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ABSTRACT

The main purpose of this paper is to provide teachers of mathematics in higher education with a guide to a selection of web-based resources which it is hoped will be useful in their teaching. Short reviews of a number of web sites are provided. It is not claimed that the collection of sites reviewed is exhaustive, or indeed that those reviewed are the best available. However, it is hoped that the present work will at least give an impression of the wealth of material that is available on the web and stimulate the reader to investigate further. It should be noted at the outset that many more sites were visited by members of the working group than have been included here; we have included those sites which we consider have something to offer the practicing lecturer. (Author)

The use of the internet in teaching mathematics (group B)

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Introduction

The main purpose of this paper is to provide teachers of mathematics in higher education with a guide to a selection of web-based resources which it is hoped will be useful in their teaching. Short reviews of a number of web sites are provided. It is not claimed that the collection of sites reviewed is exhaustive, or indeed that those reviewed are the best available. However, it is hoped that the present work will at least give an impression of the wealth of material that is available on the web and stimulate the reader to investigate further. It should be noted at the outset that many more sites were visited by members of the working group than have been included here; we have included those sites which we consider have something to offer the practising lecturer.

We begin with a short discussion of some of the issues surrounding the use of web-based resources. Firstly, it is noted that there is a great deal of software now available to support the teaching of mathematics. The present working group was not concerned with these, but wished to isolate those issues that are particularly important to *internet*-based resources as opposed to more general I.T. resources.

It was noted that examples of good internet resources abound, with excellent web sites existing on, for example, the history of mathematics, the properties of the Fibonacci numbers, fractals, general encyclopaedias of mathematics and interactive tutorial sites. Certainly there appears to be no shortage of relevant and interesting sites. Commercial environments are now being developed, which support general use of the internet, providing teaching resources, such as files and course outlines, discussion areas, and even on-line testing: see **http://www.blackboard.com/** for example. However, these are often too general in scope, and lack the kind of support specifically needed for mathematics.

There are a number of ways in which such resources might be incorporated into courses in mathematics. At the most modest level, a broadly traditional course might be enhanced by references to suitable web sites given throughout the teaching offered to

students. Such an approach would add an extra dimension to the study of the syllabus by encouraging students to explore differing approaches to a given topic, without detracting from the merits of traditional teaching methods.

A more ambitious aim would be to use internet resources to totally, or at least partially, replace conventional methods of providing tutorials and student assessment. Pursuance of this aim would have some substantial ramifications. In particular, it would be expected that increased use of internet resources would lead to a corresponding decrease in the amount of time spent attending conventional tutorials. This would have some advantages, in particular it would give students greater flexibility of times of access to resources and allow each student to proceed at his or her most comfortable pace subject to meeting deadlines set by the tutor responsible for the course. On the other hand, it would also present the need to closely monitor students to ensure that no student was either becoming discouraged or failing to maintain their commitment to their course for want of sufficient interaction with tutors. It is certainly not the wish of the group to suggest that internet resources - particularly for on-campus students - are a total replacement for the physical presence of a teacher of mathematics!

Effective use of web-based resources requires the provision of hardware and software which reach a certain minimum specification. The speed of development of both hardware and software mitigates against giving definitive specifications but the group are agreed that provision should satisfy the basic criteria that it must be sufficiently fast and reliable to encourage rather than discourage student use of the resource. There are several issues which need to be addressed by those responsible for resource provision.

Firstly, staff and students need to have a sufficient number of PC's available whose specification enables them to run a suitable web browser efficiently. Although most institutions now meet this requirement, it cannot always be taken for granted. There is also a need for suitable embedded equation editors, and email facilities that allow the interactive communication of mathematical symbols.

Secondly, the provision of electronic whiteboard facilities, and even graphics tablets, can assist in the remote interaction required to communicate mathematical ideas between teachers and learners and within groups of learners.

Thirdly, there is a need to cultivate in students adequate search skills to enable them to locate the web resources required without the onset of the "lost in cyberspace" syndrome resulting in the loss of so much valuable time.

