Blended learning in a first year mathematics subject

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Abstract: *This paper argues that the achievement of learning objectives for a first year mathematics subject, Operations Research Modelling, can be best fostered through a blended learning design. 'Blended learning' can be used in a variety of contexts. In this paper, the definition used is that of the integration of 'traditional' learning activities ─ lectures, tutorials, Mathematica and optimisation laboratories, and paper-based assessment tasks ─ with learning activities and environments more usually associated with other disciplines ─ collaborative learning, online assessment, peer review, cases studies, spreadsheet technology, and the information and communication technology, Blackboard. It is argued that a blended learning design includes learning activities that more closely mirror professional practice, and is more likely to encourage a deep approach to learning. Effectiveness of the blended learning design is examined from the perspective of students and teaching staff, through the analysis of responses to questionnaires and comments collected.*

Introduction

Rationale

Oliver and Trigwell (2005) argue that the term 'blended learning' is 'ill-defined' (p17). Certainly, different definitions are prevalent and frequently open to interpretation. Blended Learning here is taken to mean 'the integrated combination of traditional learning with web-based online approaches' (Whitelock and Jelfs 2003) and other approaches that seek to mimic professional practice (collaborative learning, peer review, cases studies, and spreadsheet technology).

This paper will then seek to answer the following questions:

- What determines the right blend in the learning activities, assessment, resources and support for a subject?
- How do learners respond to the blend?
- Does the blend produce effective learning?

Background – about the subject

These questions will be addressed in the context of a first year mathematics subject ─ Operations Research Modelling (ORM). The subject provides an introduction to mathematical modelling, operations research methodology, models and practice, and the solution of a variety of problems in management. The subject is compulsory for all students undertaking undergraduate Mathematics degree programs, and is offered in each of the two fourteen-week semesters. Enrolments are of approximately 150 (Autumn) and 40 (Spring). The subject has been offered in blended mode since Autumn 2001, when the information and communication technology (ICT) Blackboard was made available university-wide. In Spring of 2004 however, it was offered in distance mode for the first time.

Operations research, or management science, is the application of knowledge and skills in mathematics, statistics and computing, and knowledge and skills peculiar to operations research, to the solution of management problems. Its methodology is scientific method. Its practice requires oral and written communication skills, the ability to meet deadlines, to work effectively in isolation and as part of a team, to set directions and goals, to lead and manage a project, and so on.

A subset of the graduate attributes of an operations researcher (Gunawardane 1991) was selected as learning objectives for the subject. This selection formed part of the 2002 UTS course accreditation for the undergraduate mathematics degree programs.

The learning objectives then sought to ensure that, by the end of the subject, the student should be able to:

- understand and use the methodology of operations research and recognise when this methodology is appropriate;
- formulate and solve practical operations research problems and the model classes – linear and integer programs, simulation, decision trees, dynamic programming, and network optimisation;
- understand and apply the basic concepts of linear algebra required for an understanding of linear modelling;
- solve operations research problems using spreadsheets (Excel) and mathematical programming modelling systems (LINDO and/or LINGO);
- use terms peculiar to the field and identify problems amenable to solution through the application of operations research; and
- communicate their understanding of the subject in written form.

The subject's learning design

'Learning design' is taken to refer to the design of the student learning experience in order to achieve the learning objectives. That is, it deals with the *how*, the teaching approach (and its underlying philosophy of teaching and learning), and the *what*, the blend in learning activities, assessment, resources and support required to facilitate the successful attainment of the objectives.

The how

Given the subject's learning objectives, it was decided that these would be best developed by encouraging *deep* approaches to learning (Ramsden 1992). Students using these approaches are characterised by, for example, being engaged and seeking to be challenged by what is being learnt, taking responsibility for their learning, and being open to new ideas and experiences. They are more likely to see the broad context of their studies, to develop competence in a range of outcomes and make use of the knowledge, skills and values they acquire. In addition, students adopting a deep approach frequently seek to connect new learning with previous and related learning, thereby constructing knowledge, skills and values on existing foundations ─ a *constructivist* model of learning (Biggs 1991).

The deep approach to learning was primarily fostered through relating the subject to likely future professional practice. This served to *acknowledge context* (Boud and Prosser 2001; Harper, Oliver and Agostinho 2001) and demonstrate *relevance*, and was implemented through the inclusion of real-life problems and case studies. The learning design also included activities involving self-direction and collaboration. Computing skills were integrated in *problem solving* and project administration, further reinforcing the relationship between the learning objectives, learning activities and professional practice. *Practice* in the achievement of learning objectives was initiated by demonstration or discovery, reinforced by repetition, and extended through graded *challenge*. ICT was integrated in teaching and learning activities to provide students with flexibility in accessing content and for communication. It was felt that this would provide students with a greater sense of control of their learning experience and thereby result in a stronger sense of *ownership* of, and *responsibility* for, their learning.

