

PLENARY SPEAKERS:

Are Online Learners Learning or Just Online? A Status Report on the Teaching of Undergraduate Mathematics on the Web

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The w WIDE-w is becoming WIDER at an increasing rate. It is virtually impossible to take any kind of accurate snapshot at one time of the state of its development. Undergraduate mathematics courses presented on the internet are relative newcomers to the race but are nevertheless increasing in numbers at the same phenomenal rate. Internet education is developing as a new mode of teaching with its own characteristics and possibilities, different from any traditional way of teaching. Research on this new mode of teaching is sparse and open research questions are temptingly plentiful. Speculation about the future in such a fluid environment is both risky and fascinating. In this talk we try to capture the world of internet teaching of mathematics with its myriad of possibilities. We give an overview of the scope of mathematics courses presented via the web, attempt a graphical classification, discuss characteristics and implications of this mode of teaching/learning mathematics and try to envisage some possible future trends.

Johann Engelbrecht teaches mathematics at the University of Pretoria (South Africa). He was trained as a mathematician and his original research was in functional analysis. He changed to mathematics education about ten years ago. Since then he has been involved in numerous activities in undergraduate teaching of mathematics. His main research interest is in teaching mathematics via the internet and most of his recent research outputs are on this topic.

He is co-founder of SAMERN (the South African Mathematics Education Reform Network) and 1998 recipient of the Claude Harris Leon Championship in Mathematics Teaching Award in South Africa. With his research colleague, Ansie Harding, he organises the MUTI (mathematics for undergraduates teaching initiative) activities at the University of Pretoria.

He has been involved in the Delta activities since it started in 1997, serving on the international panel for Delta'99, main organiser of Delta'01 in the Kruger Park, South Africa and currently member of the International Delta Committee.

He is married to Heloise and his second proudest asset is his brand new (and first) grand daughter, Nicola!

Visualization is in the Mind of the Beholder

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My aim in this paper is to discuss the complexity of visualization and the roles of different kinds of visualization in mathematics teaching and learning. On the example of a teaching experiment about iteration of functions, I show how teacher-generated computer animations may lead students to developing erroneous figural ideas about the mathematical concept thus illustrated. I point to the difficulty, for the students, to strike a balance between visual and analytic thinking. I also analyze the factors that may contribute to achieving this balance. I distinguish three kinds of factors of conceptual change in students: the social context of the teaching situations, the mathematical problems the students are given to investigate and the teacher interventions. In my experiment, the highest conceptual “leaps” towards the more balanced conceptions appeared to occur in situations of indirect, written and oral communication with feedback from the addressee. Small group discussions were less likely to contribute to the visual-analytic balance. Investigating more complicated functions and “monster examples” was better in that respect than looking at iterations of linear functions. I propose that, whenever possible and sensible, students should be given the opportunity to create their own visualizations, rather than merely watch teacher-generated visualizations.

Anna Sierpinska is a professor in the Department of Mathematics and Statistics at the Concordia University in Montreal. Her degrees include M.Sc. in Mathematics from Warsaw University in Poland and Ph.D. in Mathematics with specialization in didactics of mathematics from the Higher School of Pedagogy in Cracow, Poland. She has worked at the Warsaw University, at a secondary school in Warsaw, at the Institute of Mathematics of the Polish Academy of Sciences, and, since 1990, at the Concordia University in Montreal. She published papers in non-commutative algebra (radicals of rings of polynomials) and, since 1985, in mathematics education (students’ understanding of limits, infinity and of linear algebra). She has written a book, “Understanding in Mathematics”, published by Falmer Press in 1994, and translated into French in 1995 (“La compréhension en mathématiques”, Modulo Editeur), and co-edited two other books, “Mathematics education as a research domain: a search for identity” (Kluwer) and “Language and communication in the mathematics classroom” (NCTM). Her present interests in mathematics education include (a) the study of relations between high achievement in mathematics and students’ ways of thinking, using a combination of qualitative and quantitative methods, (b) study of mathematical texts using a model of functions of language, and (c) investigations into the phenomenon of frustration among mature students re-learning mathematics. In the years 1990 - 1998 she served on the Executive Committee of the International Commission of Mathematical Instruction (ICMI) and was a vice-president of the Commission in 1995-1998. She is presently the editor-in-chief of the journal *Educational Studies in Mathematics* (Kluwer).

Refractions, Reflections, Recombinations: Democratizing Maths for Mass Education

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Two powerful currents affect collegiate mathematics at the beginning of the 21st century: the growing world-wide stress on universal access to tertiary education and the extraordinary spread of mathematical methods to fields as diverse as cinema and genomics. Paradoxically, as the usefulness of mathematics expands, so does competition for the mathematically-minded students. To thrive, mathematics must diversify and democratize, allowing students access to its unique and powerful benefits from many different angles.

Lynn Arthur Steen is Professor of Mathematics and Special Assistant to the Provost at St. Olaf College in Northfield, Minnesota. He is the editor or author of many books on mathematics and education, the most recent being “Quantitative Literacy: Why Numeracy Matters for Schools and Colleges” (2003). Earlier volumes include “Mathematics and Democracy” (2001), “Why Numbers Count” (1997), “On the Shoulders of Giants” (1991), “Everybody Counts” (1989), and “Calculus for a New Century” (1988). His recent work has focused on public policy for secondary and tertiary mathematics education, especially on the quantitative and mathematical requirements for contemporary work and responsible citizenship.

Lynn Steen has given invited lectures in numerous countries and has written extensively about mathematics and mathematics education. He is a founding member of the Mathematical Sciences Education Board (MSEB) of the U.S. National Academy of Sciences and served as Executive Director of that Board from 1992 to 1995. Previously he served as President of the Mathematical Association of America (MAA), Secretary of Section A (Mathematics) of the American Association for the Advancement of Science (AAAS), and as a member of Advisory Committee for the Mathematical Sciences of the U.S. National Science Foundation. Steen received his Ph.D. in mathematics from the Massachusetts Institute of Technology in 1965.

Statistical Thinking and its Development

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The ultimate goal for statistics education is to enable students to acquire as much as possible of the sets of problem solving techniques and thinking skills that professional statisticians use to solve real-world problems. Teaching the use of techniques is something we can (almost) manage. But what about the more subtle, and typically more valuable, thinking skills? We hardly know where to start. Part of the problem is that we are not really very aware of what we do. We just do it! In this talk we will discuss these issues together with teaching practices and some of the research that has been done to address them. This will include discussion of the model for statistical thinking that the author has developed with Maxine Pfannkuch.

Chris Wild is Professor and Head, Department of Statistics at The University of Auckland, New Zealand, President of the International Association for Statistics Education and co-author with G.A.F. Seber of *Nonlinear Regression* (pub. Wiley, 1989) and *Chance Encounters: A first course in data analysis and inference* (pub. Wiley, 2000). He was co-leader with Matt Regan of a team that won a New Zealand Tertiary Teaching Excellence Award in 2003. He has been an Associate Editor of *Biometrics*, and is currently an Associate Editor of the *International Statistical Review*, the *Statistics Education Research Journal*, and the *Australian and New Zealand Journal of Statistics*. Although his main research contributions have been in statistical methodology he also publishes in statistics education where his major interest is in the ways in which statisticians think and how these thinking patterns might be passed on to students.

PANELS

Bridging: Mathematics Courses and Initiatives

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This panel discussion focuses on the nature of bridging mathematics courses and initiatives and the relationship between such courses and undergraduate mathematics. Descriptions of current practice over the last decade or two in three regions (Africa, Australia and New Zealand) will inform this discussion. Within these descriptions the panel members will develop a picture of the philosophical and educational frameworks which underpin the majority of bridging mathematics initiatives and discuss the role of bridging mathematics in undergraduate mathematics courses and in the development of academic numeracy across the university curriculum. The audience are asked to reflect on the following questions:

- * What is the difference between undergraduate mathematics and bridging mathematics?
- * What is the relationship between bridging mathematics and basic numeracy?
- * What mathematical needs do bridging mathematics students have?
- * What role is, and could, technology play in bridging mathematics?
- * Do bridging mathematics courses need to be separate or can such courses be integrated into mainstream undergraduate mathematics courses?

Statistics: Vital Components of Statistics Education

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Statistics draws on a range of ideas and these need to be reflected in education. The panel will present some of these vital components, including

- the need for geometry in the mathematics curriculum
- the role of technology in statistics education
- student-centered investigations in service teaching

Participants are invited to contribute their own ‘vital components’.

Technology: Three times three on the three M's

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All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident.

Arthur Schopenhauer (1788 - 1860)

Use of technology in teaching undergraduate mathematics is progressing from the second to the third stage leaving the opposition behind dimly shouting in the distance. In many ways technology has been the inspiration for innovation in teaching and learning approaches. The three panel members will each address three questions on one of three modes of technology - on the micro, medium and macro levels. Mike will focus on CAS calculators, Bill will focus on software on PCs and Ansie will focus on the WEB. The three questions to be addressed are

- Why should you use it?
- How might you use it?
- What does the future hold?

Undergraduate: Teaching and Learning

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Matt and his team have adopted an 'all one-team' model of sharing resources, ideas and skills in their approach to the delivery of their large introductory statistics course: The result of this model, together with the use of technology, has helped them to provide students with multiple learning paths. Student reaction to this use of flexible delivery has been very positive.

Mathematical models form the basis of the teaching of mathematics at the University of Uruguay. Victor will cover several examples of mathematical models related to Mathematical Analysis, Laplace, Transform and Numerical Methods but the most interesting examples are connected with ODE. and PDE. models. These models are very important for students of Chemical Engineering and other related careers. Victor will comment on the results obtained with students over the last six years and discuss students' and teachers' comments and opinions.

Service teaching, or cross-disciplinary teaching, forms a large part of the work of a mathematics department. Leigh will report on a project that examined students' reactions to cross-faculty teaching.

To stimulate debate on ways in which we can build undergraduate mathematics for the future, Pat will raise 4 issues very briefly:

- innovative responses to curriculum design in the face of what Lynn Steen has termed a "revolution by stealth", including those raised at the 2003 ICIAM minisymposium;

- our responsibilities for and contribution to engineering mathematics, and problem-solving/project-based approaches, in particular;
- how and what we can learn from education research;
- building better partnerships with education and other disciplines: we are perceived by some as arrogant!

CONTRIBUTED TALKS

A New Approach to Distance Learning

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Many secondary schools have set up accelerated programmes, which allow exceptional students to take mathematics at a faster rate, often resulting in them sitting the Bursary Calculus paper in year 12. A problem then arises – what mathematics should these students be doing in their final year of school? Such students are also often offered direct entry into second year courses at University. Even for exceptional students, the difficulties they face in missing out the vital work in first year mathematics is very real and may cause lasting problems. The Department of Mathematics and Statistics at Canterbury has been successfully running a first year mathematics course for local secondary school students for the past six years. With funding from the University, the Department has now set up a course for schools outside the Christchurch area.

The key to the success of our Level 100 Distance Learning Course for Secondary School Students is the web-based programme **NetTutor**. This programme is designed principally for *communicating* mathematics. It enables students to work directly with the lecturer in *real time* via a “whiteboard” which contains the specialised symbols that mathematics requires.

In this talk I will discuss the development of our distance course, the issues and resources (including human ones!) involved in running it, and the problems associated with distance learning and how NetTutor has largely overcome these.

