Large classes across disciplines

Introduction

Although the majority of academic disciplines have unique characteristics, many teaching and management methods are universally applicable. Gibbs (2000) acknowledges that the inculcation of discipline-specific knowledge requires certain expertise, but insists that the generic principles of pedagogy pervade teaching and learning in all discipline areas. Nevertheless, this document concentrates on the discipline-specific methods addressed by education literature. Though all academics are encouraged to peruse the section on the methodology employed in the humanities and social sciences, as it has been studies in these disciplines that have led research in the area and many of the principles are applicable across a wide range of disciplines.

Social Sciences & Humanities

There has been a dramatic increase in the popularity of social science courses over the last few decades (Lambert & Knight, 1985). This increased popularity, combined with the fact that these courses are an economic means of providing instruction, has resulted in particularly large classes, especially in first year courses. The abstract and theoretical nature of the knowledge imparted, as opposed to the more resource-intensive problem based learning involved in engineering or computing courses, has propitiated burgeoning class sizes in the social sciences and humanities. But it is the abstract nature of the course content that necessitates the employment of additional small-group classes to stimulate interactive and higher-order learning and ensure the comprehension of the concepts taught in the lecture program. This is often impossible with the resources allocated in these disciplines and the use of innovative teaching techniques, such as computer conferencing (Campbell & Ben-Zvi, 1998), as well as peer-assessment, group-assessment and self-assessment (Falchikov & Goldfinch, 2000; Campbell, 2001) have become increasingly popular. Nevertheless, subjects exclusively comprising lectures remain a common feature of many social science courses, but various strategies can be applied to produce positive learning outcomes in these environments (Newby, 1991).[1]

Psychology

There is abundant literature concerning effective teaching practices in large psychology classes, due in part to the fact that first year psychology classes are among the biggest at many universities (Silverstein, 1985). Student numbers are so large because subjects in psychology are attractive as electives and, as a consequence, a large proportion of the students enrolled in these classes do so as credit for other degree programs. Various strategies have been implemented to manage courses, where student enrolments number in the thousands. At York University in Canada, the student numbers in first year psychology courses have amounted to 3400 students a term and at the University of Glasgow they exceed 1000. The approach implemented to manage the courses at York has been to teach the subject over two semesters by twelve different lecturers, each with classes of between 150-500 students (Rosenfeld, 2001). Under this system each lecturer is given the freedom to determine the course content, although the assessment procedures employed remain uniform across the classes. The University of Glasgow has adopted a different strategy and has elected to cap student enrolments at 500 to maintain quality teaching with the limited resources available (Martin, 2001). Under this program, students are expected to attend three lectures a week, weekly tutorials comprising 12 students, as well as three three-hour practical laboratory sessions on computers in groups of 25 during the semester.[2]

The reliance on large classes in providing first-year psychology courses is an attractive means of instruction amongst university administrators because of its low consumption of resources (Jenkins, 1991). Nevertheless, lecturing in large classes can be a positive experience for students and provide inspiration them to undertake further study in the area (Jenkins, 1991; Waugh & Waugh, 1999). But for teaching in large classes to be effective, it is essential that lecturers utilise the plethora of resources available to them, including visual aids to explain experimental designs and findings, short films, OHT's, and handouts that outline the structure and content of lectures. The provision of pre-prepared notes can also be an effective means of ensuring that the audience obtains the correct and relevant information from the lecture material (Jenkins, 1991). Various innovative techniques for teaching large psychology classes have been suggested by Oxford Polytechnic in the UK (Gibbs, 1992b). These strategies are designed to combine cooperative student learning with the use of a set text and study guide to provide a diverse range of assessment, reduce the number of lectures required and lessen staff hours. These include:

- Grouping students into learning teams of five to facilitate interaction, discussion and peer support. They undertake two essays and all practical sessions together.
- Having learning teams undertake eight laboratory sessions together where experiments are conducted, with reports on four of the sessions required from each team.
- Running workshops where teams present their practical work for discussion with other groups.
- The employment of six multiple-choice tests, which are marked by computer and scores averaged across the learning team. The objective of this assessment is to facilitate cooperation and peer tutoring.

[1] For more information about such strategies, refer to the section: *What's different about large classes?*
[2] For further information on these and other large 1st-year Psychology courses around the world, see Teaching Psychology in large classes: An international survey of solutions.