The what

The blend of learning activities, assessment, resources and support is represented by Figure 1. Integration of technology into the learning design (and its implementation) is indicated by the use of italics.

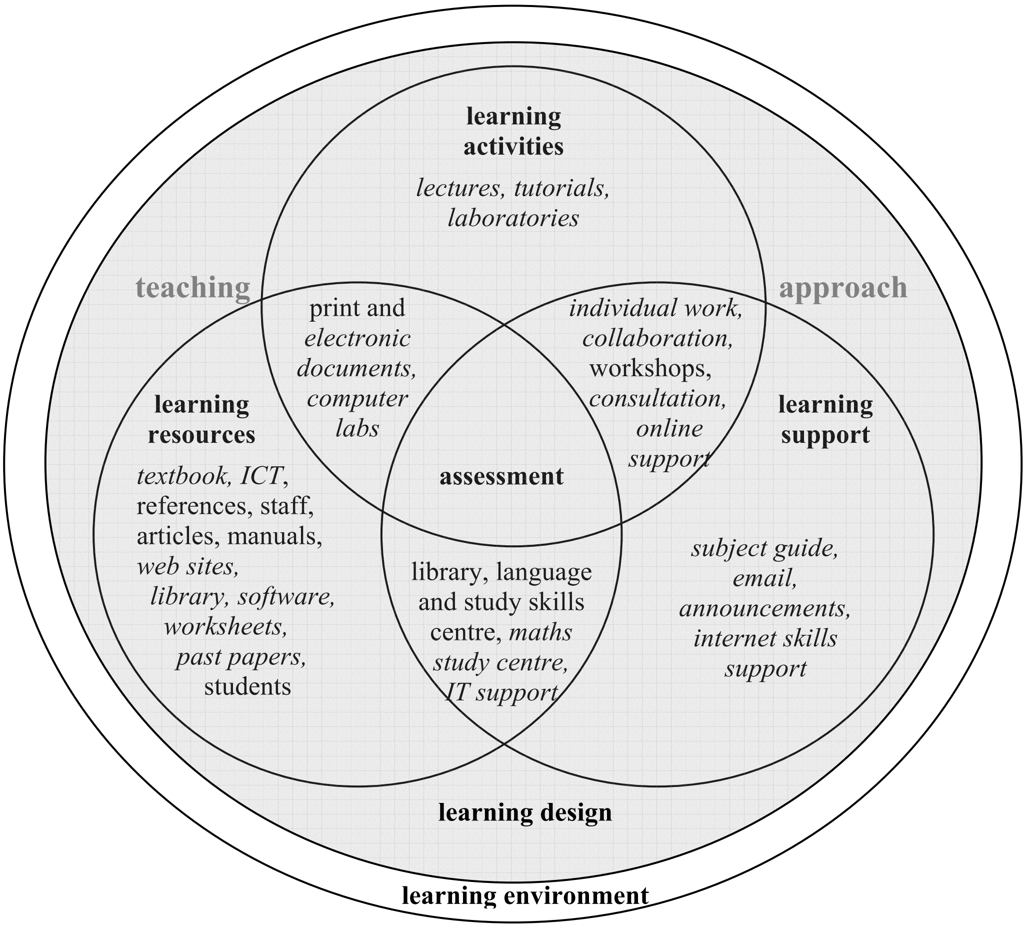

Figure 1. Relationship diagram for learning design
(Groen 2003)

Learning activities in ORM included lectures, combined computer laboratory and tutorials, private study and group work. Lectures served to convey, clarify, explain, extend and place emphasis on the knowledge and skills objectives. They also served to provide direction, place content in context, motivate students' interest and encourage an appreciation for the discipline, to provide a forum for discussion, and to encourage critical thought. The combined laboratory and tutorial sought to develop their knowledge and skills in application of methodology, modelling, and solution technologies, and to develop communication and skills in collaboration.

The ICT 'UTSOnline' (*Blackboard* 5) was integrated throughout the learning design to provide flexible (24 hour) access to information, for lecture delivery, online assessment of computer skills, for assignment submission, for communication, and for subject support and administration. A comprehensive text with a student version of optimisation software was used. *Excel* was also used in the laboratory sessions (for linear modelling and optimisation). A variety of reference materials (print and online) were supplied through the university's library. Students had access to staff during both tutorials and laboratory sessions as well as through the Department's office tutorial scheme.

The assessment of the knowledge and skills objectives of the subject was also blended. The first assessment task (worth 10%) was a traditional assignment, consisting of a number of questions requiring written answers with working. The second assessment task (worth 30%), the class test, was conducted online with emphasis on direct assessment of laboratory skills. The third assessment task (worth 20%), a group report on a real-life operations research problem of the groups' choosing, fostered the development of teamwork skills, project management, written presentation skills and gave the students practical skills in the implementation of the operations research methodology. The final assessment task was a traditional final exam that assessed remaining knowledge and skills objectives (worth 40%).