Students’ Derivations of Modelling Functions Based on Numerical Patterns of Rates of Changes

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The presentation will report findings from a research study which examined undergraduate students’ strategies for deriving modelling functions from numerical patterns with rates of changes in contrast to the equation-graph matching approach prevalent in schools. Students involved were final year mathematics undergraduate students some of whom were practising teachers of mathematics or were intending to teach. Students had already examined the cases of linear, quadratic, cubic and some exponential functions and were requested to extend their projects to quartics, other exponential functions and a trigonometric (sine or cosine) or logarithmic function. The presentation will discuss similarities and differences between students’ strategies for deriving quartic, exponential, logarithmic and trigonometric modelling functions. It will also offer some implications for enhancing the teaching and learning of functions and limits at all levels.

Experience with Texas Style Topology

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Students often don't get the chance to do mathematics for themselves. This talk reports on the experience of a "Texas Style" course in Topology for honours students at the University of Canterbury. They worked as a group through material (Definitions, Examples and Propositions similar to basic textbook material) and practised finding their own proofs and explanations. They discovered the proofs themselves. Textbooks were forbidden. Students took turns presenting and writing up the material.

The Transition to Mathematics at University: Students' Views

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The purpose of this research study is to investigate barriers that inhibit improved outcomes in the teaching and learning of mathematics for students making the transition from high school to university. By improved outcomes, we wish to see students with a more autonomous learning style, encourage independent thinking and be better versed in "problem solving". The student population in stage 1 mathematics courses at the University of Canterbury is large and diverse. Many students, 85% in our target group, have declared majors outside mathematics. For these students, mathematics is seen as a service course. In general, many of these students are only prepared to give a minimal amount of time to studying mathematics. However, as mathematicians, we also want to maintain the integrity of mathematics in the courses taught.

For most students, their experiences at high school could fairly be described as surface learning. Whilst many students see the value in a deeper approach to learning, they, for various reasons, remain wedded to a surface approach at university. In order to gain some insight into these reasons and to formulate an approach to the mathematics curriculum that might encourage a deeper learning experience, first year students were surveyed twice, at the beginning of the year and at the beginning of the second semester, on their beliefs about the teaching and learning of mathematics. The results of these questionnaires and the students' performance in the Bursary Calculus paper and the two in-term tests during the course are used as a basis for this study.

The Mismatch Between the Theory and Practice of Outcomes Based Education at Tertiary Level: Training Pre-Service Mathematics Teachers

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Two fundamental components in the training of pre-service mathematics teachers are: the subject content of mathematics and the methodology of how to teach mathematics. Is it possible that the presentation of these two components could contradict each other resulting in students making little attempt to adopt any new or alternative approaches to teaching mathematics? For example, if the methodology that is being used to present the subject content to the students is not modelling the methodology being taught to the students in training them to teach mathematics, does this affect their ability or willingness to try new approaches? Is it viable to expect pre-service teachers to adopt a learner-centred, outcomes-based approach to teaching mathematics if their own experience of learning mathematics is limited to a more traditional "chalk and talk" approach, even at a tertiary level? This paper discusses the experiences of some second year education students at a university in South Africa in the light of these questions. The students are enrolled for a second year general mathematics content course and this is supplemented by a methodology course. The courses are being presented by two different lecturers who apply unlike angles in their approaches to teaching. The content course is presented in a predominantly lecturing style with the use of a textbook and mainly summative assessment through testing. The methodology course takes a principally interactive approach and makes use of continuous formative assessment with no final exam. This paper seeks to explore and identify the impact of these two different approaches on the

development of the mathematics teaching style of the students involved. The paper does not set out to prove that one approach or course is better than the other or to evaluate the two lecturers. It serves rather as a basis for further investigation into the potential value of modelling a desired methodology of teaching mathematics within the teaching of the subject content course.

The LTSN Mathsteam Study 2003: Diagnostic Testing and Student Centred Support

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Funded by the Learning and Teaching Support Network (LTSN), the LTSN MathsTEAM project published three booklets in April 2003 as the culmination of its work. These booklets are called:

Diagnostic Testing for Maths. ISBN 07044 23731.

Maths Support for Students. ISBN 07044 27358.

Maths for Engineering and Science. ISBN 07044 2374X.

These each contain some 20 case studies contributing to the transfer of knowledge within the higher education community in the United Kingdom. Each case study offers practical suggestions from academics to gain a better understanding of the national state of affairs in mathematics at the school-university interface and the common purpose part of degrees in which mathematics plays a key role. Related topics that deserve further exploration and research are also discussed. The booklets are highly accessible, broadly readable within an hour or two in total, and give a close insight into the current process of induction of students into UK undergraduate programmes in science and engineering. In each booklet the authors talk about the barriers and enablers in setting up different learning initiatives. For those academics considering the implementation of any of the programmes, each case study provides the opportunity of reviewing the learning processes and tools.

The website/url for the MathsTEAM project is at: <http://www.ltsn.ac.uk/mathsteam>

“A Fiercely Held Modesty”: The Experiences Of Women Studying Mathematics

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This paper draws on a study of young women's experiences of studying undergraduate mathematics. We briefly introduce the work, and reflect on some of the theoretical and methodological questions that arose for us. We then present some interview data and argue that, although individual women's responses are distinctive, there are nonetheless a number of common threads in their narratives and these relate to a difficulty in acknowledging their successes. We suggest that dominant discourses around mathematical attainment make it hard for these women to position themselves as 'mathematicians'.

Language Issues in Undergraduate Mathematics: A Report of two Studies

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The dynamics of learning mathematics in English when it is not the learner's first language are not fully understood. In many English-speaking countries there are large numbers of students studying mathematics at tertiary level who have English as an additional language (EAL). As a step towards addressing their needs, an indicative study of eighty first year undergraduate mathematics students at Auckland University was undertaken at the beginning of 2003. It indicated that in comparison with native speakers of English, EAL students experience a 10% disadvantage in overall performance through lack of understanding mathematical text. It also indicated that technical mathematical discourse is less well understood than general English; that EAL students who have studied mathematics in English for more than six years still experience disadvantage; and that EAL students rely on symbolic modes to make up for textual disadvantages, but that this is a false reliance as they do not perform well in this mode.

This paper briefly reports on the preliminary study, but also reports on a follow-up study that is being undertaken in Semester 2, 2003. In this study a large number of first year L1 and EAL students will be given examination-type questions in two forms, one expressed in general English, the other in technical English. The technical form will exemplify two specific forms of mathematical discourse that have been identified in the literature. Students will be asked to report details of their language background, and their level of understanding of the question, as well as to show working for their attempted answers. It is expected that the results will allow statistically significant confirmation (or otherwise) of the results of the initial study, and some initial information about the impact of specific discourse features.

Geometry Of Surfaces Using Maple

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Maple is being used to fundamentally change the teaching, learning and assessment paradigm for a third year mathematics subject for geospatial science students (surveyors) from the traditional lecture mode of two lectures per week to a lecture plus computing laboratory "practical" mode. This is a very classical differential geometry "geometry of surfaces" subject which supports the study of geodesy. The content of the subject includes space curves (the Frenet apparatus), quadric surfaces (parameterization and plots), the metric tensor components (the first fundamental form, length, area and angles), the second fundamental form and the classification of shape of a surface, normal curvature, principal directions and curvature, the contravariant metric tensor, the Christoffel symbols and geodesics. All the Maple worksheets used have been developed by the author. Maple is used to do numerical computation, plot graphs and do exact symbolic manipulations and word processing. The lectures are also (mostly) presented using Maple. This is an immersion course where all student computation is done using Maple – the examination (presented as a Maple file and in hardcopy) is conducted in the computer laboratory and the Maple files are submitted as the students' responses. The examination is marked from the electronic responses (without printing out the files). This course has been run for many years, with the first computing laboratory version introduced in 1998 using Mathematica. However, since we have a site licence for Maple, the course has been rewritten and developed using Maple since 1999. Using the computing laboratory as an integral part of their course is new, educationally effective and ENJOYABLE for the students and for the staff.

Artistic Mathematics - Mathematical Art

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In my work as teacher at a Secondary School, as a lecturer at the Vienna Technical University (pre-service training for ongoing maths-teachers) and at many occasions during in-service training courses for teachers I have met the experience that addressing the esthetic feeling of the audience initiates a high motivation for doing mathematics. Examples cover exploring the system of coordinates, working with elementary functions and parameters to create variable figures, applying Boolean expressions for describing and creating patterns, finding the mathematical backgrounds of architectural designs (gothic windows, etc), up to generating paintings in the complex plane and designing 3D-objects. I found that I could seduce even weak and mathematics refusing students to increase their attitude for this subject.

New Forms of Teaching Provoke and Require New Forms of Assessment

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Within the 3rd Austrian CAS-project, one project group focused on new forms of assessment. New ways of teaching mathematics using modern technologies like graphing and symbolic calculators and CAS-programs do not only require a new “culture of examples and problems” but as a consequence provoke new forms of assessment to overcome traditional habits.

Among others we tested split assessments (basic knowledge and problem solving), performed group assessments, and experimented with various forms of oral presentations.

The project group consisted of several classes of upper secondary level (age 16-18). It is our opinion that some of our ideas could and should be tested also on college and university entrance level.

The project was evaluated by an independent academic authority, the CENTER FOR SCHOOL DEVELOPMENT. Results of this fascinating project will be presented.

Multiplicative Thinking: Procedural Rather than Conceptual Knowledge as a Source of Difficulties for Teachers and their Students

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Multiplicative thinking and the fraction and ratio ideas that grow out of it are the key to the development of mathematical ideas in the secondary school and in tertiary study. Yet research in Australia, New Zealand and elsewhere suggests that many students are not gaining these ideas in the middle years of schooling and are consequently avoiding or failing the more advanced mathematics courses in the latter years of high school. Research has also suggested that inadequate conceptual and content knowledge in middle year teachers may be a contributing factor. This paper reports on the difficulties experienced by undergraduate students taking a foundational mathematics education course that provides a major focus on conceptual, practical and theoretical investigations of multiplication, common fractions, decimal fractions and proportional thinking. Despite entering the course with very high tertiary entrance scores, many students express concern at their lack of ability in these areas (and the related notion of division) and carry with them misconceptions and errors that are very difficult to overcome. These students often have a procedural rather than a conceptual view of mathematics, believing that mathematics is a body of rules that simply need to be memorised. Examples of persistent errors will be presented and analysed to show the underlying causes of these difficulties, such as confusion among their 'rules' or generalisations of ways of operating into domains where they no longer apply, and the way in which they inhibit the development of more advanced mathematical thinking. If teachers of students in the middle years carry such limited understanding with them to their teaching, students are likely to reflect that confusion in their own mathematical thinking.

Understanding What You are Doing: A New Angle on CAS?

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Powerful Computer Algebra Systems (CAS) are often used only with reluctance in early undergraduate mathematics teaching, partly because of concerns that they may not encourage students to understand what they are doing. In this exploratory study, a version of a CAS that has been designed for secondary school students was used, with a view to considering the value of this sort of student learning support for first year undergraduate students enrolled in degree programs other than mathematics. Workshops were designed to help students understand aspects of elementary symbolic manipulation, through use of the Algebra mode of an algebraic calculator, the Casio Algebra FX 2.0. The Algebra mode of this calculator allows a user to undertake elementary algebraic manipulation, routinely providing all intermediate results, in contrast to more powerful CAS software which usually provides simplified results only. The students were volunteers from an introductory level unit, designed to provide a bridge between school and university studies of mathematics and with a focus on algebra and calculus. The two structured workshop sessions focussed respectively on the solution of linear equations and on relationships between factorising and expanding; attention focussed on using the calculators as personal learning devices. Following the workshops, structured interviews were used to systematically record student reactions to the experience. As a result of the study, the paper offers advice on the merits of using algebraic calculators in this sort of way.