Foreign Languages

Large classes in language instruction are measured on a different scale to other subjects, with 50 students often constituting a large class. Gibbs (1999) has defined the principles and features common to the teaching of foreign languages. Examination of these principles suggest that they could be effectively implemented irrespective of class size, provided that the instructor makes good use of other teaching strategies, such as peer interactions and cooperative learning. These features include:

- Repetition by the instructor and by students;
- Oral practice by students (verbal repetition, conversations, role plays);
- Careful planning in the unfolding of the teaching program and the selection of practice activities;
- Practice at combining and using the rules of language in familiar and new ways;
- Providing an enjoyable and socially safe environment in which to practice and perform.

Research by LoCastro (1994) has supported this view that the instructor's role is primarily as a facilitator. LoCastro studied English teaching with Japanese university students, using the Strategies Inventory for Language Learning (SILL) and group interviews to ascertain the effects of class size on language learning. Variables such as teaching methods, teacher characteristics and personal effort were found to have a more profound effect on grades and language acquisition than class size. The interviews discerned that there was a widespread belief amongst students that the teacher was primarily a source of motivation and feedback, rather than the sole source of knowledge and understanding.

English Language & Literature

Inducing student interaction and questioning are crucial components of stimulating higher-order thinking. Tom Burton from the University of Adelaide insists that this is possible in large classes and has indicated that he employs this strategy in his teaching of English language and literature subjects. He argues that the discipline of literature, with its requirements of text interpretation and analysis of symbolism is an excellent medium for stimulating higher-order thinking. Burton's most effective tool for achieving this is to make his lectures interactive, by eliciting responses from the audience to prompt further discussion (CUTSD, 1997).

Education

The efficacy of lecturing has long been questioned (Bligh, 1971), but this method of inculcating knowledge is even more questionable in the discipline of Education, which purports to furnish students with practical knowledge and skills. Research by Waugh and Waugh (1999) repudiates this view and has suggested that large lectures can be an effective means of instruction. Their contention is that lectures in the discipline of education should be orientated towards creating an atmosphere conducive to learning, with the provision of knowledge about sources of information, the availability of resources, motivation, a desire to question, and inspiration about researching various subjects further. This is in contrast to the customary use of lectures, which is to provide detailed content.

Small Group Teaching

Tutorials or seminar groups are commonly used in the social sciences and humanities to accompany lectures. Small group teaching has been widely demonstrated by research to be more effective in changing attitudes, improving communication skills, and consolidating knowledge imparted in lectures (Blake, 1990; Buckelew, 1991; Gibbs, Lucas & Simonite, 1996; Lewis & Dahl, 1972). This is because it facilitates higher-order thinking skills, including analysis, synthesis and evaluation of information, as well as providing an avenue for peer interaction and group work.[3] The efficacy of small group teaching, as an accompaniment to large classes, applies across all disciplines. But despite the benefits of tutorial sessions, many large courses eschew their use because of their additional expense, as repeat classes and additional teachers are required to be employed.

The University of New Mexico employed an innovative approach to small group teaching in a large first year English class (Buckelew, 1991). At the inception of the class the teacher circulated informal questionnaires to students asking them to identify factors that might stimulate their participation in class discussions. The teacher then collated the information and, together with Bloom's (1956) taxonomy of educational objectives, devised sets of questions related to their assessment items (in this case, essays and group presentations). The questions were dispensed as sets of four to students, who were organised into groups of four, with each individual in the group given a different set of questions. This method demonstrated success in improving the quality of student essays, group presentations and, by systemising student participation, ensuring the interaction of the more diffident students.

Group Work: Problems and Strategies

Although group work is a common strategy pursued in universities to decrease marking loads, it is frequently criticised by students from all disciplinary backgrounds. The primary complaint is that group-assessment does not differentiate between the different levels of contributions, as it awards a common grade to all group-members. In the literature on group work, several methods have been identified to overcome this problem. McKinney and Graham-Buxton (1993) advance the 'ticket-in' technique as a means of ensuring collaborative learning in large sociology classes. This requires students to individually prepare for a group assignment task by completing worksheets of questions or compiling ideas. Students are expected to produce their 'ticket-in' when they arrive at class and those who do not are excluded from the group work for that week and fail to receive the appropriate credit. Another technique for promoting student accountability involves requiring students to provide a cover-sheet on group assignments indicating the percentage or part of the assignment each individual contributed. An additional requirement is that the cover-sheet be signed by all members of the group to attest to their agreement with the allocations (Campbell, 2001). Stephanie Hanarahan, from the University of Queensland, has employed a variant of this method, requiring students to complete group evaluation forms (CUTSD project, 1997). Under this system, each individual of a group completes a group evaluation form, bestowing upon each member a mark between +8 and –8 representing their level of contribution. All of the allocations must equate to zero when added together. In cases where there has been an equal contribution from all group-members, they would all be awarded zero. Hanarahan then averages the scores for individuals, which is used to adjust their result by applying it to the original group score.