Fourthly, the web offers both teachers and students the chance to make materials available without any of the usual constraints of printed media, so that materials used in the learning process may never have been scrutinised before being made available. Students often assume that materials they read are true, when in fact they may be wrong, and this can lead to many lost hours trying to understand an erroneous statement. Students need to allow for this by developing their critical faculties together with a

healthy academic scepticism particularly for information presented to them which is unsupported by solid evidence.

Fifthly, the web does provide materials that are created and supported elsewhere, however this can lead to problems. For example, the use of unusual (and not locally available) fonts in documents, the demands made by animations, video clips or different paper sizes, can mean that actually running or printing learning material may be a time consuming and frustrating experience for students.

Finally, there is a need for reliability in web-based resources. It is hoped that important web sites will be backed up by the provision of mirror sites that may be accessed if the original site fails or is removed - the web is a dynamic series of links that work today but may not be available, or even exist, tomorrow. There is also a substantial need for technicians and technical support for staff and students using web-based resources to ensure that all users are able to make the most of what is available. Addresses specified by staff for student use should exist even in cached form at least for the duration of the course being studied.

A number of mechanisms already exist for identifying good web sites and promulgating them across the community. In particular, organisations such as the Learning and Teaching Support Network for Mathematics and the Institute for Learning and Teaching could act as centres to be accessed by staff wishing to view potentially useful sites; perhaps UMTC could itself provide a place for materials to be gathered and knowledge shared, although it would still need enough technical support to make this available and keep it maintained. The group suggest that the mathematics education community will need to accept responsibility for the creation and maintenance of such a resource, since no individual will have the time to devote to such a time consuming operation. Currently, there exists a number of sites giving extensive lists of links to useful web pages. It may also be useful if mathematics departments produce current bookmark lists of useful sites for their own students, such as those reviewed in the present work.

Reviews of Web Sites

The following sites represent some of the better sites visited by group members during the course of UMTC2000. The sites have been grouped according to their mathematical content. The group feel that it is worth making the general point that limiting searches to **.ac.uk** reduces the amount of learning material found substantially. It also seems to produce few actual on-line learning materials, apart from lecture notes on the web.

Group 1 - General Interest

URL: http://www.mcs.surrey.ac.uk/personal/R.Knott/Fibonacci/fib.html
Title: Fibonacci sequences
Audience: School and College

Content: A plethora of interactive pages, for example: Fibonacci Numbers and Nature; the Golden Section in Nature; Fibonacci Puzzle Pages; the Mathematical Magic of the Fibonacci Numbers.
Strengths: An excellent, extensive site with plenty of interesting information and interactive slots that have to be visited to be appreciated.
Weaknesses: N/A.

URL: http://archives.math.utk.edu/topics/
Title: Topics in Mathematics
Audience: All levels
Content: Listings of link to WWW resources in mathematics, arranged by topic, with indications of the level of mathematical background assumed and of features such as interactivity, animations, etc. for each site.
Strengths: An excellent, comprehensive site
Weaknesses: N/A

URL: http://www.dcs.warwick.ac.uk/bshm/resources.html
Title: History of Mathematics
Audience: All levels
Content: Links to Web Sites on the History of Mathematics
Strengths: Comprehensive and still being developed
Weaknesses: N/A

URL: http://www-history.mcs.st-and.ac.uk/history/
Title: History of Mathematics
Audience: All levels
Content: The MacTutor History of Mathematics archive.
Strengths: A most extensive collection of biographies.
Weaknesses: N/A

URL: http://www.geom.umn.edu/
Title: The Geometry Centre
Audience: All levels, including teachers
Content: Gallery of Interactive Geometry.
Strengths: A number of graphical images available but more novelty than pedagogy.
Weaknesses: Non-interactive

URL: http://www.pbs.org/wqed/lifebythenumbers/standard/index.html
Title: Life by the Numbers
Audience: All levels
Content: Patterns of nature
Strengths: General interest
Weaknesses: Limited scope

URL: http://archives.math.utk.edu/popmath.html
Title: POPMathematics

Audience: School and College
Content: General interest
Strengths: Interactive
Weaknesses: Requires a download of software

URL: http://dir.yahoo.com/Science/Mathematics/
Title: Index of Mathematical Topics
Audience: All levels
Content: Directory of mathematics resources
Strengths: Comprehensive
Weaknesses: N/A

