Meeting expectations – a focus on professional practice in a final year undergraduate mathematics course

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This paper argues that achievement of many of the attributes required of graduates in professional practice in operations research, or quantitative management science, can be developed best through a learning design that reflects current professional knowledge, skills and values. This necessarily places the focus of the learning design squarely on the student, with technology and communication at the nexus of the subject learning activities, and assessment tasks tailored to reflect this. The first steps in the examination of the effectiveness of this form of learning design are undertaken for a final year capstone subject in the Quantitative Management Science major in a Bachelor of Science program. This examination is undertaken from the perspective of students and teaching staff, through the analysis of discussions with students conducted at milestones throughout the semester. Positive student outcomes can be identified.

Introduction

By the time mathematics students reach their third year of full-time study, they frequently specialise and may have an expectation that subjects comprising their major will assist them in their future professional practice. These components of a degree program are referred to as graduate attributes ─ the knowledge, skills, and personal qualities to be used appropriately and effectively, not only in familiar and highly specialised contexts but also in changing or unfamiliar contexts that may be experienced by a graduate in both their professional and personal lives. By design, graduate attributes may be acquired through the successful achievement of subject learning objectives (although the scope of this achievement is not always evident from the stated subject objectives, which tend to focus on learning outcomes, and which it could be argued are restricted in their scope). It is argued here that it may be appropriate for a broader set of objectives to be specified, and a more diverse set of learning activities undertaken, in final year undergraduate mathematics subjects in order to develop the broad spectrum of knowledge, skills and values required of professional practice.

Steps in this direction are examined in the context of a specialisation in Quantitative Management Science (also known as Operations Research), with a focus on the inclusion of explicit subject objectives relating to professional practice, and the implementation of a blended learning design in an environment that simulates contemporary practice. It is argued, and demonstrated, that through an emphasis on professional practice, students come to an appreciation of the role of other subjects in the major, develop new skills in the use of prerequisite knowledge, and learn how to exploit methods and build models of challenging problems in unfamiliar settings. Through such a process, it is argued that students are better placed to meet the expectations and demands of their chosen profession when they leave university.

Accordingly, this paper seeks to answer the following questions:
- What characterises a successful learning design when it comes to a focus on professional practice?
- How effective is the learning design with regard to fostering professional graduate attributes?
- How do learners respond to such a learning design?

The section which follows this introduction provides a brief background to the subject. The next section deals with the first research question, while the subsequent section provides the answer to the second and third research questions. Implications of the study are discussed in the conclusion.

Background - the discipline, the subject, the program and the students

The research questions are addressed in the context of a third year mathematics subject ─ Operations Research Practice (ORP). Operations Research is the application of knowledge and skills in mathematics, statistics and computing, together with discipline-specific knowledge and skills, to the solution of problems in management. ORP is the capstone of the major in quantitative management science of the University of Technology, Sydney (UTS) Bachelor of Science in Mathematics. The emphasis of the subject is firmly on problems arising from complex systems.

The objectives of the subject, stated in accreditation documents, are:

a. to identify, model and solve problems involving the application of operations research to real-life and realistic problems;
b. to demonstrate competence in the use of verbal, written and electronic communication, including the use of professional language, and use these forms of communication to convey understanding of the subject;
c. to locate, critically assess, manage and apply information from academic publications, the internet and various other sources;
d. to develop critical thought and reasoned arguments;
e. to identify, plan, manage, critically assess and complete a project;
f. to appreciate the approaches of risk assessment and managing for quality;
g. to understand group dynamics, to demonstrate the ability to work effectively as a member of a team and to exercise leadership where appropriate;
h. to respond flexibly, ethically, appropriately and effectively to the requirements of professional situations with due regard to the social and environmental contexts of professional practice;
i. to demonstrate awareness of the importance of self-motivation and time-management; and
j. to participate in professional societies and organisations.

The subject, offered for the first time in the second semester of 2004, has three and a half hours of weekly class with an additional four hours of external work expected. Enrolments in the subject are typically small ─ 15 students in 2004, 11 in 2005, and 13 in 2006. Students come from a variety of cultural backgrounds, and have undertaken at least a second year optimisation subject, in addition to core subjects in mathematics and statistics as part of their studies to date.

In the following section, details of the learning design are presented with a view to answering the first research question.