Peer- and Self-Assessment

Another method of decreasing the marking and feedback load of large classes in the humanities and social sciences has involved a greater shift to peer-assessment and self-assessment. (Falchikov & Goldfinch, 2000). By introducing a system of seminar presentations by individuals and pairs, in order to encourage peer-assessment and self-assessment, Sociology teachers at Oxford Brookes University in the UK have reduced their marking loads by 70% (Gibbs, 1992b). The Sociology courses also comprise interactive workshops, which involve students being divided into groups of four to undertake data analysis and interpretation activities under the direction of a tutor. Oxford Brookes found that the implementation of these techniques had the result of facilitating feedback and discussion between students and teachers, stimulated student interaction and encouraged peer support. At the same time, these courses consumed only about 40-50% of the

[3] For a detailed case study about the introduction and management of a tutorial and tutor-training program, see the report entitled Managing a large team of tutors in first year psychology.

resources devoted to the course in its previous incarnation, which utilised more traditional methods of instruction. But it should be noted that for peer-assessment to be fully effective and of an appropriate standard, it should always be directed and monitored by tutors. This may involve additional training of teaching staff, but the saving of resources by implementing peer-assessment outweighs the cost of employing teachers to mark excessive amounts of assessment.

Other Non-traditional Methods of Teaching

Computer resources and other forms of information and communication technologies (ICTs) have become increasingly popular in recent years in the restructuring of programs in the humanities. Campbell and Ben-Zvi (1998) at the University of Alberta have examined the redesign of a large Introductory Religion course to a web-based format. The teaching staff introduced computer-mediated conferencing (CMC), which had the effect of reducing costs at the same time as enabling students to access transcripts of online conversations and debates about course material. Campbell & Ben-Zvi argue that CMC is a positive innovation for students, as it allows a greater degree of non-threatening interaction than does a classroom, and facilitates a more expansive exchange of ideas. They also insist that it has additional advantages including improving writing ability, enhancing the acquisition of meta-cognitive skills such as self-reflection, and the relation of personal experience to theoretical frameworks. Although at Alberta, CMC was used only as a teaching instrument, it could be adapted to become an assessment tool. But it should be noted that access and familiarity with the Internet are fundamental requirements for the successful use of ICTs in teaching.

Business Related Disciplines

Economics

Undergraduate (particularly first year) economics courses frequently have very large enrolments because they often service a variety of related disciplines, such as business, commerce, accounting, journalism and social science. The traditional teaching methods employed in undergraduate economics courses focus on lectures providing supplementary and explanatory information to assigned readings, with assessment by multiple-choice exams (Becker and Watts, 1996; Benzing and Christ 1997; Siegfried, 1995). There has been a suggestion that the tenacity of these dated teaching approaches, and the lack of avenues for cooperative learning in comparison to other disciplines, are responsible for the declining interest amongst students in studying economics.

There are various alternatives to this system, which involve a greater use of ICTs and student interaction. Becker and Watts (1996) have studies the development of alternative methods of teaching in undergraduate economics courses over the past 25 years. They particularly highlight the advances in the field of experimental economics, which has successfully introduced games and simulations into the classroom. Other innovations involve the use of computers in a tutorial system, where the necessary software is included in the supplementary materials packaged with economics texts. Williams, Teschner and Miller (1995) also advocate the use of computer technology in facilitating cooperative learning processes. The introduction of activities, assignments and group interactions encourage understanding and deep learning. But it must be noted that caution needs to be exercised in the application of computer technology as a teaching tool. Vachris (1999) has demonstrated that attrition rates in economics courses are doubled when those courses are offered on-line. She recommends a combination of Web technologies and classroom activities to facilitate deep learning and maintain student interest.

Collaborative Problem-solving

Students of Economics are advantaged in their studies when they possess higher-order thinking skills. These include abstract thinking, the ability to apply theoretical constructs in practical exercises, and the capacity to express complex ideas logically and fluently (Johnston, James, Lye & McDonald, 2000). But the development of these aspects of thinking is a challenging task for students in their early undergraduate years. The failure of courses to facilitate their development could explain why students often view economics as a difficult subject. Stimulation of higher-order thinking is a difficulty made even more problematic with large classes.

