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ABSTRACT

In January 2000 a network of discipline-based centers was established for higher education in the UK, including a Mathematics, Statistics & Operational Research (MSOR) Network which will: support and enhance academic practice in teaching MSOR; coordinate networks of MSOR academics; disseminate innovation and good practice in learning, teaching and assessment; create a forum for the exchange of information, ideas, philosophies and research findings; and exploit and harness change associated with new technology, integrating this into pedagogic developments. The presentation will outline our current and future plans to take full advantage of technology to make teachers of Mathematics, Statistics and Operational Research more effective in Higher Education. The prize will be that students will be educated to their full potential in these subjects. (Author)

A Strategy for the Use of Technology to Enhance Learning in Maths, Stats and OR

by
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A STRATEGY FOR THE USE OF TECHNOLOGY TO ENHANCE LEARNING AND TEACHING IN MATHS, STATS & OR

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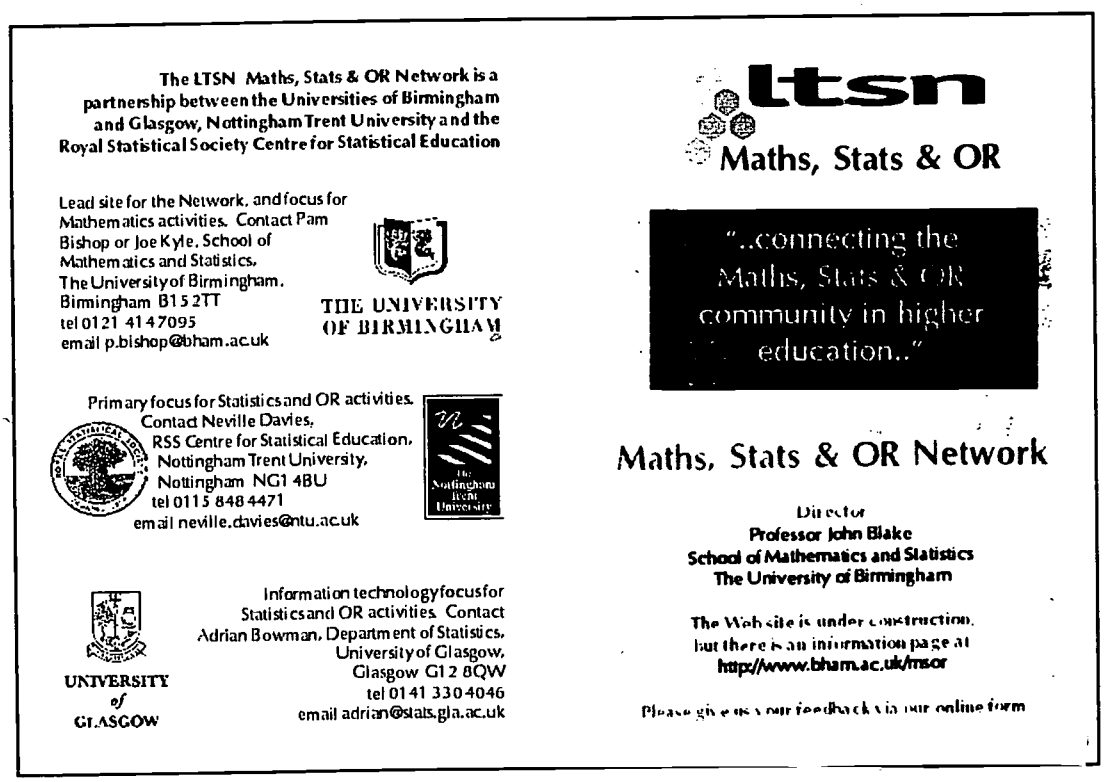
In January 2000 a network of discipline-based centres was established for higher education in the UK, including a Maths, Stats & OR Network which will:

- *support and enhance academic practice in teaching MSOR*
- *coordinate networks of MSOR academics*
- *disseminate innovation and good practice in learning, teaching and assessment*
- *create a forum for the exchange of information, ideas, philosophies and research findings*
- *exploit and harness change associated with new technology, integrating this into pedagogic developments*

The presentation will outline our current and future plans to take full advantage of technology to make teachers of Mathematics, Statistics and Operational Research more effective in Higher Education. The prize will be that students will be educated to their full potential in these subjects.