Learning support tended to be what might reasonably be expected for any first year subject and included print and online information, office consultation, and advice from the Faculty's academic liaison officer. Students had access to the Mathematics Study Centre, an English language centre, and a computing learning centre. Information technology support was provided through the Faculty and the University, and study skills support through Student Services.

Assessment of the blend ─ methodology, data and results

Students in the Autumn 2005 class were asked to complete a 35-item questionnaire in the last teaching week, of which 22 items were relevant to the current study. The questionnaire addressed the learning design (8 items), the students' approach to learning (9 items), and students' perceptions of the effectiveness of their learning (5 items). The questionnaire presented two styles of question, questions requiring a response on a Likert scale, and open–ended questions.

Students' perspectives

Is there evidence to suggest that students are adopting deep approaches to learning? To examine this issue, ten questions were selected and analysed. The statistics for these questions are presented in Table 1. (No scores for strongly disagree (1) were obtained for these questions.)

Table 1. Statistics for Questions on Deep Learning and Effectiveness

Question (Sample size)	2 Disagree	3 Neutral	4 Agree	5 Strongly agree	Mean (Std dev)
Context (65) [4. I liked the fact that the models, techniques and skills learnt were placed in the context of problem-solving.]	5 (8%)	18 (28%)	36 (**55%**)	6 (9%)	**3.6462** (0.7990)
Engagement (65) [7. I felt engaged by the content and/or activities covered in the subject.]	16 (*25%*)	23 (35%)	23 (35%)	3 (5%)	*3.185* (0.900)
Challenge (65) [8. I felt occasionally challenged by the content and/or activities covered in the subject.]	3 (5%)	16 (25%)	32 (**49%**)	14 (**21%**)	**3.8923** (0.7930)
Construct knowledge (64) [11. The way the subject was taught encouraged me to build on the knowledge and skills I had acquired as I progressed through the subject.]	12 (*19%*)	19 (30%)	32 (**50%**)	1 (1%)	3.313 (0.871)
Understanding (64) [12. The way the learning activities were constructed encouraged me to attempt to really understand what I was doing.]	10 (15%)	27 (*42%*)	24 (38%)	3 (5%)	*3.266* (0.895)
Responsibility (65) [15. I feel I learned to be responsible for my own learning.]	4 (6%)	15 (23%)	37 (**57%**)	9 (14%)	**3.7846** (0.7602)
Open to new ideas (65) [21. I feel open to new ideas, points of view, problems and approaches in Operations Research.]	9 (14%)	28 (*43%*)	22 (34%)	6 (9%)	3.354 (0.909)
Relevance (65) [13. I feel that it is likely that the use of technology in the subject has helped me prepare for professional practice.]	5 (8%)	20 (30%)	35 (**54%**)	5 (8%)	**3.6000** (0.7866)
Team work (65) [19. I improved my ability to work as part of a team.]	4 (6%)	20 (31%)	34 (**52%**)	7 (11%)	**3.646** (0.837)
Problem solving (64) [20. I learned to apply model building, solution techniques and technologies to real-life problems.]	7 (11%)	20 (31%)	29 (**45%**)	8 (13%)	**3.578** (0.887)

These statistics support the conclusion that deep approaches were being adopted. In the characteristics – acknowledgement of context, challenge, and sense of responsibility – positive outcomes can be noted (boldface in Table 1). Some positive outcomes can be identified for the construction of knowledge, with 50% of students agreeing that 'the subject was taught in a way that encouraged me to build on the knowledge and skills ….' The remaining deep learning characteristic listed, 'I feel open to new ideas …' exhibited a fairly even spread. Close to neutral mean scores were identified for engagement with the content and activities, and seeking deeper understanding (indicated by italics). This suggests the areas for future work in the learning design of the subject.

Is there a positive relationship between the blend and deep approaches to learning? To examine this issue, average scores for blending responses (Questions 1-3, 6, 24, 25, 34, 35) and deep learning (Questions 4, 7-9, 11, 12, 15, 17, 21, 22) were constructed for each student. (Remaining questions can be found in the Appendix.) A scatter plot of these scores can be found in Figure 2. The Spearman's correlation between the two scores was found to be 0.660. This was found to be statistically significant at the 0.01 level. Therefore a positive relationship can be inferred between student reactions to the blended learning design and their approach to learning.