In a bid to promote higher-order thinking in its Economics discipline, the University of Melbourne introduced a package of measures designed to introduce collaborative-problem-solving (CPS) into the tutorials of a second-year macroeconomics subject (Johnston, James, Lye & McDonald, 2000). The tutorial system was revised to incorporate problem-solving sessions where students would work in small groups to discuss practical applications of economic theory. Other initiatives under the CPS program involved the provision of a tutorial guide to all students, which included set readings, related review questions and examples of the kinds of problems that were addressed in the tutorials. The tutors were also provided with teaching guides that contained suggestions for encouraging student participation and learning. Johnston et al. compared the CPS trial group with a control group that was exposed to traditional teaching practices. They found that students in the CPS group were more prepared for tutorials, were more satisfied with the tutorial experience, had developed more personal relationships with both their tutors and fellow students, and had acquired better communication and teamwork skills. But contrary to expectations and existing research (such as Slavin, 1990), most of the students in the CPS group did not gain any advantage in terms of achievement or the maintenance of interest in the study of economics. The exceptions were the international students in the CPS group, who achieved significantly better results than those in the control group had. Despite the inability of the CPS methods to make a significant impact on achievement levels for the majority of students, they did have positive effects on the student experience and would be a worthwhile investment for undergraduate economics curriculums.

Web-based Learning

Web-based learning strategies and ICTS are an innovative inclusion to both on and off campus education. Chizmar, Walbert, Hurd and Moore (1999) have successfully employed web-based activities for on-campus students in large undergraduate microeconomics and econometrics courses. They have designed a series of web pages to serve a number of purposes including:

- disseminate information (including the on-line syllabus and assigned readings);
- collect information from students (regular structured feedback, classroom opinion polls, the results of sampling experiments);
- supply links to sites containing data sets and articles relevant to the class;
- provide on-line teaching through using Excel workbook, and on-line laboratory sessions and tutorials.

The on-line laboratory sessions and tutorials require students to collect and produce data, make predictions, study important economic controversies, discuss findings, analyse data, conduct simulations, write explanations, and access the wealth of information available on the Internet.

Chizmar et al. (1999) also advocate the use of ICTs to stimulate interaction between students, as well as between teachers and students. They promote the concept of ‘think-pair-share’ to enhance comprehension, where students work in teams and post a message on a Web-based discussion application that explains a particularly difficult concept. In their teams the students then analyse the contributions of other teams and discuss any differences or similarities with their own postings. The ‘think-pair-share’ concept is based on the premises that the act of writing itself improves clarity and precision in communication (Meyers and Jones, 1993) and that the larger the audience, the more improved the quality of the writing (Klass, 1995). The other advantages of the process are that it improves understanding of difficult concepts, computer literacy and provides a tangible demonstration of participation. But although Chizmar et al. have demonstrated the efficacy of ICTs in the teaching of Economics subjects, they warn that good pedagogical principles should drive the use of technology, not cost-efficiency or the implementation of technology for its own sake.

A technique for improving feedback about the effectiveness of teaching and student comprehension is the combination of the one-minute paper and web-communication (Light 1990; Chizmar and Ostrosky 1998). The technique is employed in the final minutes of a tutorial and involves the teacher asking students to respond to two questions concerning the class: *What was the most important idea presented in class?* and *What was the least clear idea?* The teacher can then edit the responses and post them on the Web-based discussion program, or use them as the starting point for discussion in the next class. The paper also should request an e-mail address from each student, which enables the teacher to respond immediately to any student who indicates that they are experiencing problems with the course. The one-minute paper has been used with large economics courses and has resulted in decreasing students' feelings of anonymity and confusion, as well as improving knowledge by approximately 7 percent (Chizmar & Ostrosky, 1998). It has also been a useful tool in encouraging student-staff interactions, improving student motivation and assisting with self-paced learning.

Business Management and Accounting

The education of Business students in recent years has evolved from traditional large class teaching techniques to skill-based teaching and learning. This transition has been the product of greater demand for graduates to have the skills to translate their knowledge to practical contexts (Bartels, Bommer & Rubin, 2000). Computer based simulations have performed a dual role, by reducing the strain on teaching resources, as well as providing a means of applying the decision-making process to simulated business scenarios (Pascoe, 1992). The objective is for students to focus on the applications, rather than the definitions, of business concepts, principles, and methods. The simulation ensures that the process is competitive and dynamic, requiring decisions to be made simultaneously and interactively, as in an authentic business environment.