URL:http://www.mathsource.com/Content/Applications/Engineering/Electrical/0204-
Title: Library of Mathematical Materials
Audience: Second and third year
Content: Engineering mathematics
Strengths: An excellent interactive source site for various aspects of undergraduate mathematics.
Weaknesses: Limited scope

URL: http://forum.swarthmore.edu/library/
Title: Internet Mathematics Library
Audience: All levels
Content: Mathematics resource listing
Strengths: Wide ranging
Weaknesses: N/A

URL: http://www.ex.ac.uk/cimt/
Title: Centre for Innovation in Mathematics Teaching
Audience: Schools and Colleges
Content: The Centre, established in 1986, is a focus for research and curriculum development in Mathematics teaching and learning, with the aim of unifying and enhancing mathematical progress in schools and colleges.
Strengths: A good example of an informative site.
Weaknesses: Non-interactive

URL: http://www.ams.org/mathweb/
Title: Math on the Web
Audience: Year one courses
Content: Maths on the web.
Strengths: A First Stop for finding mathematical sites on the web
Weaknesses: Non-interactive

URL: http://spanky.triumf.ca/
Title: The Spanky Fractal Database
Audience: Year two and higher courses

Content: Fractal Geometry
Strengths: Good interactive site
Weaknesses: Mainly graphical with little mathematical content.

URL: http://www.cs.ubc.ca/nest/imager/contributions/scharein/KnotPlot.html
Title: The KnotPlot Site
Audience: Specialist courses on Knot Theory
Content: Animations of knots amongst other items
Strengths: Good animations and extensive
Weaknesses: Mainly graphical with little mathematical content.

URL: http://www.shu.edu/html/teaching/math/reals/reals.html
Title: Interactive Real Analysis
Audience: First and second year courses
Content: Interactive Real Analysis is an online, interactive textbook for Real Analysis or Advanced Calculus in one real variable. It deals with sets, sequences, series, continuity, Lebesgue, topology, and more.
Strengths: Comprehensive coverage
Weaknesses: Non-interactive

URL: http://www.cut-the-knot.com/front.html
Title: Interactive Mathematics Miscellany and Puzzles
Audience: School and College
Content: Interactive mathematics in a variety of topics
Strengths: Lots of interest and a variety of interactive topics
Weaknesses: Not mathematical in content, more illustrative.

URL: http://www.teach.virginia.edu/teacherlink/math/links/interactive.html
Title: Interactive Projects
Audience: All years
Content: Compendium of web sites offering interactive mathematics.
Strengths: Large list of web sites.
Weaknesses: N/A

URL: http://SunSITE.UBC.CA/LivingMathematics/V001N01/UBCExamples/
Title: Living Mathematics
Audience: All levels
Content: Lots of interactive mathematics
Strengths: Interesting site
Weaknesses: No consistent theme - a collection of isolated topics.

A maths search engine: http://www.maths.usyd.edu.au:8000/MathSearch.html
The original CTI Mathematics site: http://www.bham.ac.uk/ctimath/
The LTSN Maths, Stats & OR Network http://www.bham.ac.uk/msor/
Information on technology in teaching: http://www.hull.ac.uk/mathskills/

For some articles dealing with the more general issues of computer-based learning (how to use it, how to measure its effectiveness) see also http://www.hull.ac.uk/mathskills/umtc/

Group 2 - Linear Algebra

URL: http://forum.swarthmore.edu/linear/linear.html
Title: Math Forum - Linear Algebra
Audience: More suitable for teaching staff (American biased)
Level: Assorted
Content: List of links (with reviews) to hundreds of other sites. The site claims to be "The best Internet resources for linear algebra: classroom materials, software, Internet projects, and public forums for discussion." Doesn't actually provide content, but gives a "yahoo" type list of sites with reviews.
Strengths: Very good selection - covers a wide range of topics.
Weaknesses: Possibly too much information - hard to find specific examples. Many examples are basically lecture notes, together with programs for specific packages, and so are of limited use.

URL: http://www.sisweb.com/math/tables.htm#top
Title: Dave's Math Tables
Audience: lecturers and students
Level: First year students
Content: some mathematical theory, and some tools for teaching over the internet
Strengths: tools - the whiteboard for interactive tutorials. Message board for students to use.
Weaknesses: very limited mathematical content.