Elements of the learning design

The learning design refers to the combination of the learning activities, the teaching approach, the assessment, resources and support needed for the successful attainment of the subject objectives.

Learning activities

The learning design includes activities involving self-direction, discovery and collaboration; the application of tools and techniques of the profession; the development of skills in problem definition, modeling, solution, implementation, documentation and presentation; and the fostering of an appreciation for the profession and its role in society. Specifically, activities include talks by representatives of professional associations, short lectures, internet research, chapter readings from texts, case studies, technical (text and computer) exercises, videos, student seminars, undertaking project management, small group work, facilitated group discussion, role play and simulation. The aim is that through these activities students are encouraged to see their prior study and personal experience in a broader context, to demonstrate competence in a range of knowledge and skills

outcomes from their previous studies, to apply these outcomes to new problems, and to develop further knowledge, skills and values relevant to professional practice (as well as to life in general). (These are characteristics of a deep approach to learning (Ramsden 1992).)

All activities are set in an environment that seeks to simulate professional practice. Classes are conducted in computer laboratories, reflecting the indispensable nature of the computer and its integration within the professional environment. Correspondingly, presentations and seminars are conducted in meeting rooms. The learning activities and learning environment are chosen to reflect professional practice as far as possible with the resources available.

Teaching approach

The emphasis on developing the 'professional' in the student, suggests a student focus in the teaching of the subject. This further suggests that the academic responsible for the conduct of the subject primarily plays the roles of designer, facilitator and supporter (as well as assessor).

Learning resources

As noted earlier, all classes are conducted in computer laboratories with computing skills integrated throughout the learning activities and assessment tasks. These are exploited in research, problem and case modeling and solution, project management, report and seminar presentation. They are also used for information and communication, particularly through UTSOnline (*Blackboard*) ─ assignment submission, communication with and within the class, subject management and information support. A particular aim in the use of this environment is to lessen the need for teacher direction, by encouraging students to seek answers for themselves, thereby fostering greater self-reliance and confidence.

In the initial cohort of the subject, extensive use was made of journal articles to provide current applications and case studies. Unfortunately, this approach failed to provide a sufficiently comprehensive resource. For subsequent cohorts, a textbook was selected, with this providing a solid foundation for the concepts, models, techniques and applications of the subject. Another feature of the text was the 'Links to Practice' sections which provided brief case studies from actual companies, with some of these supported by short videos outlining the implementation of concepts or techniques.

Assessment

There has been increasing emphasis on the role of professional practice in assessment as universities seek professional accreditation of their programs, for example, in engineering (Palmer 2004). As a consequence, all assessment in ORP is project-based and individualised, with the development and demonstration of communication skills featuring strongly in the design along the lines of Butkus and Kelley (2004). The assessment focuses on applications (Armacost and Loew 2003) and seeks to mirror the professional workplace, thereby 'partly … signaling what is really valued' (Knight 2001, p2).

The assessment in ORP comprises four assignments based on real operations research problems taken from case study texts and journal articles. The demonstration of teamwork, skills in project management, oral and written communication, and problem-solving are the significant components of the assignments. In the first assignment (15%), students work in small groups to complete a case study. All groups attempt the one case. The second (30%) and third (30%) assignments are paired and designed to simulate client-consultant activities. This is done through the development of problem specifications by students acting as clients and through student consultants acting to solve the client specifications. Specifically, in Assignment 2, students are asked to gather a client group and to develop a real operations research problem. They are required to gather the data and present the problem statement, the data collected and research questions. The specification is presented to

the consultants (another group in the class) at a meeting (a role play). Assignment 3 then sees the students from the client group became the consultants for another student client group. Students organise additional meetings with their client group, examine and refine the problem, collect further data if necessary, formulate a model and solve their model. Their findings are presented as a report and seminar. Marks are allocated for content, technical accuracy, presentation, creativity, and project management. In the most recent version of the fourth assignment (25%), students are allocated the background exercises of an interactive case study taken from one of their texts, as well as a different interactive exercise from one chapter. The grades for the subject are simply allocated based on the sum of the marks of the four assignments under the usual High Distinction, Distinction, Credit, Pass and Fail grades. Given the individualised assessment and the small class size, staff and students can have confidence that student results accurately reflect their efforts.