But although computer based simulations have strong face validity as a teaching tool, there are contradictory and inconclusive findings about their efficacy (Miles, Biggs, & Schubert, 1986; Moutinho, 1988; Randel, Morris, Wetzel, & Whitehill, 1992; Smith & Boyer, 1996; Vaidyanathan & Rochford, 1998; Wolfe, 1985). Greenlaw and Wyman (1973) reviewed early research in this area and found that although simulations did instil certain skills, they were not particularly successful at achieving course objectives. The research into the instructional effectiveness of simulations has continued to produce mixed results in the 25 years since this review was completed. Randel et al. (1992) reviewed 68 studies that had compared the teaching effectiveness of computer simulations with other pedagogical methods. They found that 56% of those studies discovered no difference between simulations and traditional instructional methods, 32% found that simulations did improve student achievement, and only 5% favored traditional instruction.

Chapman and Sorge (1999) conducted one of the more recent studies into the effectiveness of computer simulation when compared to traditional methods of teaching. They found that students who indicated having high degrees of engagement with the simulations also reported better understanding of management issues, greater satisfaction with the course and scored higher on general learning objectives. The researchers analysed GPA and expected grades in the course, and were able to rule out the suggestion that the study had only revealed that better students are more likely to have higher involvement with a course.

Science and Technology

Biology, Chemistry and Physics

As with most of the other disciplines already discussed, subjects in the natural sciences customarily involve very large classes, especially in first year courses. Introductory biology, chemistry and physics subjects are undertaken by first year students from a variety of natural, medical, environmental and engineering science programs. The diversity of the student population, the broad scope of the course content and the large class sizes all contribute to increasing the difficulty of teaching these classes. Furthermore, the nature of these disciplines means that the fundamental role of the lecturer is the delivery of detailed information, such as sequences of equations and facts, which is necessary before knowledge can be applied. This means that courses in the natural sciences often involve passive and individual learning of information provided in large lectures, and are not particularly conducive to group work and other academic activities that stimulate higher-order thinking skills. This concentration on transmitting facts has resulted in many first year science students reporting feeling overwhelmed (Mathews, 1998) and others eschewing reflective learning to concentrate only on learning assessable information (Zoller, 1999).

Although there is an emphasis on teaching in the natural sciences to inculcate a significant amount of tangible concepts and facts, effective pedagogy requires an avenue of application and interaction. Research undertaken at the University of Sydney by Sharma, Millar and Seth (1999) demonstrated that the introduction of cooperative learning tutorials into large first-year physics classes had a positive relationship with attendance related to academic achievement. But unfortunately, most courses in the natural sciences provide very few opportunities for interaction between teachers and students. This is particularly concerning because students in large science courses, which are often first-year, lack the necessary study skills and learning strategies to prepare for exams (Mathews, 1998).

Many of these problems could be overcome if lecturers implemented techniques that facilitated student development in the areas of self-directed learning and study skills, such as the inclusion of a study guide as a companion to the text book. But for a study guide to be effective in promoting independent learning, it needs to be integrated into the teaching program, with references made in lectures, practical sessions and tutorials to link it to topics in the course and encourage its use. If it is not integrated in such a fashion, students will fail to use it until it comes time for preparation for exams (Kelly, 2001).[4] The implementation of peer assisted learning programs, such as PASS (Peer Assisted Study Sessions)[5] can also serve to integrate a study guide, as well as increase student motivation and peer support. The PASS program and varieties of it have been employed successfully at the Queensland University of Technology, the University of Queensland, and other universities to assist first year science students in large classes (Martin & Arendale, 1993).

Promoting Higher-order Thinking

Although there is a prevalence of case studies describing the efficacy of various class sizes in the natural sciences, there remains limited experimental research into a comparison of small versus large group teaching methods. A recent study by Zoller (1999) which compared the outcomes of large and small organic chemistry classes at different universities in Israel produced notable results. Zoller investigated the effectiveness of teaching in these different class sizes at improving higher-order cognitive skills (HOCS). Students were subjected to inquiry-oriented class discussions, interactive problem-based learning, HOCS-type examinations, peer-assessment and explicit mention of learning strategies and processes. They were allocated to small discussion groups that were given tables and/or diagrams representing different situations in chemistry and asked to

[4] For other ideas on using study guides in large science classes, see the case study entitled Team teaching in 1st-year biology on this site.
[5] PASS is described in more detail in the section on Administration and management of large classes.

interpret and evaluate these within their group. Discussion questions (for group-work and as homework) asked students to relate formulae and facts to situations that they had encountered in real life. Zoller found no statistical differences in the achievement levels of students in small versus large classes. Assessment designed to examine the development of HOCS is resource-intensive, but Zoller recommends the employment of self-assessment and peer-assessment strategies, and/or the introduction of semi-automated marking systems to alleviate this problem. Although factors such as motivation, enjoyment and intention to study were not exmained directly, Zoller received sufficient anecdotal evidence to suggest that they were positively enhanced as a result of the use of teaching methods designed to stimulate HOCS.