Using AcroTeX to Provide a Structured Learning Environment for Mathematics

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This paper reports the results of an investigation into the feasibility of creating interactive web-based material for a second year mathematics course

MATH2001 -- Vector Calculus and Complex Variables is a course designed for students with a broad range of interests. It is one of the basic analysis courses for mathematics and science students, in addition to being a service course for engineering students. The enrolment is typically around 700 students, some of whom benefit from being able to gain easy access to those ideas from first year calculus and algebra courses that are assumed knowledge for MATH2001. Given the size of the class, the provision of online material seemed a practical way to offer such additional assistance. We wanted to link any new material to the existing course material, which included comprehensive lecture notes, exercises and solutions, the source files of which are in LaTeX.

We report on our search for a suitable tool with which to do this, and give reasons for our eventual decision to use AcroTeX. Using AcroTeX, we have produced solutions to tutorial exercises that are hyperlinked pdf files. In these solutions, whenever a step depends on some concept covered in previous work, there is a link to an explanation of that concept. This material can be viewed from <http://www.maths.usyd.edu.au/u/UG/IM/MATH2001/>

Our investigation also included an extensive survey of existing web sites, since we were interested in whether any existing material would be useful for our students. The results of this survey are presented. We have included a number of sites that are useful for undergraduate mathematics students in general, as well as those particularly relevant to students of vector calculus and complex variables.

Experiences in Teaching a Scientific Computation Course with Matlab

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Modern software tools such as MATLAB provide both basic programming facilities and sophisticated functions that allow the teaching of scientific computational skills. The challenge is thus to teach these skills to students with poor programming backgrounds. A course in computation and modelling using MATLAB was introduced in the engineering intermediate year. It is to be complemented by a further course at the first professional year. A second year MATLAB course is also running. The whole MATLAB programme is in the process of being rationalised. This programme will necessitate the development of instructional methods that effectively involve large classes of students in problem solving techniques encompassing decision making, transforming a problem into a model and thence into a computer process to provide solutions. A knowledge of numerical methods together with appreciation of floating-point arithmetic and associated computational error will be involved. One aim of the MATLAB courses is to make students technologically capable. In terms of the various education taxonomies, the course seeks to provide a student with a process to encourage knowledge and understanding leading to a level of mastery that will enable application of the concepts in new and concrete situations. In essence the student is invited to construct, from given basics, an understanding of the methodologies involved in using MATLAB as a tool in scientific computation. The "MATLAB in Scientific Computation" course has run 5 times in the past 3 years including as a very concentrated summer course. The course is very intensive and whilst the basic structure has remained essentially the same in terms of being a lab based, hands-on, hierarchical

approach, the intimate involvement of the teaching staff in the course and the feedback obtained both verbally and by observation, has prompted changes in the instructional process.

Pastoral Care in Large Classes

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Recent enhancements in flexible modes of delivery in higher education have given academics involved in teaching large classes a greater choice of methods to promote more effective learning for their students. However, it is still difficult for the academic to give the personal attention to each student that can occur in smaller classes. In this paper we describe and evaluate a range of approaches that contribute to the provision of pastoral care for large groups of students. These include replacing standard mathematics tutorials in first-year classes with peer-assisted study sessions (PASS), where second-year students act as facilitators to encourage learning and which also promotes the development of friendships and networks in the small group setting. Such sessions have been popular in science and business but present new challenges in mathematics and statistics courses. We have also used software tools and data which provide easily accessible snapshots of the students. These snapshots include actual student photos as well as autobiographies written by the students at the start of the course, allowing the academic to build a comprehensive understanding of the class, as well as providing a specific personal backdrop for each student when responding to emails. Finally, we have looked at assessment items that encourage students to be personally involved in the course, such as free experimental work in a statistics course, reflective journals, and poetry writing. Combining these different approaches has led to a unified community of students with which the academic can interact on a personal level.

Some Experiences with Teaching Large Classes

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This paper addresses some problems faced when teaching large service courses such as 1,200 students in a stage one statistics course. Some of the issues discussed are the problems of finding sufficient space for students in spite of streaming, keeping the streams aligned, and catering for the diversity of interest and capabilities of the students. The large numbers enrolled necessitates streaming. Previously, overcrowding during the first few lectures of the year was ignored as, overall, seating was sufficient. This is no longer true and videoing of lectures is now used to supplement the streams. The videos have proved popular and so we plan to keep CDs of these in the library. To keep the streams parallel, we use the same day and lecturer for the three repeated lectures and use pre-prepared overheads and power-point presentations. Since financial considerations make us accept students with insufficient background, we often have to cater for students with a wide level of preparedness. Regular tutorials and assignments are given but recently introduced "consultation" or "drop-in" sessions are proving to be immensely popular. Self-test quizzes on WebCT have been added as a means for students to assess their grasp of the subject. Putting course notes on the Web before the lecture helps overcome the problem many have with copying notes. A work-book containing all the year's tutorials and assignments, and a CD of other course material including lessons and tests of the background material that students are expected to know is planned for next year. A small token mark ($\frac{1}{2}\%$ of final grade) is given for attendance at tutorials and this is making a difference to tutorial attendance. Excel has been chosen as the computer software for the course; special optional tutorial sessions for Excel are held at the beginning of the year.

Transition from Secondary to Tertiary Education in Mathematics – Strategies that Work

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The ‘gap’ between secondary and tertiary education in mathematics is a complex phenomenon covering a vast array of issues. Attempts to resolve certain problems lead researchers to the very core questions on the nature of mathematics and its role in today’s society. Although mathematics in elementary and high school has a special position compared to other subjects (e.g., most time and energy devoted to planning and teaching), the knowledge and skills of incoming university students do not echo this fact. University teachers have witnessed a decline in their students’ algebraic proficiency, and also in their computational, numeric and problem-solving skills. In high schools, geometry is given little attention, logical thinking is not emphasized, and the idea of mathematics as a rigorous discipline is usually ignored. Students coming to university are more numerous and more diverse; they have different views of mathematics and its role in their future career. University teachers are, mostly, unaware of (or unwilling to accept) the magnitude of these changes. In this interactive session we plan to discuss a rough outline of a new international project focused on the transition. Developing an overall philosophy and understanding of what mathematics is, the project aims to analyse the dynamics of the process of the transition from various perspectives (high school teachers, university teachers, students, and researchers). It will identify and study relevant issues and analyse best international practices, in order to develop strategies for effective dealing with the transition. Special features of the project include active participation of all groups involved, its comprehensive character and international nature (expected 40-50 countries from all continents). We plan to produce and disseminate, in various forms, detailed, workable and tested recommendations, suggestions, and ideas. Among the goals, the creation of productive interfaces between secondary and tertiary teachers tops the list.

Mathematics, Computers, and Umbilical Chords

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Recent research within a technology-enriched first-year Australian Algebra and Calculus course has revealed that while some early undergraduate students are quite strongly empowered by the use of technology, others are clearly not, and that it is difficult to predict the nature and levels of their use of technology. This report summarises some aspects of data gathered in 2001 and 2003, which identified a range of factors as poor predictors of the nature and level of their use of technology when doing mathematics. Attitude factors that demonstrated no significant relationship with their levels of use of technology when doing mathematics included students’ computer confidence levels, their mathematics confidence levels, and their professed attitudes towards the use of technology in the learning of mathematics. Experience and behaviour factors included their prior use of technology when doing mathematics, their levels of engagement in weekly technology tasks over the

semester, and their class attendance. Proficiency factors included their mathematics grade prior to entry to the course, and their grade on an exit examination. The latter yielded a significant but weak correlation. These trends emerged under different conditions: within a group of 29 students doing non-test voluntary late in the semester, and under more pressured conditions in a mid-semester test for 109 students two years later. Of particular interest are those students who made little use of technology despite professing positive attitudes, and otherwise engaging conscientiously in technology tasks regularly over the semester. We raise questions on the reasons for their preference for hand methods. Are some students' prior learning habits and experiences like umbilical chords? Do they hinder their assimilation of new cultures of learning and practice?

Seriously Teaching Mathematics is not Teaching Seriously...For All Those Serious University Students.

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Mathematics can be taught with fun at any stage, not just at kindergarten and primary school. Through my action research, I have attempted to employ kindergarten-learning strategies into tertiary education. In the formative years of kindergarten, learning happened without the recognition of the skills being used. Will sending them back to kindergarten advance their university degree? It seems socially acceptable, even fashionable, to lack any mathematical skills yet still hold the esteem of your peers. The role of the lecturer is changing from a conveyer of information to a distributor of learning strategies and knowledge on the chosen topic. Recognition of differences between the espoused theory and the theory-in-use with relevance to the education of mathematics will aid both delivery and reception of the topic. We explore the cognitive skills of the non-mathematical undergraduate participating in the basic mathematics course. Do we need to revamp the status of mathematics by taking the serious overtones out and bringing in the fresh colours?

Development of Effective Learning Materials for the Mathematics Learning Centre

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This paper seeks to explore issues inherent in the development of effective learning materials for the Mathematics Learning Centre (MLC) at Central Queensland University (CQU) and the manner in which these issues have been addressed by the MLC. It also presents a number of guiding principles for the design and development of learning materials used by the MLC. As many adult students access the services and resources of the MLC, an understanding of the principles of adult learning is integral to this study in order to critique their application within this educational context. The MLC is a support unit which provides assistance to students experiencing difficulty with the mathematics or the quantitative component of their course at Central Queensland University. The MLC also offers a range of preparatory and bridging courses in mathematics for enrolled and enrolling students undertaking course work, with a mathematical component.

Experience of Undergraduate Teaching of Mathematics in France

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Over the last 20 years the volume of mathematics in secondary schools has been shrinking and the programs have been reducing the abstraction level. Therefore university teachers are confronted with the decrease of the level of preparation and mathematical maturity. Moreover the number of students who choose science has been plummeting dramatically. Ways of dealing with the situation will be presented.

Rationale For Collaborative Learning In First Year Engineering Mathematics

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Research into tertiary students' first year experience in Australia has focused on the extent to which students adapt to university and their levels of satisfaction, how students adjust to the larger social setting, and issues of transition from school to university, especially approaches to learning. The development of performance indicators has involved the widespread introduction of direct measures of student evaluation of the quality of teaching. Few studies have addressed the relationship between the effectiveness of the learning experience and the broader factors that contribute to student satisfaction or to learning outcomes. The learning of mathematics is often viewed as an isolated, individualistic matter where one sits alone and struggles to understand the material and concepts at hand. This process can often be lonely and frustrating. Small-group collaborative learning can provide an alternative to both traditional whole-class expository instruction and individual instruction systems. This paper will provide a rationale for the integration of collaborative learning into first year engineering mathematics learning and instruction based on a review of international and Australian literature. It is argued that despite an overwhelming acceptance of collaborative learning among researchers and educational organisations, this strategy is not very frequently adopted and used at tertiary level in mathematics. We believe that collaborative learning is an ideal way to help with the transition to engineering mathematics at university from both a social and academic view. It could reduce the large attrition rate in these courses and improve attitudes to engineering teaching and learning.