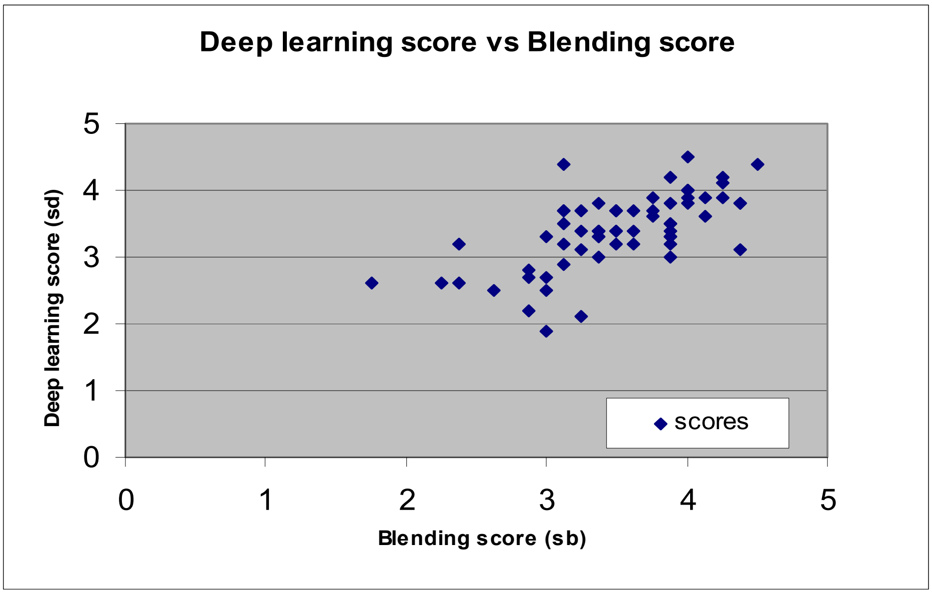

Figure 2. Relationship between characteristics of deep learning with characteristics of the blended design.

While many students chose not to respond to the open-ended questions, the majority of students who did respond to the questions indicated that no improvement was required in learning activities, assessment, resources or support. Responses also indicated that the students found the subject 'interesting' and 'challenging'. They also liked the 'relevance to real world problems' and 'The interactive nature of lectures and the opportunity to participate in problem solving'. A small number of students indicated short–comings in the textbook, or that they'd like to see more examples.

With the questionnaire undertaken prior to the final exam, only students' perceptions regarding the effectiveness of their learning could be examined. Questions 13 and 20 in Table 1 all demonstrate positive outcomes. Unfortunately, the mean score for students' perceptions of their attainment of the subject's objectives (Question 23) received a mean of 3.161 with a standard deviation of 0.853. This was somewhat disappointing, and indicates another area for investigation.

Staff perspectives

Beyond the overall organisation of the learning design, it may be argued that the use of ICT had a significant impact on teaching activities. The extensive integration of ICT into the subject required a significant time commitment when initially developed. However, that time commitment has been more than recouped over the semesters as the technology has provided scalability, reusability and consistency, ease of use, accessibility, and has served as a library and record of subject materials, assessment tasks and communication. Other strengths of ICT included its facility in providing flexible, effective, consistent and, immediate or asynchronous, communication. The assessment environment was particularly useful for the assessment of computer skills.

Conclusions

What determines the right blend in the learning activities, assessment, resources and support for a subject? The learning objectives, both the subject specific objectives and the broader skills and values requirements of the discipline, the profession and the community suggest the learning design and environment. Integrated learning activities, resources, support and assessment served to give students a diverse range of learning experiences and foster a similarly diverse range of learning outcomes. In particular, the blend served to introduce students to the diverse environment and experiences comprising professional practice.

How do learners respond to the blend? In particular, is a deep approach to learning fostered?

The majority of students responded favourably to the blend. Occasional unfavourable questionnaire responses were confined to a small number of specific issues not immediately associated with the blend per se. More importantly however, there is evidence to suggest that students adopted deep approaches to learning indicated by the positive correlation between the average score on deep learning and the average score for blending.

Does the blend produce effective learning? While some scores indicated characteristics of effective learning, the overall result is inconclusive suggesting further work in this area.

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Appendix

1. There was a good balance between knowledge and skills development.
2. There was a good mixture of lecture content, tutorial questions, laboratory work and assessment.
3. I feel that the technologies used were well-integrated within the learning activities.
6. The content in lectures, tutorial questions and laboratory activities was well integrated.
9. Relevance of the subject was demonstrated to a possible career in Operations Research.
17. I applied ideas from lectures to unfamiliar problems in labs, tutes and assessment tasks.
24. The weighting of the assessment tasks was fair in relation to the knowledge, skills and objectives of this subject.
25. The topics covered in the assessment questions were consistent with the stated objectives of the subject.
34. There was sufficient access online to resources required to complete the learning activities and assessment tasks.
35. There were sufficient resources to support my learning activities.