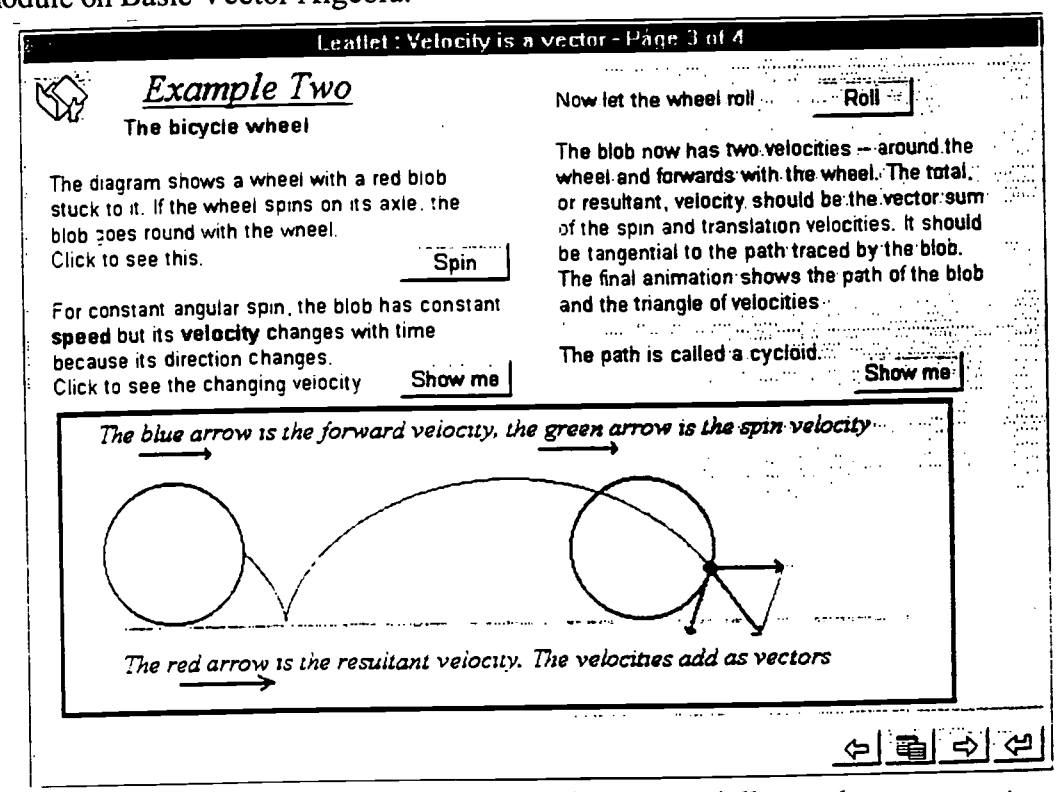
Introduction and history

The Maths, Stats & OR Network was established in January 2000 as part of the Learning and Teaching Support Network (LTSN), an initiative of the Higher Education Funding Councils in the UK. It is able to build on the resources of the earlier Computers in Teaching Initiative (CTI) centres in Mathematics and Statistics (1989-1999), and the Royal Statistical Society Centre for Statistical Education.

The CTI Centres focussed on ways that communications and information technology (C&IT) can enhance the teaching and learning of Mathematics and

Statistics. At their inception there was very little material available, and the compilation of a simple inventory was a valuable resource. Since then, in addition to the increased power of standard packages for carrying out symbolic manipulation or statistical analysis, the last decade has seen the arrival of some sophisticated systems for teaching ideas. Some of these have been commercial enterprises, including multimedia, flexible navigation and support systems. Others have been more freely available and targeted at specific areas such as service mathematics teaching or support for the use of a commercial statistical package. The Teaching and Learning Technology Programme (TLTP) was a particular stimulus to these developments in the early 1990s. Some innovative software was created and is still in use.