Online Assessment In Mathematics: Multiple Assessment Formats

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Questions used for assessment can be classified into two broad categories – Provided Response Questions (PRQs) and Constructed Response Questions (CRQs). Issues surrounding the two question types, such as the guessing factor and the enforcement of misconceptions through the choice of distracters for PRQs and the lack of partial credit for online CRQs in general, are discussed. The paper also deals with concerns relating to the two question types, both from the teacher and the student's perspective, as well as student preferences and response strategies. Two comparisons based on test data collected over a number of years, are conducted. The first comparison deals with student performance in online PRQs versus performance in online CRQs. The second comparison is on student performance in online CRQs versus performance in paper CRQs. The contribution of partial credit, a feature mostly lacking in online quizzes, is quantified from the collected data.

Postanalysis of Numerical Solutions to ODEs

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Once one obtains a numerical solution to an ordinary differential equation, how does one have confidence in this solution? Is it an approximation to the exact solution or is it algorithmic rubbish? We give two simple procedures that can help raise one's confidence levels. One is based upon comparing solutions obtained at different precisions, presumably, the higher the precision, the more accurate the solution. The second simple

procedure is that of calculating the residual associated with the solution. Plots of the residual yield both global and local information and can indicate where numerical difficulties lie. We demonstrate this through the examination of known numerically difficult examples.

Adopting a Learner-Centred Focus with Online Delivery of Service Mathematics

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With the advantage of hindsight, the comparison drawn by James Kaput in 1992, likening the task of describing the role of technology in mathematics education to that of attempting to describe a newly active volcano, appears an astute observation. His statement acknowledges the pressure that advances in technology exert as they move to drive education and the discipline of mathematics from outside and simultaneously act to support learning from within. This paper discusses a role for technology in mathematics education that few writers foresaw at the end of last century, that is, through the World Wide Web to offer online delivery of mathematics in environments that centre on the individual learner and their needs. The case for online delivery as a medium that adopts a learner-centred focus is put forward. A recent move to develop such an environment for a level-one business mathematics course at Central Queensland University will be at the core of the discussion and it will be maintained that the creation of such a learning environment offers individual mathematics learners opportunities for understanding above and beyond those offered through traditional media.

Study Context, Ethnicity and Approaches to Study Among Tertiary Mathematics Students

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Approaches to study among tertiary mathematics students were examined, using an instrument intended to reflect depth of approach in mathematics learning more accurately than established instruments do, because these instruments often specify a deep approach in ways more suited to the humanities and social sciences. Scales dealing with active study methods, intrinsic motivation, confidence and anxiety were constructed for this purpose. High scores indicated approaches hypothesised as favourable. Since more males than females still enrol in science and engineering, a scale about anticipated future use of mathematics was included, and women's and men's results were separated. A previous section of the work had found that, among Australian students, a deep approach could be identified, which correlated significantly with achievement. The present section focussed on overseas students in Australian universities, who are under very strong pressure to succeed, because of the high cost of their studies. Most of these students come from South East Asia. Their approaches to studying were compared with those of two Australian groups, in the same mathematics classes, formed by separating out those of Asian background. In comparisons of scale means, eight of ten results were significant, but scores for the group consisting of Australians of Asian background were never significantly different from those of either of the other two groups. In the significant results, overseas students' means were highest, except that the men reported less freedom from anxiety. The pattern indicates that it is not justifiable to ascribe the significant differences to cultural background without considering the contextual pressures associated with overseas study. Multiple correlations between scale scores and achievement also showed different patterns. Among overseas students, the approach best associated with achievement was dominated by active study methods, confidence, and low anxiety, whereas among the Australian group, intrinsic motivation replaced active study methods in importance.

Helping Engineers Learn Mathematics – The HELM Project

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The HELM project is a novel, major attempt to ensure that the Engineering Council's requirements of a high level of mathematical knowledge and skills are met. The project is supported by a £250,000 HEFCE- FDTL4 grant for the period Oct 2002-Sept 2005. The project team consists of staff at Loughborough and four consortium partners: Hull, Reading, Sunderland and UMIST. Another 20 HEIs in the UK are involved with trialling materials and supplying engineering examples. The aim is to enhance and extend Loughborough's successful Mathematics Open Learning materials, in particular by incorporating engineering exercises and case studies closely related to the mathematics presented. The output will consist of Workbooks, some CAL segments and a CAA assessment regime. The emphasis is on flexibility – the work can be undertaken as private study, distance learning or can be teacher-led, or a combination, according to the preferred learning style of the student and the approach of the particular lecturer.

The workshop session at DELTA '03 will give delegates the opportunity to assess and discuss the potential of the project deliverables and the assessment regime, provide feedback and possibly form links with the project for the future.

An Interesting Diffusion Problem From Four Different Angles

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Drying process of several plants in Food Technology Engineering, provides a source of interesting mathematical problems. An example of this kind of problems comes from industrialization of Chive (also called Ciboulette), which is used in typical dishes around the world. From a mathematical viewpoint, this is a diffusion process that can be modelled by a parabolic P.D.E., in Cylindrical or Cartesian Coordinates, depending on the drying conditions. On the other hand, the problem can be solved by analytical or numerical methods. By combining geometrical approaches and solution methods it is possible to obtain four different versions and then release them to the students. These four possibilities show a wide range of mathematical tools, like Fourier Series, Bessel Functions, Numerical Methods for parabolic P.D.Es., etc., in a motivating context for Engineering students. Simplified versions of these problems were proposed to the students at the Universidad de la Republica, in Montevideo, Uruguay, with excellent results. In fact, they reacted positively to this kind of motivating problem as it was shown in several previous papers using statistical techniques. In this paper the educational possibilities of this problem (in the four versions already mentioned) are analysed. Finally, several conclusions and recommendations are suggested based on the statistical results obtained in the last eight years.

Maple Labs: Calculus from all Angles

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One of the guiding principles of the calculus reform movement has been the idea of multiple representations, especially as captured in the Rule of Four: where appropriate, topics should be presented geometrically, numerically, analytically and verbally. In this paper I shall describe an attempt to apply this idea in the context of laboratory sessions where a computer algebra system (Maple) is used to encourage learning about advanced calculus. As an example I shall discuss a lab session about solutions to second order linear differential equations with constant coefficients. In this context, geometric and analytic representations are supplied by Maple's plotting and solving routines, physical representations come from the students' experience of damped spring systems and simple RLC electrical circuits, and verbal representations come from the natural dialogue occurring between lab partners working on the same computer. The availability of different representations means that students can generate expectations (from a familiar representation) which can then be used to check conclusions (derived from an unfamiliar representation). The interplay of ideas deepens the students' understanding, not just of the mathematics of the differential equations, but also of the physical systems which these equations have been used to model.

Combining Online and Paper Assessment in a Web-Course in Mathematics

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Online assessment in mathematics is becoming more prominent as mathematics and the internet become more compatible. The immediate issues are why one should venture into online assessment and how best to do it. Other issues include whether traditional paper assessment can be totally replaced by online assessment, whether standards can be maintained while doing online assessment and to what extent an appropriate combination of paper and online assessment could provide for various learning styles. We address these issues from a background of having been involved in teaching online mathematics courses for the last four years.

Reform calculus – Yesterday, Today and Tomorrow

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Reform movements in mathematics have been with us for almost as long as civilisation itself. The parody of Heraclitus (circa 500 BC) "the only thing that remains constant is change itself", reminds us that the ways we do and teach mathematics will continue to be reformed. It is crucial, and probably inevitable, that this reform will lead us forwards, not backwards. The current calculus reform ideas are a response to the profound influences of computing technology in the mathematical toolkit of mathematicians, scientists, technologists, teachers, and students. Along with other reforms, calculus reform enables us to do mathematics differently with subsequent changes in the pedagogy of the way mathematics is learned. In this paper, an attempt is made to view the current state of calculus reform as the outcome of a long history of the development of mathematical concepts, technologies, clever ideas, and smart teaching methods. The historical development of algebraic techniques has had a major influence on these changes, and the way we model and solve problems in the future

will require ongoing developments in algebraic structures and the way we do algebra. Some forecasts are made in this direction.

Mathematics With MAPLE: Arithmetic Through Linear Algebra

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This workshop will consist of a hands-on, guided tour through the materials developed by this author for a capstone, technology-based course for mathematics majors preparing to teach mathematics at the high school level (grades 9-12, ages 15-18). The author first presented the course in the fall of 1995, it has been offered every fall and every even numbered summer since, with the materials being revised for each offering. A description of the development of the course and its' progression through the fall of 1999 is contained in our article "The Use of a Computer Algebra System in Capstone Mathematics Courses for Undergraduate Mathematics Majors" appearing in *The International Journal of Computer Algebra in Mathematics Education* [Vol 7, no 1 (2000), pages 33-62]. The materials consist of a series of MAPLE worksheets and practice quizzes covering topics from arithmetic, elementary number theory, analytic geometry, calculus, and linear algebra. It will be assumed that the participants are familiar with all these topics to the extent they are taught at the undergraduate level; however, participants will not need to be familiar with MAPLE in that all required syntax will be developed as part of the worksheets. Working in teams, participants will experience a variety of methods for using MAPLE as a demonstration and learning tool in a variety of subject areas. And each participant will be given a copy of all the course materials, including sample exams.

College Mathematics For Elementary School Teachers: A Model Program

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We will describe a three-course, nine semester-hour mathematics course sequence required of all students at our university who are seeking state certification to teach in elementary school (grades K-8, ages 5-14). Our requirement went into effect in the fall of 1995 and was described in some detail in an article titled "The Nine-Hour Mathematics Sequence For the General Pre-Service Elementary Teacher at Texas Tech University" appearing in *PRIMUS*, [Volume VII, no 4, (1997) pages 341-36]. First, we will reiterate why we believe such a sequence is needed and provide a brief review of the development and implementation of our sequence. Then we will attempt to assess the overall impact of our program from its inception in 1995 to the present (fall 2003). We will do this by analysing both quantitative and qualitative data obtained from student records, student course evaluations, and interviews with both students and faculty involved with the sequence during this time period.

Mathematics with Maple: Arithmetic Through Linear Algebra

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Mathematics as an Application Tool – Studying Mathematics and Statistics in Context

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This is a report into an action research study in a Bridging Mathematics course in which students learn to use mathematics and statistics as a tool. The students begin with inadequate mathematical and statistical understandings to successfully complete their other mainstream degree papers which they are studying concurrently. The aim is to empower the students to be able to use and apply their mathematical knowledge in other subjects and circumstances. To succeed in this they need the ability to connect and link mathematical ideas and topics, and to build up a coherent mathematical structure, which makes sense to them. They also need the confidence to use mathematics and the ability to recognise appropriate mathematical or statistical tools to use.

Methods used involve questioning them so as to assess their level of mathematical understanding and then, with them, together build on the foundation of what they already know to a position where they can understand and succeed at the course. Frequently the first task is to open doors for students by removing fear of mathematics. Often students with similar needs and starting points can be grouped. The collaborative discussion possible when working together in groups on a problem has frequently been found to be a source of permanent learning as well as positive feelings of success. The tutor's input is that of a facilitator, probing and questioning when the group are stuck or digressing from the problem; challenging misconceptions and thinking; and guiding direction with links to other knowledge of the student. The course is taught mainly through contextual problems and has been successful for a large number of students.

Is There Such a Thing as a Perfect Mathematics Tutorial?