Responses and outcomes

We address the second research questions, dealing with the outcomes of the learning design from the perspective of both the students and the teaching staff.

Student perspectives

At the beginning of the first class the subject philosophy, objectives, teaching approach and learning activities are outlined to prepare students for the different style and expectations of the subject. In the three semesters the subject has been taught, in these initial discussions students express the view that they think the subject will be of benefit to them. Views expressed, and questions asked, by students concerning the assignments, clearly illustrated that they had concerns over what was expected of them with regards to the assessment tasks. In response to this, greater time was spent by the academic explaining expectations at the beginning and at the time of distribution of the assignments.

Student perspectives were assessed through the standard subject questionnaire conducted at the end of the semester and also through feedback from students, both structured and unsolicited. The subject questionnaire seeks feedback from students on the subject and on teaching, with results reported on a five point Likert scale. (Results are presented on the average of the three cohorts.) On the question ‘The subject was relevant to me’, the responses showed an average of 4.1 (and standard deviation of 1.0) compared with 3.7 for other mathematics subjects. Of particular relevance to the current study were the high scores achieved for ‘The subject was delivered in a way which was consistent with its stated objectives’ (3.9 compared with 3.7), ‘My learning experiences were interesting and thought provoking’ (4.0 compared with 3.45) and ‘Overall I am satisfied with the quality of this subject’ (4.1 compared with 3.6). This suggests that the subject is viewed more favourably than other mathematics subjects, especially with regards to relevance.

Students who are practicing professionals, but seeking formal qualifications in the field, provided additional and valuable perspective on the learning design. They viewed the objectives and teaching approach of the subject favourably. This was supported by the vast majority of students in discussions conducted at the first milestone (the return of the first assignment). The working students’ additional experience and expertise was helpful in explaining the role of the client-focused assignment. These students were also more likely to join the professional societies than other students in the class.

Staff perspectives

While the learning design seemed to be largely successful in fostering the development of many of the subject objectives, some drawbacks to the learning design may be noted. A view was expressed that the focus on professional practice, while exposing students to the diverse problems that can be solved through the application of the OR methodology and techniques, failed to provide sufficient

diversity in assessment tasks. This comment was made as a consequence of the consistency in marks and mark breakdowns across student results for the four assignments.

In the subject, initial establishment requires a considerable investment in time because of the use of a variety of resources within each class. In subsequent cohorts, the modifications to the content in needed not be as extensive as might otherwise have been the case.

Another aspect that was disappointing was that regardless of the time spent describing the subject and its expectations, students had difficulty knowing what was expected of them This was seen in the questionnaire item which received a score of 3.4 (average), somewhat below the other scores for the subject.

Conclusions

Almost universally, universities are now emphasising the development of generic skills and preparation for professional practice, with statements to this effect appearing in their mission statements. While third year mathematics subjects have strong technical content and emphasis, the majority of these never focus on aspects of the application and extension of the discipline in a professional setting. This paper has argued that in the setting of a capstone subject in a discipline a focus on professional practice can provide an interesting and rewarding alternative. While the sample space for the study of the research questions was small, the success of the efforts to focus on professional practice was highlighted by the overall response to the subject, as evidenced in the results from the subject questionnaire, the very positive response to the learning activities and assessment tasks provided by part-time students currently practising in the profession, and, by students gaining full-time employment as operations researchers.

Evidence from their assignments suggested that students were able to identify, model and solve real-life and realistic problems, and to critically assess and apply information from a variety of sources. The assignments also showed evidence of critical thought and reasoned arguments, as well as project management skills. In the execution of the assignments, only one group of the eighteen over the three year period proved to be dysfunctional, with the remainder displaying effective group dynamics. By and large, student seminars were presented professionally with many groups exhibiting creative role play in their client and consultant presentations.

The subject objective concerning professional and social values was more difficult to assess. Certainly, all but one student over three cohorts demonstrated social responsibility in their in-class behaviour (with regard to participation in class activities). However, somewhat disappointingly, the number of students who could see value in belonging to a professional societies was somewhat less than what might be hoped for.

Following on from this study, analysis of the perceptions of the subject by graduates in employment, with additional input from employers, would seem an appropriate next step in assessing the long-term outcomes of the effectiveness of the learning design.

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