URL: http://www.cougati.ab.ca/
Title: Felynx Cougati Topics in Mathematics
Audience: Undergraduates
Level: First year students
Content: Online teaching materials covering Linear Algebra - vectors, scalar products, etc.
Strengths: Quite a lot of material, quite good theory, good interactive/multimedia use
Weaknesses: Gets a bit awkward with lots of open windows, and quite slow.

URL: http://www.math.tamu.edu/~stecher/Linear-Algebra/
Title: Topics in Linear Algebra
Audience: Undergraduates
Level: First year students
Content: encyclopaedia of basic concepts, examples, and techniques.
Strengths: reasonable structure, some useful examples
Weaknesses: really just lecture notes. Also, the link to class materials (potentially the most useful part), doesn't work!

URL: http://www.horizonweb.com/js/equat/line_alg.html
Title: Java Script Linear Algebra
Audience: Undergraduates
Level: First year students
Content: Some Java programs to do basic linear algebra operations such as finding determinants and performing matrix operations, along with explanations of the mathematics.
Strengths: Interactive
Weaknesses: Awkward interface, very limited in what operations you can do.

URL: ftp://thales.cs.umd.edu/pub/Jampack/Jampack/AboutJampack.html
Title: JAMPACK: A JAVA PACKAGE FOR MATRIX COMPUTATIONS
Audience: Lecturers
Level: N/A
Content: Collection of co-operating classes designed to perform matrix computations in Java applications.
Strengths: Useful resource that could be incorporated into teaching materials
Weaknesses: Needs downloading and setting up locally.

URL: http://www.7stones.com/Homepage/Publisher/linAlgMenu.html
Title: Visual Linear Algebra
Audience: General
Level: First year students
Content: Interactive graphical demonstration of effects of linear transformations.
Strengths: Shows how altering transformation matrices affects the image of the maps. Immediate results of changes.
Weaknesses: Little mathematical explanation.

URL: http://www.public.asu.edu/%7Esergei/linalg/LinAlg.html
Title: Linear Algebra Home Page
Audience: Staff and students
Level: First year students
Content: Some materials to support the teaching of Linear Algebra at Arizona State University, along with some links to other sites.
Strengths: Good example of the kind of layout for such a site
Weaknesses: Very specific (but appropriate for this case!)

Group 3 - Dynamical Systems

URL: http://www.cs.brown.edu/research/ai/dynamics/tutorial/home.html
Title: Learning Dynamical Systems: a Tutorial
Audience: Staff and students
Level: Not specified, but suitable forhigher undergraduate students

Content: Based on lecture course by William Shaw at Brown University. Syllabus given as topics for each of 30 lectures; on-line lecture notes provided for most of these lectures (but some unavailable or under construction), plus reading list (including some on-line articles), and exercises involving use of Mathematica notebooks.
Strengths: thorough coverage of subject at a high level (final year / postgraduate); comprehensive list of references to further reading.
Weaknesses: incomplete; requires availability of Mathematica; not interactive.

URL: http://www.math.okstate.edu/mathdept/dynamics/lecnotes/lecnotes.html
Title: Dynamical Systems and Fractals Lecture Notes
Audience: Students
Level: Appropriate to final-year undergraduate
Content: Lecture notes for one-semester course, with problems; by David J. Wright, University of Leeds. Uses Maple and Fractint software (the latter freely available on the Web) for examples. Long reading list provided.
Strengths: Well-organised set of lecture notes, with plenty of references (but almost entirely to print materials); good graphics, both within lecture notes and by use of Fractint.
Weaknesses: Not interactive, except when using Maple and Fractint.

URL: http://www.ifs.tuwien.ac.at/~aschatt/info/ca/ca.html#Introduction
Title: Cellular automata
Audience: Staff and students
Level: Probably aimed at postgraduates.
Content: Tutorial on cellular automata by Alexander Schatter, University of Vienna. Lecture notes giving comprehensive introduction to theory and examples of cellular automata.
Strengths: Well organised tutorial to a fairly advanced topic in dynamical systems.
Weaknesses: Not interactive; use of English sometimes of dubious quality.