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The efficacy of mathematics lectures as learning experiences has long been questioned. In contrast, mathematics tutorials are widely seen, by both students and academics, as useful to the learning process. At the University of Sydney, more than 150 tutorials are conducted each week in first year mathematics courses. Approximately half of these are taken by casual tutors (generally postgraduate students). Student surveys over many years have consistently shown that students regard tutorials as valuable, and tutorials are often rated as the most important aspect of the teaching and learning process. Nevertheless, anecdotal evidence suggests that the teaching in tutorials is not always exemplary. At the beginning of 2002 we embarked on a program to improve the teaching of casual tutors in tutorials. The program involved training sessions and mentoring of casual tutors by experienced staff members. In order to inform the development of this program we surveyed more than 1000 first year students, and ran several focus groups. Students were asked to comment on various aspects of tutorials, and to suggest improvements. An analysis of the data indicates very strongly that students have a wide variety of preferred learning styles. Some interesting differences of opinion between advanced and normal students, and between males and females were also apparent. We have also canvassed the views of academics and casual tutors on what makes a tutorial successful. Not surprisingly, perhaps, the views of students and academics do not always coincide. This paper reports some of the more interesting results of the survey, and discusses whether or not it is possible to provide a learning experience which pleases everyone.

Supporting Good Practice in Assessment

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In 2001 the Learning and Teaching Support Network Generic Centre (Generic-LTSN) in the UK published a generic resource pack called *Assessment Series* comprising a collection of 12 booklets. There are Guides for Senior Managers, Heads of Department, Lecturers and Students and 8 booklets on topics such as plagiarism. These are available for free download from <http://www.ltsn.ac.uk/genericcentre/>.

The Mathematics, Statistics and Operational Research LTSN (MSOR-LTSN) in the UK commissioned us to write a similar set of articles on *Supporting Good Practice in Assessment of Mathematics, Statistics and Operational Research*. These are a commentary on the generic series, which selects and expands these ideas and is written specifically for the Mathematical Sciences community.

There are three booklets: A Guides for Lecturers (particularly those new to university teaching), and a Guide for Heads of Department; A Guide for Students; Seven essays dealing with: Key Concepts in Assessment, The Assessment of Key Skills, The Assessment of Portfolios, The Assessment of Large Groups, The Assessment of Work Based Learning, Self, Peer and Group Assessment and Plagiarism.

This paper approaches undergraduate mathematics teaching from the angle of assessment. It describes the MSOR booklets in more detail and gives some examples from the texts. For example, the Guide for Lecturers stresses the necessity to connect assessment methods with learning outcomes (LOs); it includes guidance on writing LOs and provides suggestions for methods of assessment that are appropriate for particular LOs. The Guide for Students explains why assessment is so important, that students should observe that LOs include skills, not just facts, describes the purposes of different modes of assessment and gives tips on preparing for assessment. The paper also gives a commentary on our writing, providing a rationale and indicating the pedagogical issues involved.

Conceptests: Active Learning in Calculus

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Conceptests—a powerful tool for improving student learning—were originally developed by Eric Mazur at Harvard to teach introductory physics. They were subsequently adopted in chemistry and biology. ConceptTests are now available for calculus, where they have shown the same impressive results. The talk will describe what a Conceptest is, how they came into being and how they are used. (Copies will be available for participants.) The pedagogy underlying Conceptests is active learning and peer-instruction. These have proved effective in many contexts, particularly for non-traditional students who do not learn as well in a passive lecture format. The research data showing the effectiveness of Conceptests in calculus will be presented.

An Affordable, Realistic Student Model of a Motor-Vehicle Suspension System

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A realistic model of the suspension system of a motor vehicle should incorporate the tyre as part of the system. Indeed, the tyre can be regarded as a “spring” coupled to the suspension spring. It is well known that the following ODE models the movement of a mass attached to a linear spring: $m(d^2x/dt^2) + \gamma(dx/dt) + kx = F(t)$. Here the attached mass m has displacement x in time t and undergoes a damping force $F_d = \gamma(dx/dt)$ where dx/dt is the velocity of m , k is a "Hooke's law" spring constant, γ is a viscous damping coefficient and $F(t)$ is some impressed external force on the mass. For both of the springs involved here, it is easy to determine k by experiment. It is also easy to determine the coefficient of damping γ of a shock absorber in the suspension spring system. Indeed, take a shock absorber and pull it out at a constant speed v and measure the force F_d needed to do this. Because $F_d = \gamma v$, one can solve for γ . However, in order to measure the damping force of the "tyre spring", much more needs to be done. The solution to this problem turns out to be non-trivial, but well within the grasp of undergraduate students who have studied a first course in ODEs and have access to a computer algebra system (CAS). Gathering the data on the coefficients involved requires the following apparatus: a ruler, a vernier calliper, a motor vehicle with its jack, a bathroom scale and a stopwatch. Consequently, the data-gathering part of the experiment is almost cost free, a factor that many cash-strapped schools will appreciate!

Work Moments In Mathematical Modelling By Practising Mathematics Teachers With No Prior Experience Of Mathematical Modelling And Applications

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Theories and developments on practices; the sociology of scientific knowledge; knowledge-making as a local workbench activity and activity systems theory foreground the importance of the work setting in the production of knowledge artefacts. The common argument in underlying these theoretical orientations is that the operational setting structures the knowledge-making endeavour and the dependency of the agent on the setting is crucial in any knowledge-production activity.

Inspired by these theoretical orientations the “acts of making” a mathematical model by practising teachers with no prior experience of “the mathematical modelling way of working” in an in-service mathematics teacher education course was studied. This study is described and reflected upon in this paper. The description is organised around the concept of “work moments”. These work moments are the particular actions that are the focus of attention of the mathematical model-building activity at a given time. During the work actions, a table constructed by the participants played a crucial, mediating and guidance-given role. The work moments manifested in this study were:

- (i) shedding —starting but not continuing with a course of action because it is not, at the particular moment, deemed crucial for pursuance of the intended objective,
- (ii) compensation through environmentally-specific domain know-how —bringing to bear the ‘nearest’ information for data not supplied or deducible from the information being provided, and
- (iii) variation —trying different combinations of selected vectors to assist in deciding the best possible ‘model’.

It is concluded that the theoretical orientations alluded to in the opening paragraph provide mechanisms for nuanced analysis of teacher modelling work which is important for the design of appropriate programmes for

mathematics teachers in situations where mathematical modelling and applications was not part of their preservice mathematics education.

Learning Mathematics Through Oral Presentations

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We will present a project aiming at studying how to create an environment for peer learning, where students teach students, by making oral presentations of problem solving and theories in connection with the teaching of mathematics on the master of engineering programme at Campus Norrköping, Linköpings Universitet Sweden.

This project was designed to take the students through learning experiences involving the basic rules and tools of a good presentation in order to strengthen the students' understanding and perception of central mathematical concepts. By reflecting why the student has chosen to interpret and present a certain mathematical concept the way he has, he will gain deeper understanding and more qualified learning. The reward of this will be great when it comes to self-confidence and deeper and shared understanding.

We wanted to closely reflect how the environment should be created and designed for a more effective learning to take place in connection with these presentations. It seems that the focus had been more to go through with the presentation than to focus on the content. As the presentations are part of the assessment we wanted to produce a guide with tools for the teachers as well as for the students - tools that will be a support when creating the environment where the presentations take place in order to strengthen the students' understanding of central mathematical concepts and improve the oral presentations from a learning point of view.

Functions and Operators in MAPLE and MATLAB

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Some of the most distinctive features of computer algebra systems and numerical packages are their implementations of the concept of a function. When thoughtfully matched and integrated into the curriculum these realizations may be extremely helpful for the students' development of a multi-faceted concept image. On the other hand, thoughtless use of either kind of package may cause more confusion, more harm than good.

In this paper we contrast two major features. On one side are the overloaded definitions that make MATLAB so powerful, convenient, and beloved by the advanced user. Typical examples include the sine and reciprocal of a vector, the exponential (which?) of a matrix, and the division by a matrix, in particular, when it is not square. At a time when students are supposed to learn to distinguish different objects such as scalars and vectors, and different rules for algebraic operations among them, such overloaded functions are potentially hazardous - but when purposefully integrated, these features can facilitate learning to work with different algebras.

On the other side, both MAPLE and MATHEMATICA distinguish between pure functions and expressions. For the unprepared user this can be a nightmare, but when thoughtfully integrated, these features are wonderful aides to help students develop powerful ways of working with functions. We focus on the key operation of function composition (including taking inverses), derivatives f' without a need to name a variable (with respect to which the derivative is taken) as opposed to the usage in physics, and the next step towards differential operators.

The main objective of this talk is to develop an awareness for the consequences of choosing a specific technology, and both its hazards for curricular integrity as well as exciting opportunities to improve the curriculum.

A Qualitative Approach to Differential Equations with Dynamic Geometry

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The traditional teaching of differential equations is most of the time reduced to an algebraic approach consisting of solving the equation following a given algorithm. Previous research carried out fifteen years ago showed how a qualitative approach offers a complementary point of view contributing to the construction of meaning for the notion of solution of a differential equation of first order. But a qualitative approach requires the ability to move between the geometrical, the graphical and the algebraic settings: without solving the equations, it is possible to study the behaviour of its solutions by reasoning on the slope field and on the isoclines. Dynamic geometry renews the potential of a qualitative approach and even allows the design of new kind of tasks helping the students to learn the flexibility between settings. The talk will present and discuss these tasks as well as the behaviour of university students faced with those tasks.

Descartes Returned

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The idea is to show, based on historical examples in maths and physics, how geometry used to be central in supporting major scientific development (Descartes in his Optics, Newton and the universal gravitation, Durer and perspective drawing etc).

In a second part we will show why, later, geometry declined. And finally, how, today, with dynamic geometry systems like Cabri Geometry, we are back at a renewal of the power of geometry, as a "thinking" tool for students and teachers and as a modelling tool for engineers and others.

The Impact on Tertiary Statistics, IT and Other Areas of a Decade of Changes Across Mathematical Education.

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Changes across mathematics education in Australian schools since 1990 have been varied and extensive, with some intentional and others not. Details differ across the geographic and educational spectrum but the general effects are similar and also have at least partial analogies in similar education systems such as the UK. The focus on the effects of such changes tends to be on engineering and on tertiary mathematics itself, but there is a growing need for informed discussion of broader effects, both specific and generic. This paper aims to achieve a balanced and informed identification of the changes and their impact on broad areas but with particular reference to statistics and IT, and with constructive suggestions where possible.

Using History in Teaching

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This talk reflects on some efforts of using, when the proper occasion arises, a combination of history of mathematics and certain aspects of cultural importance to elucidate undergraduate teaching. The teaching of mathematics in South Africa at university level spans a period of about 130 years, while serious research in mathematics commenced about 80 years ago. The result is that very little local “history of mathematics” is available.

Local: At Stellenbosch University, we can tell the students of the first professor of mathematics, namely the Scotsman George Gordon, who died in August 30, 1882. Another Scottish mathematician, Thomas Muir, was the Superintendent-General of Education in the Cape Colony during the years 1892 – 1915. Of interest also are the artifacts found in the Western Cape, showing the counting processes of the early inhabitants of the area.

Real analysis: A short introduction to the early years of the Moscow School of Mathematics with its famous mathematicians and mutual ructions in the uncertain times of that period usually goes down well. The students usually find the so-called *Luzin Tree*, and the graves in the Novodevichii Cemetery interesting. Also of interest in the teaching of real analysis is the sojourn of Bolzano in Prague, his suspension, the fact that he was forbidden to publish, and his meetings with Cauchy in Prague, and pictures of the Bolzano House.

