricular impact

The curriculum management committee used a range of evaluation data, not just this study, in deciding to include ILAs as an instructional method in the new curriculum. The eventual format of ILAs that was introduced focussed additional resource on providing tutor support to check progress during PBL step 6. Preparation was provided during practice ILAs in an 'introduction to medical studies' theme. Further work would be required to determine whether this model of large class PBL had any other impact in terms of change management effectiveness and sustainability of curricular innovation.

Practice points

- In institutions with limited resources to support small group problem based learning (PBL), the large group Integrated Learning Activity (ILA) might be a useful alternative instructional method.
- Students seem to achieve equivalent outcomes with either small group PBL or large class ILA formats in terms of basic science knowledge and learning activities.
- Students would prefer the characteristic benefits of small group PBL if resources were available.
- E-learning may be a useful way of supporting some of the steps of the large class ILA format.

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