Tips for instructors in science

There are many avenues in large science courses for inspiring student interest, and stimulating greater student interaction, as a means of improving quality of learning and motivation. For example, Howes and Watson (1982) suggest conducting large-scale demonstrations that involve students 'acting out' various manifestations of physical laws, accompanied by the lecturer's commentary of the process. In one particular demonstration, students acted in the roles of molecules and, by following the instructions of their lecturer, demonstrated the behaviour of molecules in various states of matter, as well as the effect of heat in engendering changes of state. Howes and Watson have also employed such demonstrations in astronomy classes to instil understanding of the behaviour of gas and liquid, as well as, at higher levels, the concepts of entropy, nuclear fission and stellar evolution. Examination of achievement levels have reinforced that these demonstrations are effective at explaining various concepts and facilitating student interactions, as well as producing higher levels of student enjoyment of the courses.

Lecturers of science in Australia have become concerned that burgeoning university intakes have resulted in a reduction of the background knowledge and competencies possessed by first year students (CUTSD Project, 1997). David Hewitt from Monash University has noted that chemistry students have progressively become less confident and less proficient in simple mathematics, and has introduced various measures to remedy these deficiencies. He has introduced pre-laboratory exercises, which permit students to work through various problems, and, most importantly, to receive immediate feedback and assistance on their progress. Hewitt has also implemented computer demonstrations, laser disk displays and live demonstrations in lectures to illustrate difficult key concepts. Students are also provided with paper copies of all the projected material, as a framework for note-taking and to guide study. Computer programs are also available to:

- encourage regular student learning using fortnightly tests;
- provide tutorial support for difficult concepts;
- permit analysis of data in laboratory exercises;
- provide pre-laboratory experience (that is, simulations of laboratory exercises).
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Mathematics

In recent years the popularity of pure mathematics as a major has declined to the point that some universities no longer offer a three-year degree majoring in the subject. According to Thomas (2000), the exodus of Australia's most experienced and innovative researchers overseas is one of the primary explanations for this trend, reducing university mathematics teaching staff by 25% since 1995. Nevertheless, large courses in applied mathematics, such as statistics, engineering and computer science continue to be prevalent in the first and second year degree structures of many universities. Unfortunately, there has been very little research in Australia on the successful teaching and management of large maths courses.

Nevertheless, there is a wealth of anecdotal information from Australian academics on the teaching of large classes in mathematics, collected as a part of the Committee for University Teaching & Staff Development project (CUTSD, 1997) to solicit academics reflections of their teaching.

Lecturers who responded emphasised that successful teaching involves departing from passive means of instruction to engage the students. They indicated that large lectures were not effective in mathematics, but were used to encourage interest in the discipline, promote enthusiasm for learning, showing students how to 'think mathematically' and for demonstrating and explaining ways in which mathematicians think. When lectures were used, most academics suggested that best practice involves actively engaging students in the lectures and encouraging them to ask and answer questions. As many students take mathematics subjects as electives from other degree courses, the major objective of many mathematics academics in first-year courses is to attract students to the discipline and stimulate their appreciation of mathematics and its usefulness as a support for their major areas of study.

Although there has been little large-scale research in Australia into the teaching of large mathematics subjects, studies have been done in the USA. Hilton and Anderson (1991) have analysed program reviews of college mathematics and statistics courses in Florida. They found that emphasising students' roles as apprentice mathematicians and statisticians, as well as providing activities that promote these roles, had the effect of bolstering student satisfaction and morale. As with many other disciplines, mathematics students would benefit from greater interactivity to promote problem-solving abilities and mathematical reasoning capacities, which are not stimulated in the traditional lecture/demonstration format. Hilton and Anderson also argue that there is a need for greater administrative support and the facilitation of greater collegial interaction of mathematicians, such as the implementation of team teaching.

Lopp (1999) also undertook a large-scale report on mathematics teaching in the USA to investigate the factors that result in high and low retention and pass rates. He had similar results to Hilton and Anderson (1991), discovering that faculties with high retention and pass rates reported use of more active learning structures in the classroom, such as cooperative group activities in conjunction with board-worked problems and demonstrations. Those with low retention and pass rates invariably confined their teaching to providing lectures and the setting of problem questions.