Discrete mathematics: The magic square on the Passion Façade of the Sagrada Família in Barcelona is a good starting point to discuss the theory of magic squares in general. This particular magic square has some connection with the *Dürer square* in the famous engraving *Melancholia* (1513).

Cultural break: The paintings of Tibaldi and Granello on the seven liberal arts (*Artes Liberales*) in the library of the Monastery of San Lorenzo near Madrid are usually well received.

Teachers Assessment: a Comparative Study with Neural Networks

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Specially on the university-level, considerable research has been done in the area of teacher’s assessment. Some of the studies focus on the diverse assessment strategies, and on different ways to obtain accurate results from carefully chosen questionnaires. The goal of most of these is to find the essential qualities of a teacher to be successful, in an attempt to formalize our knowledge in this area. As in many social studies, we sometimes crash with the difficulties of trying to formulate rules that should apply to human behaviour, which is beyond any doubt a complex domain to analyze.

According to this, an interesting approach has been done by some researchers, focusing on exemplary teachers, analyzing their performance and expertness, specially their exemplary practices. Most of these studies showed that it seems to be better to avoid experiments with no certain results, and that is preferable to adopt methods and practices learned from successful teachers.

In the case of our group, we used different approaches and different evaluation instruments. First, a descriptive study was made on this research line, later another study analyzing data with mathematical tools like Multivariate Analysis, and recently introducing a different approach with Artificial Neural Networks, specially Multi-layer Perceptrons and Hopfield ANNs, establishing a comparison among them.

As in other social areas, the use of non-linear computation like ANNs, is useful to detect anomalies, also to generate hypothetical scenarios. The increased knowledge that can be obtained this way, can later be used designing adequate questionnaires in order to minimize the evaluation error by measuring only the important teachers' qualities, also adopting planned policies of promotion, and discussing the results of the assessment with them, getting a constructive feed-back in a context of continuous improvement.

Mass Transfer: The Other Half Part of Parabolic P.D.E.

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Parabolic equations represent one of the most important topics in P.D.E. courses at undergraduate level. This kind of equations is usually presented in textbooks as Heat Transfer P.D.E. Nevertheless, Heat Transfer problems represent only half of the story. In fact, other diffusion problems (like Mass Transfer ones) also correspond to the same mathematical model. In this paper, several Mass Transfer problems are analysed, relating to Food Technology Engineering, air and water pollution, Chemical Engineering, etc. These problems are useful in order to present different mathematical topics like Cylindrical and Spherical Coordinates, Bessel Functions, Laplace Transform, Fourier Series, etc., in service courses for Engineering students. Their mathematical richness and educational possibilities are analysed in this paper, based on different experiences carried out in the last eight years at the Universidad de la Republica, in Montevideo, Uruguay. These experiences were developed in Chemical Engineering and Food Technology Engineering undergraduate courses, where simplified versions of Mass Transfer problems were proposed to the students. Results from educational viewpoints are noted and statistically analysed. Finally, several conclusions and recommendations are formulated taking into account all these experiences.

Cognitive Diagnosis of Algebra Errors

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Universities around the world continue to report declining levels of mathematical understanding (particularly in the domain of algebra) by students entering tertiary studies. Hence, many universities have introduced diagnostic tests and increasingly these are being conducted on-line. The task of ascribing causes to errors made in the performance of cognitive tasks is called cognitive diagnosis. Early research showed good results for tasks where only a single solution technique is available. One such system is DIAGNOSYS, which uses a hierarchical network of skills that represent the algebra domain. However the skills are broadly defined and if a student incorrectly answers a problem such as Factorise $(x+3y)^2 - y^2$, the system reports that the student has not mastered the skill "Factorise a Difference of Two Squares". Finer-grained diagnosis can only be achieved if the system has a means of identifying which solution technique the student adopted because different solution paths require different skills and hence expose the student to different error sources.

The current research aimed to develop techniques that would automate fine-grained cognitive diagnosis. This was achieved by developing a taxonomy of algebra errors that exploits the structural relationship between an erroneous answer and the solution path that led to it. The approach has been evaluated by applying case-based reasoning to implement a system for standard algebra problems. The choice of paradigm enabled us to use partial matching during search and retrieval. This is important because arithmetic slips could lead to an infinite variety of answers and hence prevent the system from ever finding an exact match for a student's answer.

This paper provides an overview of the error analysis that underpins the system, describes the design of the system and includes an evaluation of its performance.

Mathematics and Non-Math Majors

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Our university has been re-evaluating its pre-calculus level mathematics courses. During this re-evaluation, we (the authors) began to compare our entry-level mathematics courses with those in other disciplines, for example, in literature. After taking an entry-level literature course, most students seem to have reasonably good ideas concerning what writers do and what literature is. However, after taking a skills-based college algebra course designed for those students planning to take calculus, most students seem to have little, if any, understanding of the real work of a mathematician. We decided to try to develop a college-algebra level course to introduce students to mathematical thinking. Our goals included helping students to understand the creative nature of mathematics and to experience the struggles, frustrations, and joys of “doing” mathematics. In this paper, we summarize our first attempt at teaching this course, and we explain our revised plans and goals in preparation for teaching this course again.

We taught this course using fuzzy set theory, cryptography, and spherical geometry as the main topics. In teaching this course again, we will replace fuzzy set theory with game theory. Fuzzy set theory was for the students more “book-keeping” with the membership functions than creative questioning. Further, we hope game theory will emphasize the dependency of conclusions on hypotheses. We understand our students cannot experience the depth of mathematics as a mathematician, but we do believe our students can, at certain levels, “discover” mathematical ideas and appreciate the value of mathematics. One of our revised goals will be to help students better understand the history and applications of our main topics. We hope this context will allow them to see mathematics as a process of natural discovery and development.

An Investigation into the Performance of Students in Applied Mathematics at the University of the Witwatersrand, Johannesburg

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The School of Computational and Applied Mathematics has this year (2003) embarked on a complete overhaul of the teaching of applied mathematics to students in the undergraduate years of study. The school offers courses in the following areas: numerical analysis, optimisation, control theory, mathematical modelling, differential equations and mechanics. The motivation for this change is due to the poor performance of black African students in the third year of study. As a result of this poor performance the participation of black African students in the honours and higher degrees programmes has declined. We have observed the performance of students from other race groups has deteriorated over a period of three years, but not as dramatically as that of the black African students. To improve the performance of black African students the School has adopted a problem solving approach to teaching in all areas of study. In this paper we discuss some of the challenges we have faced from inside and outside the school as well as the responses of students to the change in teaching methodology.

Calculators as a Tool to Develop Number Sense for Prospective Elementary Teachers

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Calculators are common in school classrooms at all levels. Yet, while the technology keeps improving, few teachers do more than simply allow students to “check their work”, which often leads to an over-reliance on the calculator for basic skills.

The majority of the students in my math for prospective elementary teacher courses are dependent on their calculators for basic calculations. They are unaware of how to use calculators as a tool for developing number sense. Since most elementary teachers did not see their own teachers use calculators appropriately, and because most teachers “teach the way they are taught”, it is essential to address this issue in both their mathematics content and methods courses.

We’ll learn two “Guess my Number” estimation/mental math games during this workshop that encourage students to think about number relationships, patterns, and operations, instead of computational skills. They would not be practical without a calculator to do the frequent computations. We’ll also explore several activities that emphasize fractions, operations with fractions, and fraction-decimal relationships.

Since different models of calculators have different operating systems, bringing your own calculator to the workshop will enable a discussion about differences in different models. I’ll plan to provide calculators for use during the workshop, too.

Preparing Historically Disadvantaged Students for University Mathematics: A Post-Apartheid Context

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South Africa’s policy of apartheid has left a crisis in Mathematics and Science Education. The systematic exclusion of the majority of South Africans from enjoying a proper education in Mathematics and related disciplines has created demographic imbalances at universities and in industry. We briefly review the policies implemented by the apartheid government and their effect on education. Then, we look at the attempts to redress the problems in education, in particular, at university. We discuss, especially, the University of Pretoria Foundation Year Programme (UPFY).

The programme was initiated in 2001 by the management of the University and will have 10 years of intake till 2010. Only students who come from disadvantaged backgrounds (previously disenfranchised communities) can apply for the programme. Students from these communities who do not gain university entry but who show good aptitude for Mathematics and Science are accepted for the year-long programme. Initially (2001) only the top 64 students in the admission tests were accepted. That number was doubled in the second intake and, in 2003, 192 students were accepted (which will remain the yearly intake until 2010). All students were, up to this year, given full scholarships by the University. These students, on successfully completing the one-year programme, will proceed with studies in the sciences.

We consider the design of the programme, confining most of our attention to the mathematics component. Choices for the curriculum, teaching strategies and assessment techniques are discussed. We attempt to evaluate the success of the mathematics course by way of tracer studies on our ‘graduates’ of the programme. Apart

from monitoring students' performance in the mainstream departments, we also attempt to ascertain students' adjustment socially and otherwise into an environment their parents would never have been allowed to enter.

Investigating the Influence of Second Language Mathematics Instruction on Calculus Performance in South Africa

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Understanding the abstract concepts and ideas in mathematics if explained in any everyday language is tough as it is. Worldwide it is a recognised problem that students often have to master the mathematical content via a second or third language. This problem applies to the majority of South African students. In a quantitative study of first year Calculus students at the University of Pretoria, we investigate two groups of students: In the one case tuition takes place in the home language but the textbooks are in English, a second language; in the second case, both textbooks and tuition are in English, a second or third language. By factoring out the influence of various social factors and the mathematical backgrounds of students, more insight is gained into the success with which Mathematics is taught to these groups.

Fostering Students' "Calculus Sense": Geometrical and Physical Intuition for Concepts in Calculus

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We will discuss our on-going program of investigations regarding undergraduate student's "calculus sense". In particular, we are working on methods to foster and assess the development of student's geometrical and physical intuition for concepts in calculus. We will include preliminary results of comparative studies between calculus classes in the U.S.A. and in England that are planned for the (Northern Hemisphere) Autumn Semester 2003.

Tertiary Mathematics Input: Can it Play a Role in Prompting Teachers' Thinking about Teaching?

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A group of senior mathematics teachers from the four schools took part in two professional development opportunities offered by the University. The schools involved are currently part of the Mathematics Enhancement Project that is operating under the auspices of the Mathematics Education Unit at the University of Auckland. The stimuli for discussion in the two episodes were different. In one model the teachers attended lectures on advanced mathematical topics from two University lecturers, in the other they watched a video of a lecturer teaching a year twelve mathematics class. This paper analyses the subsequent discussions and highlights the possibilities of using mathematics content as a stimulus for fostering productive discussion of both content and pedagogy amongst classroom teachers.

Mathematical Expectation: An Analysis of the Operation of a Professional Gambling Syndicate

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The concept of mathematical expectation has a variety of practical applications and is central to the application of probability to decision making. The topic is now included specifically in many secondary school mathematics subjects, including the Queensland Year 11/12 syllabi. Earlier research by the author demonstrated that relatively sophisticated applications of this concept can be performed by students with relatively little mathematical background. Consequently, the author has developed a mathematical content elective unit in probability for BEd primary preservice teachers at Queensland University of Technology based around the mathematics of games of chance and mathematical expectation. The concept of mathematical expectations in a variety of gambling situations and games of chance is central to the unit. One application in the subject shows how professional gambling syndicates can operate with a positive mathematical expectation. This paper illustrates the development of the concept within the unit and includes a mathematical analysis of a report in The Brisbane Courier Mail, 3/10/00, "Betting sting on ice after TAB hit" by the class. The analysis shows how the syndicate operated with a positive mathematical expectation.