URL: http://www.cnd.mcgill.ca/computing/doc/xpptut/start.html#toc
Title: XPP Tutorial
Audience: Staff and students
Level: Higher undergraduate students
Content: Tutorial and examples using XPP (a system for solving differential and integral equations using phase-plane analysis) to study dynamical systems.
Strengths: XPP gives good graphical presentations of behaviour of dynamical systems.
Weaknesses: Requires familiarisation with XPP before starting work on dynamical systems; not suitable for basic studies of the theory.

URL: http://trixie.eecs.berkeley.edu/~chaiwah/introduction.html
Title: Introduction to Non-linear and Chaotic Phenomena
Audience: Not Specified
Level: Final year undergraduate students
Content: Brief introduction to non-linear dynamical systems, by Chai Wah Wu, University of Berkeley.

Strengths: Clearly presented with some good graphics.
Weaknesses: Very brief introduction: only 4 pages of notes; some of the graphics take a long time to download (some failed); not interactive.

URL: http://alamos.math.arizona.edu/~rychlik/557-dir/index.html
Title: Introduction to Dynamical Systems and Chaos
Audience: Not Specified
Level: Final year undergraduate students
Summary of main points from each lecture on a 36-lecture course at University of Arizona.
Strengths: References to earlier equations are hyperlinks.
Weaknesses: Only one or two lectures actually have a set of notes from which one can learn; the remainder just have a series of bullet-points, or nothing at all.

URL: http://mtl.math.uiuc.edu/modules/discrete/index.htm
Title: Discrete Dynamical Systems for Mathematics Teachers
Audience: In-service mathematics teachers.
Level: Not specified but see below.
Content: Distance-learning module from University of Illinois, very thorough tutorials on elementary theory of dynamical systems (appropriate to first year of a mathematics degree), with examples and exercises to be done on a TI-82 calculator.
Strengths: Complete module: no other instructional material required; clear explanations of theory, with good integration of examples and exercises.
Weaknesses: Requires particular calculator.

URL: http://www.ldeo.columbia.edu/~mspieg/Complexity/Problems/Problems.html
Title: An Introduction to Dynamical Systems and Chaos
Audience: Not specified
Level: Not specified
Content: Tutorials covering the fundamentals of dynamical systems and chaos in an informal manner, with examples involving use of the STELLA package, by Marc Spiegelman, Columbia University.
Strengths: Easily intelligible explanations of the basic concepts.
Weaknesses: Does not go very deeply into the theory; not interactive; not clear who it is aimed at.

Group 4 - General Calculus

URL: http://www.mathacademy.com/platonic_realms/encyclop/articles/dif_rule.html
Title: Rules of Differentiation
Audience: Anyone wishing to look up the rules of differentiation
Level: First year students
Content: Rules of Differentiation and many other rules of the calculus
Strengths: None
Weaknesses: List of the common results, no derivations, no examples.

URL: http://ccwf.cc.utexas.edu/~egumtow/calculus/
Title: Help with calculus for idiots
Audience: College students, especially those majoring in subjects other than mathematics.
Level: First year students
Content: A "read-through" exposition only. Written from the point of view of a student, explaining many topics in calculus in a way that fellow students will understand.
Strengths: None in particular
Weaknesses: No example sheets for students to try, no animations, no student support to speak of.

URL: http://web.mit.edu/wwmath/index.html
Title: Introduction to the calculus (MIT)
Audience: Undergraduate students at the time of writing
Level: First year students
Content: Starts with the basics and develops the topic as a whole. Seems to concentrate on the exposition but does give some examples. Worth a look but the site looked at was by no means complete.
Strengths: Appears to be fairly comprehensive in its long term aim.
Weaknesses: Very few examples for students to try and those that were looked at were not interactive in any way. The package gave the problems and the answers but, for example, no credit rating or second chances. The examples did not contain variable parameters or feedback mechanisms

URL: http://www.hofstra.edu/~matscw/RealWorld/Calcsummary4.html
Title: Applications of the derivative
Audience: Undergraduate students
Level: First year students
Content: Mainly elementary applications of the derivative but does include some "step-by-step" approaches to problem solving which students may find useful and informative.
Strengths: Diagrams and a step by step approach, detailed worked examples which should prove useful to students.
Weaknesses: As is often the case, there is insufficient material for students to practice. Some attempt is made at giving feedback but this is a rather weak area.