Lecturing strategies

Academics in the CUTSD (1997) project also reported various innovations and strategies, especially through the use of computer technology, in delivering lectures on mathematics. The facilitation of visualisation is an important tool in consolidating understanding of the quite abstract processes of the discipline. Consequently, computer assisted demonstrations, or more mundane methods of board work and overhead transparencies, are commonly used to provide graphic illustration of concepts. Various computer applications were also used for more specific purposes, including ANUGRAPH for function work in calculus, as well as MINITAB and EXCEL for data analysis in statistics courses.

A number of lecturers commented that they had altered their presentations of lectures in order to ensure that they did not overwhelm their students (CUTSD, 1997). Some of these modifications were elementary and have been undertaken in many other disciplines, such as the provision of pre-prepared lecture notes or ensuring their availability for photocopying in the library, prior to the lecture being delivered. Almost all the respondents had noted the necessity of matching the pace of the lecture to the level of the students and, in many cases, this has meant slowing down the delivery. One particular lecturer varies the lecture content by interrupting the lecture at various points to introduce an example for students to work on either individually or in pairs. She circulates the room to monitor their progress and answer any questions that may arise. As most lectures have been targeted at the less adept students, another academic has attempted to maintain the interest of the more erudite individuals by providing extension work to be picked up after the lecture, or worked on during standard demonstrations.

The University of Sydney introduced an innovation to assist students in tutorials (CUTSD, 1997). It purchased 30 graphics calculators at a cost of more than $200 each, specifically for use in tutorials, but which were also made available to students outside those times. The calculators were used in conjunction with mini-manuals and a set of tutorial exercises that included written hints detailing the ways that the calculators might be used. The primary objective of the calculators was to facilitate student understanding of the mechanical processes of mathematics, and allow teachers to concentrate on presenting more abstract ideas and modeling situations designed to enhance the comprehension of those concepts. The University of Sydney did encounter problems relating to ensuring access to the 30 calculators for the 300 students in the course, and in developing student understanding of the proper uses of the tool. They also found that some students had a propensity to become too reliant on the use of technology to assist in the solving of problems. This undermined the very reason that the calculators were introduced, which was to enhance understanding of mathematical concepts by providing a tool to facilitate questioning, analysing and interpreting of the results.

Assessment

The most common form of monitoring progress for mathematics academics was the use of weekly or fortnightly tutorial papers and assignments. This was done on both a formal and an informal basis. The use larger assignment tasks is not an option in mathematics, due to the fact that cheating and copying are major concerns in the discipline because they are difficult to detect, as there is only ever one solution to a problem. The primary concern with examinations is that they encourage rote learning, rather than understanding of key concepts. As a consequence, many academics include small proportions of written assessment, constituting only 10-20%, or require students to answer questions about their written work as part of the exam. Others attempt to design questions that assess understanding and problem solving, rather than recall, or include formulae sheets with exam papers.

Computer Science and Engineering

The primary concerns of academics teaching large computer science and engineering classes are the isolation and alienation of students, due to the nature of the courses. Related problems include managing the decreased teacher-student interaction during instruction, maintaining students' interests and controlling disruptive influences (Godfrey, 1998; Maheshwari, 1997). The bulk of the literature on large class teaching in Computer Science and Engineering has been in the form of case studies.

Lecturing in engineering

Various strategies for teaching and managing large classes in engineering have been delineated by Keith Godfrey at the University of Western Australia. His article, *Tips for lecturing large classes of first year students* (Godfrey, 1998), is particularly aimed at the instruction of electrical and electronic engineering and is based on a review of his Electrical Fundamentals unit. He found that there was widespread student dissatisfaction with his course, primarily due to the compulsory and abstract natures of the subject. Godfrey's solution was to use the first lecture, when most students make the effort to be present, to explain the importance of the unit, its relation with their program of study and the relevance of the abstract nature of material. These points were reiterated in lectures throughout the semester whenever the opportunity arose. Godfrey also modified his tutorial sheets to ensure that each clearly defined its aims before presenting any of the problems or issues for discussion. He concluded from the exercise that student attitudes could be modified when proactively confronted and addressed in lectures and other aspects of a course. Godfrey has also suggested a series of other presentation techniques and ideas for improving large engineering lectures, including:

- Grabbing students' attention at each main point and specifically inform them that certain information is crucial or assessable.
- Eye contact must be maintained to demonstrate confidence in your ability, but avoid fixating on the few students who invariably meet your gaze.

- Monitor student progress and attention when they are occupied with writing or copying down notes.