Numerical or Symbolic: A Choice between the Devil and the Deep Blue Sea?

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For first and second year mathematics classes learning about limits, sequences, sums, integrals, functions, vectors, matrices, etc., etc., we have seen two approaches adopted – either the numerical approach using mostly Matlab or the symbolic approach using a CAS like Maple or Mathematica.

The author has made use of both approaches and in this paper we will hope to demonstrate their strengths and weaknesses with many examples drawn from lecture material, tutorials and laboratory classes.

It is vital that we, as educators, face the fact that there can be major problems with either approach and do not merely use one approach blindly without appreciating the possible drawbacks.

Foundation Programmes in Mathematics: Any Wisdom Gained?

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Students' abilities to deal adequately with mathematical concepts and operations do not seem to care much for any social criteria or measure used to distinguished among them. This fact is demonstrated by the achievements of students in international competitions. They often come from vastly different backgrounds and with severely different educational opportunities. Unfortunately, the same holds true for misconceptions and the lack of skills in problem-solving. The only positive aspect of the latter situation is the fact that mathematicians and mathematics educators can gather and reflect upon their concerns, which carry an unusual sameness with them. In this paper we reflect upon a number of practices, which obtain within the South African situation as ways of

addressing such conceptual and other concerns at first year entry level. Some suggestions are then made towards an initial effort to define a programme aimed at establishing a coherent and, hopefully, effective approach to dealing with ‘ill-prepared’ students entering tertiary mathematics programmes.

What on Earth is Sustainability in Mathematics?

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Between Warthog Delta and Remarkable Delta, an important event has taken place. At the Johannesburg Earth Summit in September 2002, recognising the vital importance of education for sustainable development, a plea was made to the academic community to integrate issues of sustainability within that mainstream curriculum in order to prepare students for the needs of the Earth in the Twenty-first Century. Most universities in the Western World are signatories to agreements that express their commitment to the notion of sustainable development. This commitment has often led to the greening of university campuses, but not to the actual integration of issues of sustainability in the curriculum. In an area such as mathematics, it seems difficult to even conceive of how this could be done! Our approach to the problem is to synthesise various strands of our research programme. In previous research, we have established that students and teachers determine the focus of learning and teaching in relation to their perceptions of the nature of professional work as a mathematician. In a study funded by *Environment Australia*, we found that academics understand the ideas of sustainability in the curriculum in a variety of different ways, and from yet another project, we also know that people have a range of different views about the environment. When we combine these research findings with our current investigations in mathematics education, we find that we can address the critical issue of ‘sustainability in mathematics’ in a coherent and integrated fashion without compromising the substantive mathematical content of our courses. In this paper we will explore these ideas and suggest ways in which university teachers of mathematics can address the plea of the Earth Summit and provide a quality learning experience for their students that includes the notions of sustainability within the mathematical context.

Statistical Literacy: How Should We Teach It To Large Introductory Statistics Courses?

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Statistical literacy is essential in today’s information-laden world where decisions on medical, business, government, and other societal issues are increasingly being based on data. Therefore the development of students’ statistical literacy is increasingly being recognised as a key goal in statistics education. This paper describes our initial approach in explicitly teaching the comprehension, interpretation, and critical evaluation of statistically-based reports in a large introductory statistics course at The University of Auckland. Data gathered from the lecturers of the course during the implementation of the two teaching units are presented. Implications for the teaching of statistical literacy are discussed.

Undergraduate Mathematics Curricula – A New Angle

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As is the case with mathematics departments across the country, the University of Ballarat has faced both declining student numbers and little aesthetic appreciation for mathematics and its applications. Within a year of reforming the mathematics curriculum, the department has dramatically increased its student numbers, offered more choices to students, provided a greater breadth of mathematical experience, and assisted students to better appreciate mathematics. Traditional units were previously offered but feedback from students indicated both dissatisfaction with the concentration on calculus and a sense that much of the mathematics covered seemed irrelevant, especially for preservice teachers. It was decided to reform the curriculum to both improve student attitudes and motivation and attract a wider audience. The department wanted to include much of the previous content as well as broadening the range and depth of mathematical topics by providing units developed around themes in which the mathematical skills are introduced in the thematic context. This paper will describe the details of the establishment of these new units to meet all of the prescribed goals. The content and assessment of three of these new units; namely: Upon the Shoulders of Giants; Space, Shape and Design; and Profit, Loss and Gambling will also be discussed. For each of these units, this paper will discuss the incorporation of current technology, the utilisation of realistic problems, the engagement of students in mathematical thinking, writing and discussion, and the use of portfolios and projects as assessment tools. Progress towards meeting the goals of this new curriculum has been closely monitored. Results to date indicate an increase in both initial enrolments and retention rates, increasing awareness of the relevance of mathematics for other disciplines and everyday life, some reduction in mathematics anxiety, increasing interest in mathematical thinking and an improved understanding of mathematics for most students.

Mathematics Students' Conceptions of Mathematics

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In this paper we report on the first phase of a study of mathematics students' conceptions of mathematics, their notions of professional work in the mathematical sciences, and the relationship between these ideas and the way they go about learning mathematics. Our research investigates the transition between tertiary study in mathematics and the mathematical profession, against a background of declining enrolments in a field whose professional profile comprises a wide range of careers linked by the methods and approaches of mathematics. The raw material of the study consists of a series of in-depth interviews with 22 later-year students majoring in some area of the mathematical sciences and 14 graduates who are presently working in the field. These interviews asked students about their views of their subject and their future profession, and were analysed using a phenomenographic approach. Previous investigations by Reid and Petocz in the area of statistics described an overarching framework, the 'Professional Entity', relating students' understanding of their discipline and their perceptions of professional work in that discipline. Students' conceptions of mathematics could be arranged in a hierarchy ranging from the narrowest view as a focus on techniques, through a notion of mathematics as a focus on models, to the broadest view of mathematics as an approach to life and a general way of thinking: they also demonstrated a clear awareness of the classical distinction between 'pure' and 'applied' mathematics. These results confirm the existence of the Professional Entity in mathematics. Our project investigates the important difference between simply learning mathematics and becoming a professional mathematician, and highlights areas that are important to the development of students' mathematical thinking and their future professional role as mathematical scientists.

An Undergraduate Course for Talented Senior High School Students

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In most large university cities there are a significant number of high schools which have a problem challenging their high-achieving final year students. In this paper we describe the experience of our Department in developing and delivering a course to meet this need. We have used the University's Provisional Entrance procedures to allow such students to register for this course while in their final year (Year 13) of high school. They are able to credit this course to their subsequent degree studies. We discuss such things as the history, the curriculum, some of the outcomes, and the future of this course.

Explaining the Mystery of Statistics

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Why use a divisor of $(n-1)$ when calculating the standard deviation of a sample? At first-year level, most teachers of statistics give a plausible explanation of why this is necessary, but some students are not totally convinced, and with some justification. Occasionally a divisor of n is proposed in the literature as a simpler alternative, with arguments advanced in its favour. Only rarely is the “real” reason referred to, utilising the underlying mathematical theory, as a “teaser” for those students going on in statistics. At second-year level, the necessary linear algebra, or vector geometry, can be taught or revised in the space of one 50-minute lecture. The appropriate visual image is a right-angled triangle, with the squared length of one side being the “sum of squared deviations from the mean.” This side of the triangle lies in an $(n-1)$ -dimensional subspace. Developing this properly allows students to see that the divisor must be $(n-1)$. Similar geometric considerations apply when there are samples from two or more study populations, with data analysed by way of t -tests or analysis of variance, and for regression or analysis of covariance (in fact, throughout “linear models” generally). For example, in the case of analysis of variance, the “treatment” sum of squares and the “error” sum of squares add up to the “total” sum of squares by application of Pythagoras’ Theorem to the squared lengths of the sides of an appropriate right-angled triangle. In this paper we describe how we used these geometric ideas to develop a new approach to teaching linear models in a second-year applied statistics course. This course was taught at the University of Canterbury for 16 years, and proved popular with the students. Similar results were obtained with a group of 80 graduate students in agriculture at the University of California at Davis.

The Secret Simplicity of Statistics

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The aim of this workshop is to reveal one of the best-kept secrets of the 20th century – the fact that our most commonly used hypothesis tests are based upon an extremely simple idea which *you* can easily understand! This idea is initially, visually explained in 2-dimensional space. In this familiar setting we’ll be doing a simple class exercise so that you can discover the secret for yourselves. For this, you’ll need to bring a pen or pencil, plus a battery-operated calculator with scientific functions if you have one (not essential - we just need to take the inverse of a tan at one point, and we can share for this). This class exercise will give you the basic idea for

the simplest case of the test of the hypothesis “population mean = 0” when the data set is a sample of size two from a single study population. In the second half of the workshop, you’ll learn how this basic idea extends to larger sample sizes in the case of a single study population, and, as further examples, to tests of comparisons between means when there are several study populations (analysis of variance), and to the test of the regression slope in a simple regression analysis. This workshop has been successfully run with agricultural researchers at Lincoln, New Zealand, and is based upon the ideas which inspired Sir Ronald Fisher in his early development of these statistical methods.

Lite Applets: Tools for Creating Interactive Online Learning Environments

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This workshop will introduce the Lite Applet (LA) concept pioneered by Frank Wattenberg as part of the Mathematical Sciences Digital Library project of the Mathematical Association of America. In brief, LA’s are a suite of flexible Java applets that can be adapted to many different purposes without any knowledge of Java – or of any programming beyond very basic HTML. The basic concept and the first applet in the suite are described in an article by Wattenberg, Stewart, and Alexandre in Volume 2 of the Journal of Online Mathematics and its Applications. After illustrating the LA concept with learning materials already available on the World Wide Web, I will pose a series of hands-on exercises through which participants can build materials of their own.

Prerequisites: a basic background in web page construction and a desire to create interactive online learning materials in mathematics.

Integration from First Principles

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Integration has traditionally been so closely linked to interpretation as an area and to the techniques of anti-differentiation as to appear inseparable from them. While largely a consequence of the fact that, in pre-Personal-Computer times, anti-differentiation was the key to effective integration and that line and surface integrals were generally intractable using that technique, the advent of computer algebra systems and easy large scale numerical computation seems not to have had much effect on the way integration is presented in standard texts. On the one hand, it is not clear what sorts of skills are required for a novice to handle computer algebra effectively and on the other hand most available software does not provide the data structures and tools for dealing conveniently with numerical integration from first principles in the general case. We focus on the latter.

In this article we examine an approach to the principles of integration based on computer manipulation of multi-dimensional arrays for the coordinate grids, referring to the area interpretation as only one among several possibilities and presenting integration as the solution to non-trivial anti-differentiation problems. Underlying the implementation of the approach is the mathematical notation of Iverson’s $\{\mathbf{J}\}$, an array-processing, functional, computer language. We suggest that the mathematical foundations of the topic - existence of, and convergence to, the limit - should be postponed till after students can effectively compute and manipulate the approximations.

Difficulties in the Acquisition of Linear Algebra Concepts

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Research shows that linear algebra is not an easy course to teach to first year university science and mathematics students. Around the world many students struggle to grasp the ideas in linear algebra, which although they may appear simple, are very powerful, with inner depth. This paper describes a study with first year mathematics students at The University of Auckland who completed a questionnaire containing some carefully designed conceptual questions examining geometric, matrix and algebraic representation of linear algebra, along with a questionnaire on their attitudes about the course. Results suggest that there are student difficulties concerning understanding definitions, a tendency toward a procedural approach rather than a conceptual one, and an apparent lack of representational versatility.