URL: http://www.mathforum.com/
Title: Mathematics Forum
Audience: Undergraduate students
Level: First and second year students
Content: Very variable, from, for example pre-calculus algebra to multivariable calculus - a compendium of Web resources for teaching mathematics.
Strengths: Lots of resources recommended for web-based teaching, not just in the calculus.
Weaknesses: Not really a weakness, but the site does need a lot of searching but may well reward the educator with useable resources for classroom use.

URL: http://www.math.psu.edu/dna/graphics.html
Title: Graphics for the Calculus Classroom
Audience: Teachers of mathematics
Level: Suitable for first year undergraduates
Content: A graphics resource intended for teachers
Strengths: Very useful graphics many of which are suitable for immediate inclusion in lessons, tutorials or lectures. Worth a visit.
Weaknesses: None really, this site is offered as a resource for others to use as they see fit.

Group 5 - Foundation Mathematics

URL: http://ole.blc.edu/~rbuelow/FM/WEB1.htm
Title: Foundations of Mathematics.
Audience: Pre-university and first year students
Level: Foundation
Content: This course is intended to serve as a general education course in mathematics and meet the needs for students pursuing Elementary Education. Topics include sets, logic, inductive and deductive reasoning, numeration systems, geometry, probability, and statistics.
Strengths: Interesting site and serves as an example of how such sites can be constructed.
Weaknesses: Non-interactive

URL: http://www.mathmistakes.com/
Title: Foundations of Mathematics.
Audience: All levels
Level: Foundation
Content: This is a list of mathematical mistakes made over and over by advertisers, the media, reporters, politicians, activists, and in general many non-math people.
Strengths: General interest
Weaknesses: Rather thin

URL: http://aleph0.clarku.edu/~djoyce/mathhist/mathhist.html
Title: History of Mathematics
Audience: All years
Level: All levels
Content: General history of mathematics
Strengths: Wide ranging and informative
Weaknesses: Non-interactive

URL: http://www.earlham.edu/~peters/courses/logsys/glossary.htm
Title: Discrete Mathematics
Audience: Undergraduate students
Level: First year students

Content: This glossary is limited to basic set theory, basic recursive function theory, two branches of logic (truth-functional propositional logic and first-order predicate logic) and their metatheory.
Strengths: What is there is good
Weaknesses: Non-interactive

URL: http://pass.maths.org.uk/
Title: N/A
Audience: General
Level: All levels
Content: Informative site covering a variety of topics
Strengths: Very attractive design and still being developed
Weaknesses: Little interaction

URL: http://www.shodor.org/master/gnuplot/software/
Title: MASTER: Modelling and Simulation Tools for Education Reform
Audience: Mathematical modellers
Level: All levels
Content: For interactive models and curricular materials, the Foundation offers its "MASTER: Modeling and Simulation Tools for Education Reform" resources. Some of the interactive models include a galaxy simulation, simulated annealing, biomedical and environmental models, and a simulation of Edgar Allen Poe's "Pit and the Pendulum".
Strengths: Interesting collection of possibilities.
Weaknesses: Cost is not specified

URL: http://www.mathsoft.org/mathematics.htm
Title: Foundation Mathematics
Audience: School and College
Level: Foundation
Content: Starting page linking to interactive resources.
Strengths: Good interaction
Weaknesses: Small content

Discussion

An overwhelming impression gained by the members of this Working Group is of the diversity of web sites related to the teaching of mathematics. They range from cases where lecturers have simply placed their notes for a lecture module on the Web, to sites specifically designed as self-contained distance-learning modules with skilfully designed interactive features. Some sites appear not to be aimed at any particular audience at all, while other sites are simply reference lists of other resources available on the Web.

There is also a wide range of quality in the sites visited, with some contributing nothing that could not be done better in print, while others make full use of the potential offered by current internet technology. Many sites are incomplete or under construction.