For example, Mathwise was developed by a consortium of over 30 UK universities as an integrated learning environment for teaching undergraduate mathematics, with modules based on the SEFI (European Society for Engineering Education) syllabus, comprising mathematical topics taught in pre-university and first year university, together with a number of key topics in second-year university Science and Engineering courses. The following illustration was clipped from an animation in the module on Basic Vector Algebra:

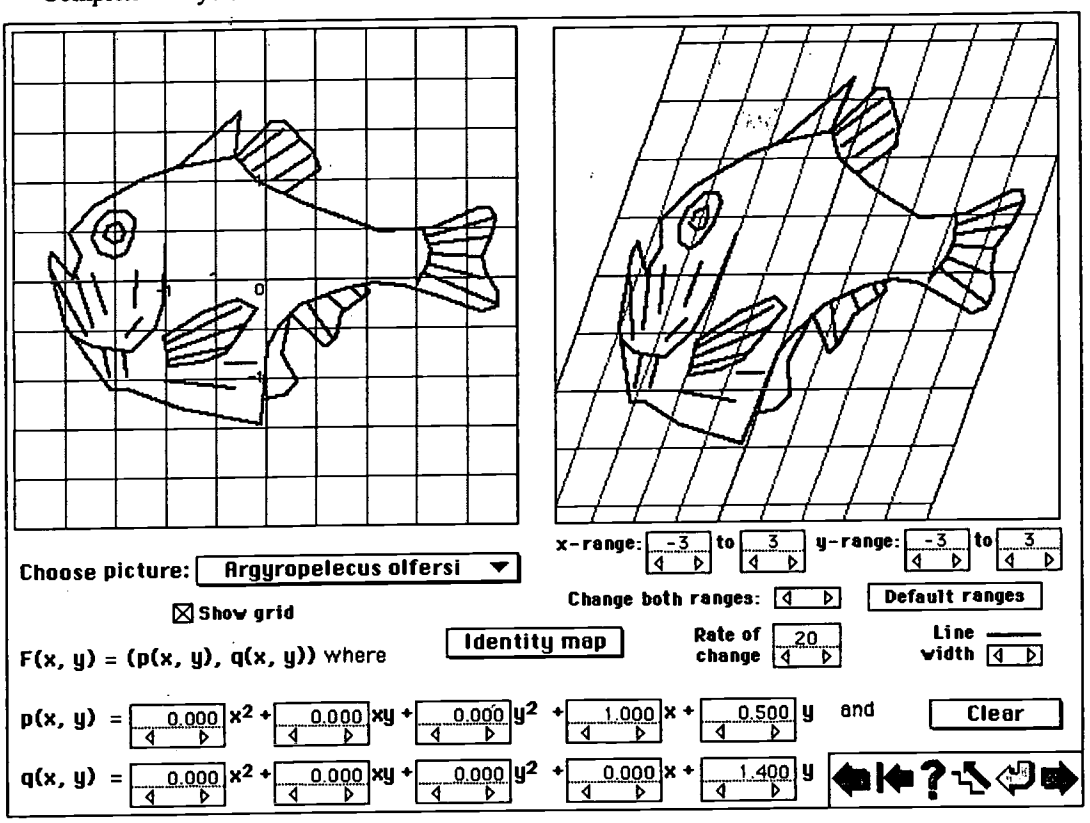


Some Mathwise modules have been published commercially, and a community of Mathwise users has been established. This group provides mutual support in the embedding of Mathwise into courses, is collating written and other support materials and making them available on a protected Web site, publishes a newsletter, runs workshops and staff development days and provides academic feedback to the publishers. An evaluation of the Mathwise project and the User Group can be found in Haywood et al (1999).

A different approach was taken by O'Connor and Robertson, who developed the system known as Mathematical MacTutor as a laboratory allowing students to conduct

mathematical experiments. They use it to supplement conventional modes of teaching at the University of St Andrews in Scotland:

> We have concentrated on areas where we think that the computer, and particularly the superb graphics capabilities of the Apple Macintosh, can give insights not available in other ways. Thus, apart from the Calculus topics that one would expect to find in any mathematical software, MacTutor is particularly strong in Geometry, Algebra (and in particular, Group Theory), Graph Theory, Number Theory and the History of Mathematics. It has some interesting stacks on Statistics, Matrices and Complex Analysis.



The Statistical Education through Problem Solving (STEPS) project was based in the UK and a team of academics from seven universities developed computer based learning material using the software authoring product *ToolBook*. The STEPS software comprised problem-based material in computer modules that can be used as support material in a variety of courses. The aims of each problem context are self-contained and have a realistic scenario with easy-to-understand discipline matter. Most of them use introductory statistical concepts and tools as required that are relevant to the problem. The emphasis is on using statistics that can provide tools to aid problem-solving, rather than an approach that is generated by a curriculum. The material was reviewed by MacGillivray (1995).