Godfrey has also offered a number of tips for lecturing first year engineering classes:

- Address the factors that make a course difficult to teach;
- Ensure that the course is organised logically;
- Give early feedback to first year students;
- The first lecture should be used to introduce the course, the university environment and yourself;
- Present material clearly and attract attention when needed;
- Employ all the lecturing aids available;
- Maintain an appropriate level of discipline and authority.

The employment of these techniques has had the effect of improving overall academic achievement in Godfrey's electrical fundamentals course, despite the size of large classes and the increased pressure on academic staff (Godfrey, 1998).

Martin Murray at the Queensland University of Technology has preferred to tackle the problem of low levels of student satisfaction by decreasing his use of lectures. He has encouraged self-directed learning by developing a comprehensive study guide to function as a companion to the existing textbook, which allows students to work at their own pace. Students are required to attend only one lecture per week, of one-hour duration. The resources and money saved by the reduction of lecturing has been channeled into the Peer Assisted Study Sessions (PASS), which engage all students for an additional one hour per week.[6] Students are openly informed that the expectation of the course is that they learn by using the study guide and reading the set text, rather than taking notes at lectures. Thus, the lectures and the PASS sessions frequently make references to both the study guide and the set text and use them to set tasks for completion each week. Students are also expected to utilise propriety software and a CBE tutorial to supplement their learning. The progress of students' individual learning is continually monitored through the use of formal quizzes and design/construct/test group projects (such as building spaghetti bridges). Murray has reported that the increased emphasis on self-directed learning has resulted in greater self-direction and team-building skills on the part of students, as well as increasing the average score on his end of semester exams (CUTSD, 1997).

Computer Science

To date there has been no large-scale research into effective teaching in large computing classes. Nevertheless, there have been numerous accounts of the implementation of successful innovations in information technology and information systems courses (Collis & Breman, 1997; Bump, 1998; Maheshwari, 1997). The major problem encountered by the teachers of large groups in these areas is the disparity in students' background knowledge and computer literacy levels (Crafford & de Villiers, 1997). Initiatives introduced to address this problem have included the implementation of bridging courses, extra classes for less computer-literate students, telecenters, cooperative learning techniques and problem-centred project work in small groups.

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[6] For more information on PASS refer to Administration and management of large classes.

Douglas Newlands from Deakin University (CUTSD, 1997) has suggested that student interest and understanding can be enhanced in computer science courses by providing information in a variety of different ways. His course is designed to enable students to view material on four different occasions:

1. The lecture gives an overview of the material explaining the main points and relationships.
2. Students do the prescribed reading to expand their knowledge of the area.
3. The next week they attend a tutorial and do exercises relating to the previous week's lecture to consolidate understanding.
4. The week after that, students attend a supervised laboratory where they produce a computer program related to their solution to the problem provided in the previous week's tutorial.

Newlands' system ensures that students are given constant feedback on their progress, facilitates interaction between students and teachers, and consolidates understanding of the key concepts of the course. He believes that a system, such as the one he has implemented, is imperative to maintain the interest and motivation of the majority of students.

Maheshwari (1997) has also redesigned his computer-programming course at Griffith University. He altered the lectures, laboratory sessions and tutorials in a fashion that would facilitate deep learning and promote creative approaches to the course material. Maheshwari transformed the objectives of his lectures from being aimed at providing detailed assessable information to stimulating enthusiasm, engagement with the subject matter and ensuring that students could relate their course content to their existing knowledge. The key content information for the course was now provided by textbooks and other written materials. The previous system of take-home assignments was replaced by three on-the-spot assessments in laboratories, which were scheduled at four-week intervals. Maheshwari insisted that this modification to the assessment process had the effect of improving students' capacities to manage their workload, promoting lecture attendance and reduced the incidence of plagiarism and cheating. The overall objective of Maheshawari's strategies was to promote deep learning strategies and, he argues that prior to their implementation, many students could successfully complete his course by merely resorting to surface learning techniques.

Conclusion

The underlying principles of quality teaching and learning pervade all aspects of higher education, irrespective of the discipline, the university or the specific teaching methods. The fundamentals of successful pedagogy involve stimulating active and deep learning, as well as linking students' existing knowledge and interest with the course content. Geoff Waugh from the University of New South Wales has stated that the impressions and attitudes that teachers inculcate is often the most crucial knowledge imparted in the long-run (CUTSD, 1997). With respect to large classes, he suggests that if a course can employ strategies designed to encouraging interactivity, large classes can be as effective as smaller ones in providing quality teaching and successful learning outcomes.