This observed diversity and range of quality emphasises the importance of developing the skills of efficient searching. Even so, lecturers seeking to use the Internet to enhance their mathematics teaching need to be prepared to spend considerable time and effort searching for resources which fit their requirements - they may in some cases find nothing suitable and so conclude that the best option is to write new materials themselves. A further issue that needs to be considered is that many of the best teaching materials on the Web are designed to be used in conjunction with other technology, e.g. symbolic manipulation packages, so the local availability of such packages needs to be checked.

One notable omission from most of the sites visited was of facilities for the assessment of students' work. It is suggested that while it is very useful to have learning material on-line, the learning process which we require our students to undergo can never be complete without thorough testing procedures in place. Such procedures should enable the students to practice applications of the theory that are taught on-line (or elsewhere) in order that the twin essentials of competence and confidence be developed on an on-going basis. In this phase of learning it is easily argued that feedback is an essential part of the learning process. A reliance on simple messages such as "Well done!" or "That's right, now try the next question" do not provide any help of a mathematical nature, indeed there is anecdotal evidence to suggest that many students find the repeated use of such patronising phrases very off-putting even to the extent that the learning process is impeded. We suggest that what is required is the development and implementation of mathematical feedback systems which are intended to be a genuine help to those who find the subject difficult. We realise that this is not a trivial problem but believe that if the Web is to ever reach its potential as a means of delivering mathematics to students with limited access to staff then the problems inherent in both self-testing and grade-testing must be addressed and overcome.

It is the experience of those responsible for this report that few Web sites address the problem of how best to use them in the teaching situation. It is also generally acknowledged that sites come and go without warning. This places the learner in an invidious position if such a site(s) is used by a teacher as a core delivery agent. With this in mind, and recognising that there is good, well thought-out material waiting to be used, we suggest that initially course designers might consider the following model in which the web is used to enrich the student experience rather than deliver the core learning material. Essentially, a "sheaf" of web addresses may be brought to the attention of the student at appropriate points in the learning material as shown in figure 1 below.

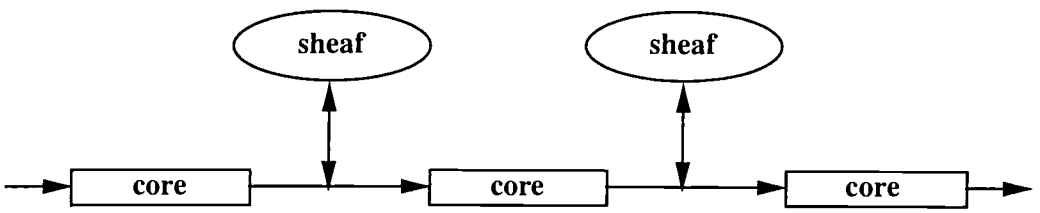

Figure 1 - The Sheaf Model of Learning Material Delivery

The members of the sheaf could be chosen, for example, because they contain particularly relevant graphics, animations, worked examples or quiz questions that the core material does not contain. This places an additional burden on teaching staff since the possible uses of the members of each sheaf will need to be carefully thought out in order to be of real use to the student.

However, the Web is still a young and rapidly expanding technology, and it is anticipated that this and other gaps in provision are likely to filled in the not too distant future.

Conclusions

Potential uses of the Internet as a tool in the teaching of mathematics range from simply giving the students a list of URLs of sites of interest to a total delivery consisting of lecture notes, access monitoring and assessment. However, the important word is "Potential", and it was felt by the group that any description of how to use the Internet would be naive. Articles purporting to describe the use of the Internet very often conclude in a wish list for facilities that can be seen to be useful but either do not yet exist or are only in the stages of primitive development.

Instead, the group decided that a 'starter list' of sites that can be investigated further would be more likely to be of use. It is recommended that these sites be viewed - there is a tremendous amount of material on the Web, much of it worthwhile. Given the diversity in both content and quality of these sites (which only constitute a small sample of what is available), it is clear that teachers will need to formulate a clear idea of how they want to use the web, and will then need to exercise discrimination in choosing appropriate sites. Alternatively, viewing what is already available may provide inspiration to create new materials to fulfil requirements not met by existing web sites. In all cases, whether using existing materials or creating new ones, we emphasise the need to ensure adequate resource provision for students, as detailed in the Introduction.

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