Over the past eight years we have been involved in studies to decide the merits, or otherwise, of a technological approach to learning and teaching mathematical subjects. See, for example, Davies and Antcliffe (1996) and Bowman, Constable, Davies, Gilmore, Gilmore and Redfern (1998) where experience with learning and teaching statistics using computer based methods are reported. These, and indeed most other, studies show that there is no difference in performance in tests of different groups of students who do and do not use technology as part of their learning experience. Also the key points to emerge from results of surveys of students attitudes to using technology to

learn are: Overall the feedback is very positive as students find that that carefully constructed computer-based learning modules are easy to understand and they enjoy using a computer to carry out learning tasks. Also, working at their own pace is attractive to them, and they invariably report that they feel their knowledge of the subject material improves with the use of a computer. Indeed it is rare for students to feel that that their understanding had worsened.

Many people are researching the use of technology in learning and teaching. The US web site http://www.learner.org/edtech/rscheval/ reports the results of research into the use of technology in education. As an example, the *Flashlight Project* develops survey items, interview plans, cost analysis methods, and other procedures that institutions can use to monitor the success of educational strategies that use technology. There are many useful links from that site.

Strategy of the Maths, Stats & OR Network

The Maths, Stats & OR Network has taken as its mission:

> to promote high standards in the learning and teaching of Maths, Stats and OR by encouraging knowledge exchange, innovation and enterprise, leading to an enhancement of the learning experience for students

and its aims are:

- to foster networks of academics in Maths, Stats & OR
- to disseminate innovation and good practice in learning, teaching and assessment
- to create a forum for the exchange of information, ideas, philosophies and research findings
- to support and enhance good academic practice in teaching Maths, Stats & OR
- to exploit and harness change associated with new technology, integrating this into pedagogic developments
- to run an efficient and effective Maths, Stats & OR Network as part of the wider Learning and Teaching Support Network

There are many activities we feel could be useful and productive for the Maths, Stats & OR community over the next five years. We have taken as our slogan 'connecting the Maths, Stats & OR community in higher education'. Existing practitioners have valuable skills, have tried out different teaching methods, have introduced flexible learning and assessment ideas and have found out what works and what does not. Collecting information about people and their skills, including best practice and reports of successes and failures, and making this information available to other practitioners will be the basis of our work. Activities enabling us to gather and disseminate this information will include local awareness raising workshops, where people can meet and exchange ideas, try out one another's materials and evaluate developments. This will enable us to identify champions of good practice in teaching in Maths, Stats & OR specialist departments and in service courses.

It will also be important to create information banks about existing and emerging resources for learning, teaching materials and effective instruments for assessment, as well as case studies of good practice using these resources. One of our first activities will be to take stock of the state of learning resources in the UK as reported by the Quality Assurance Agency (http://www.qaa.ac.uk) after its review of the subject areas of Mathematics, Statistics and Operational Research (MSOR) form 1998 - 2000, and to identify those departments with recognised good practice in Curriculum Design,

Content and Organisation, Teaching Learning and Assessment, Student Progression and Achievement and Learning Resources.

During that period teams of reviewers visited more than 70 departments. At a general level good liaison between MSOR subject staff and library or IT staff enabled the determination of those resources required, including their effective acquisition.

There were many examples of the appropriate use of IT and appropriate software integrated into classroom activities, which led to the enhancement of the students' learning experience. Good practice included opportunities for students to give oral presentations, to acquire a range of IT skills, to work co-operatively with peers and to develop as independent learners, the latter often through project work.

Good practice in the use of technology was noted for a number of providers who make information such as lecture notes, past examination papers and administrative matters available on the Web, and there were instances of the use of interactive worksheets. Several providers included the development of computer based learning activities as part of their learning resource strategy.

It is clear that in UK higher education institutions the *integration* of technology into the curriculum, rather than employing bolt-on activities in the area, produce the most effective results. We intend to conduct an international survey of research into the use of technology for learning, teaching and assessment issues in our subject areas.