Support in First Year Undergraduate Mathematics Education: A Multifaceted Teaching and Learning Approach

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This poster reflects on experiences and results gained during 2000-2002 involving first year engineering students on a support course in the School of Engineering at the University of Pretoria. Students on the support course have passed the university's admission tests assessing their ability to succeed at engineering studies. However, they are academically still at risk because of deficiencies in their educational background. The development of mathematical competence and skills needed for understanding fundamental concepts underpinning a study in calculus form a core component of the course. A multifaceted teaching and learning approach is followed in which the development of personal, academic, communication and information skills are integrated into the mathematics curriculum. In addressing personal and academic skills the effects of thinking and learning style preferences and study orientation on performance in a standard first course in calculus are considered. Aspects related to the interpretation, reading and writing of mathematics are presented. Results during 2000-2002 indicate that the combined aspects that constitute this multifaceted learning facilitation strategy seemingly have a beneficial effect on the learners involved.

By sharing the experiences and presenting the conclusions of the study, the presenters hope to give suggestions for practice, establish contacts and discuss further research aimed at developing the mathematics potential of learners.

Practical Number Theory in a Discrete Mathematics Class: The RSA Cryptosystem in Maple, Microsoft Excel and on the Web

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Digital cryptography is an increasingly important topic in modern discrete mathematics and CS/IT classrooms. The Rivest-Shamir-Adleman (RSA) cryptosystem has been around for almost 30 years. Despite many intensive efforts to crack it, these have met with only limited success. The system remains a very important, widely-used public key system, and it is certainly worthwhile to present the underlying mathematics to CS/IT majors. This paper discusses one such venture.

Developing Study Skills in a First Year Mathematics Course

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Students who enrol in first year courses are novices to learning at university with the result that many of them have an uncertain start. One of the main contributing factors to this uncertain start is the student's unrealistic expectation of the amount of work and time involved in university study. This, combined with the fact that increasing numbers of full time students now participate in paid work, means that development of time management and other study skills are now more important than ever before. Literature on development of study skills in students indicates that the most effective programs are those in which study skills are integrated into the curriculum. This paper investigates what study skills are necessary for success in a first year service mathematics course and proposes a model of integration based on a management structure in which students participate in a cycle of planning, organising, leading and controlling. Implementation of the model is described in a first year mathematics course that services science, information technology, engineering and surveying students in both on-campus and distance modes. Examples from and preliminary evaluations of study materials, assessment practice and development of group problem solving skills are presented.

A Graphical Illustration of the Limit of a Composite Function

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In first-year undergraduate calculus courses, students learn the concept of the limit of a function and the various limit laws for calculating the limits of functions. In this paper, we present a teaching idea of how to use a graphical method for composing functions to give a geometric argument of the following theorem on the limit of composite functions:

If f is continuous at b and $\lim_{x \rightarrow a} g(x) = b$, then $\lim_{x \rightarrow a} f(g(x)) = f(\lim_{x \rightarrow a} g(x)) = f(b)$.

The geometric argument serves to convince students who do not learn the $\varepsilon - \delta$ definition of limit why the theorem is intuitively true. We also give graphical illustrations of why the theorem is false if f is not continuous at b , including the case where the limit of f as x approaches b exists.

Using dynamic geometry software in teacher education

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In recent years, dynamic geometry software like Euklid DynaGeo, Cabri or Cinderella is being used in schools more and more frequently. However, teacher education at the universities is currently not taking this into consideration and does not prepare future teachers for using these new tools (moreover, it does not even let them know of their existence). This article has two purposes: To present the possibilities of dynamic geometry software for use in mathematics teaching, and to present the results and experiences of a first university class held at the University of Vienna, featuring an introduction in dynamic geometry software and its classroom application.

Dynamic geometry software – contrary to regular drawing software – keeps the relations between individual geometric objects, even if some or all of these objects change their positions (e.g. let M be the centre of a line

\overline{AB} . If one changes the positions of A and/or B , the position of M changes accordingly, so that M stays the centre of \overline{AB} . This helps students to grasp concepts like “[a certain relationship] holds for all triangles”, because they not only see the theoretical proof, but can also try the relationship on a large number of different triangles by just changing the position of one or more vertices (by “drag and drop”) and thereby experience that it holds for “all” triangles. A research study shows a significantly better understanding in pupils who used dynamic geometry software, compared with pupils who used only paper and pencil. It also indicates positive experiences with university students (future mathematics teachers).

What Students Say They Learned – A Case Study in First Year Calculus

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There is a large body of the mathematics education literature with a focus on the interaction between language and mathematics learning. Stemming from this theme, there is the particular interest in the ways students express in writing their mathematical thinking when solving mathematical problems. Most of the research involves primary and, to some extent, secondary level students. However, there is a growing interest in this area in tertiary mathematics education; examples include the use of essays, multiple-entry logs and journals as part of the teaching and learning activities in some tertiary mathematics courses.

This paper reports on the experimental use of writing in a first year calculus course as an end-of-task reflective instrument. It explores the different ways students express in writing what they have learned by completing a mathematics assignment. It also explores the relationship between student responses and their performance in the subject.

Mathematical Skills for Modelling

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The boundaries between applied mathematics, numerical analysis and computation are becoming increasingly blurred as these activities become part of more and more disciplines and are supported by ever more sophisticated software, both purpose made and general purpose. This creates both the need and the opportunities for non-mathematicians to acquire skills that complement rather than compete with the strengths of computer-aided mathematical technology. Examples from a recently completed project on modelling solute transport in natural porous media are presented to demonstrate some of these skills: the fight against complexity; the power of experimenting with a good guess; cycling between algebra, numerics and graphics; coaxing obstinate software; and thinking strategically rather than tactically. Even though modern mathematics textbooks incorporate the use of symbolic software, it is argued that these skills do not receive enough attention. Typical textbook problems are just too simple to give exposure to this inventive rather than mechanistic approach to mathematics. Traditional teaching of concepts, logic and techniques should be complemented by more substantial projects that focus on problems rather than techniques and leave room for intuition. From a teaching perspective, the main problem is to find suitable projects at an appropriate level and an exchange of tested examples between both experts and users of mathematics that would benefit all parties.

Initiatives in Industrial Mathematics

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Over the last 40 years numerous initiatives designed to foster Industrial Mathematics in the community at large, and in teaching institutions, have been introduced to increase the use of mathematics in industry. Here Industrial Mathematics (IM) is interpreted in the widest sense and includes the biological, medical, agricultural, and financial areas, as well as the traditional engineering ones. The focus has largely been two-fold:

- Under-graduate programs like the Claremont, California clinics for IM;
- IM Study groups, of real-time problem-solving such as the Oxford and Australasian IM Study Groups.

The motivation has been to increase the competitiveness of domestic industry and the economy as a whole. We recognise that much of the spectrum of mathematics talent and expertise is arguably under-utilised, and that graduates in the mathematical sciences could have (relative to other scientific and technological graduates) improved employment prospects. It is argued that these shortfalls need to be bridged.

Based on personal experience of the initiatives mentioned above, the merits of different approaches will be evaluated. A case will be made for initiatives in IM. Departments in the Mathematical Sciences will thereby provide to their students an immense opportunity for greater, deeper, and fulfilling contributions in all areas of the natural and social sciences, engineering and technology. IM programs, both under-graduate and graduate, will serve to produce a much more favourable employment market for graduates. It will create an atmosphere of trust and confidence in the community as a whole: that the mathematical sciences community, including those parts of it that have no direct interest in IM, is more ready to contribute to the solution of larger problems. This will help to keep mathematics in the key under-pinning role it has enjoyed in the last two centuries.

Cross-Disciplinary Teaching of Mathematics

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In this paper we describe a recent review of the literature on cross-disciplinary teaching of mathematics to undergraduates, as part of a review of cross-faculty teaching of mathematics at the University of Technology, Sydney. There is a major body of work in the area of disciplinary differences in learning styles which can inform teaching approaches for engineering and business students, alongside literature elucidating disciplinary differences in teaching styles. In terms of mathematics, the most common theme is the presentation of engineering mathematics, with a particular emphasis on required content with general agreement that there is a need for collaboration between teaching faculties and course faculties. Teaching statistics has also been investigated to some extent in this context. Other literature describes courses developed and reformed on the basis of inter-disciplinary teaching teams, with most articles presenting case studies of specific courses where new approaches have been tested. In tandem with these are studies of students' perceptions of "good teaching". For first year students, problems of retention highlight the differences between the secondary school and university teaching environments. Teaching context here – such as large lectures – may have a significant influence on success or failure of individual students. In all situations, it was agreed that extensive use of applications from the course discipline is necessary to illuminate the relevance of the appropriate mathematics theory. The necessity for varied teaching approaches was illuminated by differences in learning styles among students; models for improvement include the development of suitable computer-based programs and resources.

Probability with CAS as a Part of the Calculus – A University Lecture For Teacher Students

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After the recent reforms of the curricula in mathematics, **probability & statistics** and the use of the computer were fixed as a compulsory part in different grades of the grammar schools. Until the use of CAS problems of the binomial and normal distribution could only be solved with tables. In the last Austrian CAS projects (1997 – 2002) all students of the research classes used TI-DERIVE or PC-DERIVE in the mathematics lessons and at home.

The teacher students at university have a very different knowledge in working with a computer and they rarely have experience in how to teach statistics with the help of a computer at school. Therefore many teacher students find it very difficult to plan such a statistics lesson. Therefore I work with the teacher students in a computer lab with statistics software and try to develop concepts of the school curriculum with them.

With CAS calculators the students can quickly manage in the algebra window the limit of sequences, summations and integrations of functions. With CAS stochastics loses its isolated position in the curriculum. Probability becomes a part of calculus. If a table of the binomial distribution e.g. for $n=20$ and $p=0.5$ ($k = 0,1,2, \dots, 20$) is created in the data editor of the TI-92, a point diagram, a histogram and at last a probability density polygon is quickly plotted. With this sequence of figures it is possible to get an imaginable transition from the discrete distribution to the continuous distribution including the important correction. DERIVE can also plot the Gaussian bell-shaped curve of the normal distribution in the graphic window for every μ and σ . If the curve is plotted, the TI-92 is able, with the command $\int f(x).dx$, to calculate the area under the curve after the input of the lower and upper bound. The standardisation of the normal distribution loses its dominating position.

Should Structural Equation Modelling be Taught to Undergraduate Statistics Students?

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Structural Equation Modelling (SEM) is a general approach to data analysis that attempts to incorporate a range of standard multivariate methods, including regression, analysis of variance and factor analysis. Increasing use is being made of easy-to-use software such as AMOS to visually specify, view and modify a model using simple drawing tools. AMOS accepts a path diagram as a model specification and displays parameter estimates graphically. The software makes use of bootstrapping and can fit multiple models in a single analysis. In SEM interest often focuses on unobserved variables rather than on observed variables, which allows for modelling the linkage between a wide variety of response and explanatory variables. Thus models can be tested in fields where measurement is difficult and error-prone, such as econometrics, biometrics, health sciences and social sciences. SEM is a relatively young field with a methodology that is still developing. This paper attempts to discuss the advantages and disadvantages of teaching SEM at the undergraduate level.