Action research will also be carried out, for example to establish good practice in teaching MSOR to large classes, or criteria by which different approaches to teaching MSOR can be compared for both specialist and non-specialist students. We will compare the learning gain achieved by traditional methods of teaching as compared with a mixture of traditional and C&IT methods, and contrast and compare different levels of the integration of C&IT approaches to teaching MSOR within courses, at both specialist and non-specialist levels. One issue is the effectiveness or otherwise of using "black box" packages in MSOR and how they affect student comprehension of difficult topics and concepts. Experiments will compare different approaches to teaching MSOR, examine the influence of assessment methods on what is taught and learned and look at how the use of a computer affects what needs to be known. We will investigate how and when we should teach the "big ideas" in MSOR and determine what these are for specialists and non-specialists, as well as guidelines on how to enable graduates in MSOR to be good communicators and good team members.

Dissemination of the above information will of course be vital if we are to enhance the student learning experience. We will contribute to and write reports of national findings in relevant areas such as using group teaching, including projects and co-operative learning; experiences with teaching MSOR to engineers; the relationships and synergies between pedagogy, content and technology in MSOR; and the effects of technology on learning and teaching in MSOR. Our own publications, both printed and electronic, will be freely available to the MSOR community, and we will help to disseminate the findings of other groups where these are relevant, such as the recent report from Hawkes and Savage (2000) on the mathematical preparedness of new undergraduates. But perhaps the main thrust of our dissemination activities will be face to face, through workshops and staff development activities, visits to departments and discussions with learning and teaching coordinators in our subject areas.

Using generic technology to enhance learning and teaching activities

Diagnostic testing has been an obvious candidate for computer support. Greenhow (2000) describes his use of objective tests using a commercially available product while pointing out the limitations of this approach and the lack of support for mathematical notation in such standard tools. Chickering and Ehrmann draw attention to the power of the computer with regard to more complex assessment processes:

> As we move toward portfolio evaluation strategies, computers can provide rich storage and easy access to student products and performances. Computers can keep track of early efforts, so instructors and students can see the extent to which later efforts demonstrate gains in knowledge, competence, or other valued outcomes. Performances that are time-consuming and expensive to record and evaluate — such as leadership skills, group process management, or multicultural interactions — can be elicited and stored, not only for ongoing critique but also as a record of growing capacity.

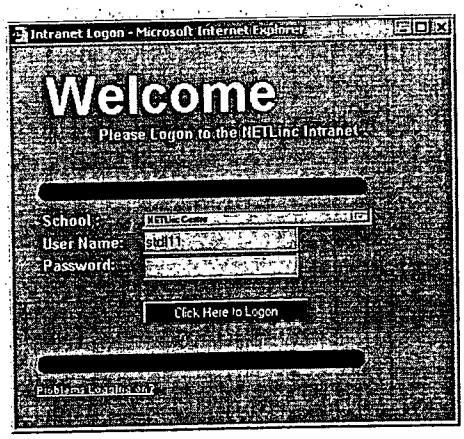
The use of email for submission of assignments or discussion of problems increases opportunities for contact between students and teachers and allows for prompt and flexible feedback. Conversely it also gives an opportunity for reflection not available in a traditional scenario, helping to overcome reticence and encouraging more thoughtful contributions. For example, one result of using electronic instead of paper forms for course evaluation at the University of Birmingham was that students added many more comments in the free text section.

Many departments are now setting up intranet sites where up-to-date course documentation is mounted for access at any time. An extension of this would be to share and exchange teaching materials between departments, such as happened in the Scottish MathPool project described by Maciocia (1997). When such sites are opened up to learners as well as teachers, an "electronic learning community" can emerge.

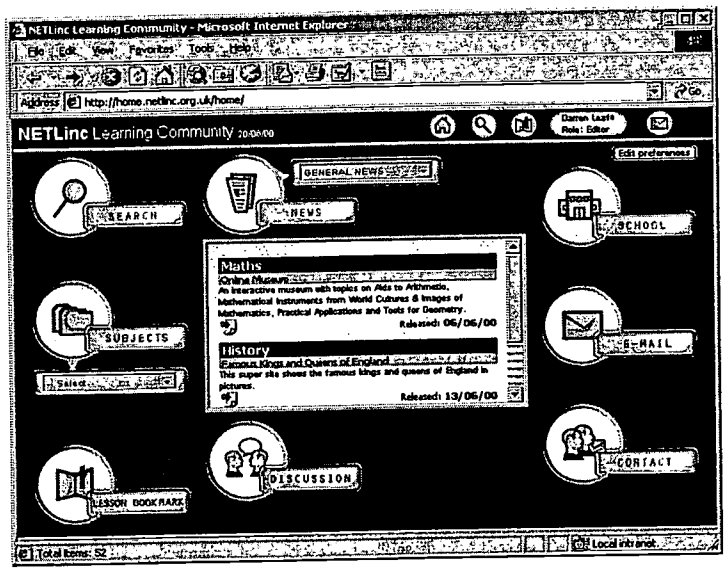
There are a number of projects at school level that are innovative and utilise web-based technology to the full. For example, an electronic learning community called NETLinc has been established for over 300 schools in Lincolnshire, a rural county in England. The provision is for all types of schools catering for pupils aged 6 – 18. Teachers are the main authors of material, but students are allowed to contribute as well. Editorial control is allocated to selected staff at each school and the resource base comprises all material from all schools.

The NETLinc system enables individual users to have their own view of the Intranet. This means that pupils will only see material that they have permission to see or that have been deemed as appropriate for them. When a pupil enters the Intranet, the system picks up their age and presents them with content suitable for their years of study. This means that materials are differentiated. Staff can view all pupil-based materials and additional resources that are classed as 'staff only'.

The following screen snaps show the secure logging on procedure and the opening screen that gives access to searchable resources.



Logon name and password give access to the NETLinc Learning Community.



Staff and Keystage 3, 4, & 5 students (ages 11 – 18) see this type of screen.

The resources are shared across all schools, with invisible demarcation between different schools. It has been very successful to date, mainly because it is very easy to use and authorised staff and pupils can continuously update the resource. All UK national curriculum subjects are catered for. We are negotiating with the authors of the NETLinc system to prototype a version that can be used as an electronic learning community for the Maths, Stats & OR Network at higher education level.

Using subject-specific technology

Powerful commercial packages carrying out computational, symbolic and statistical analysis have already transformed the teaching of MSOR subjects, especially in departments where there is a perceived need to prepare students for future employment. They permit the development of problem-solving skills, provide tools for investigational work and allow students to learn using research-related methods. The challenge is to create learning materials based on the packages that are relevant to students at different stages of their education. There is a great potential here for sharing such resources, and we expect the Maths, Stats & OR Network to play its part in encouraging collaboration in their production and dissemination.

One lesson learned from the TLTP was that the development of networked systems for learning and teaching ideas is extremely costly in resources. This cost can

be spread if the products are adaptable and easily customisable for use in circumstances other than those envisaged by the original projects. Products such as Mathwise, MacTutor and STEPS contain valuable ideas that could be extended to other platforms or rewritten for delivery using the Web. Again we see a role for the Maths, Stats & OR Network in encouraging collaboration.

Some of the latest developments in web-assisted mathematics assessment in the UK were presented at a workshop organised by the Network earlier this year, published in its newsletter as a Workshop Report (2000). This included a system with more advanced support for mathematical input, partial credit and differential marking, as described by Jackson *et al.* (2000). One outcome of the workshop has been the joint development of a pilot diagnosis instrument for use in Midland universities at the start of the autumn term, with a database of exam questions/templates in a restricted number of topics, which will be extended to collaboration with a Belgian partner in the innovative use of Maple as an assessment engine.

The advent of MathML will mean that the benefits of Web technology will be fully extended to the MSOR community, since its goal is to enable mathematics to be served, received and processed on the Web, just as HTML has enabled this functionality for text. We hope to update an earlier Workshop Report (1999) following a visit to the MathML conference due to be held shortly before TIME 2000.

Conclusions

The final objective of the UK Maths, Stats & OR Network is, perhaps, the most important learning outcome we plan to achieve, namely that the students we teach will be better educated in all aspects of mathematics, statistics and OR. In trying to achieve this we will bear in mind that the use of communications and information technology for its own sake has been a drawback in many software products that we have seen over the past 10 years. It is our experience that students can be lulled into a false sense of security merely because they interact with the software through clicking, dragging-and-dropping and so forth. This can be what they remember most about the exercise and it can lead to an enjoyable feeling about what they have done.

However, even though students may have a high enjoyment factor when using clever technological wizardry, that does not mean they retain the material studied for an 'acceptable' length of time. Deep understanding of a subject may or may not come from the use of technology, and we feel that this is an area that deserves more carefully planned research.

Finally, it is our belief that, by creating an electronic learning community, with clearly identified champions and examples of good practice forming the building blocks of our Network, teachers of mathematics, statistics and OR will have a resource from which they will be able to give a much better service to our students.

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