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## Web mathematics anyone?

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*The World Wide Web has had an impact on many areas of teaching and learning. Mathematics teaching however has only recently begun to utilise and develop this educational resource. This paper outlines a research program, which aims to uncover the extent the Internet, in particular the World Wide Web, is being used for High School mathematics education. The program includes searching out discernible Web-based teaching strategies and examining their impact on mathematics teaching and learning attitudes and achievements. Of particular interest is the extent to which deployment of the Web in mathematics teaching might increase student interest in mathematics. The first step in this process is to develop a preliminary typology of mathematical elements on the Web. The nature of these elements, their categorisation and their possible roles in the teaching and learning of mathematics are discussed.*

mathematics, World Wide Web, typology, mathematics web sites, exemplars

### INTRODUCTION

In this era of globalisation and information technology, educators have been urged to equip themselves and their students with skills that will enable them to successfully move forward into the future (Williams and Price, 1999). Doubtless, the next two decades will see new directions in education as "information technology paradigms change and organizational focus shift from on-site schools to networks of educational service bonded by web-oriented coursework and integrated delivery systems" (Miller and Miller, 2001). The wealth of information, activities and opportunities available on the Internet has caused many to advocate its use as a resource tool for teaching and learning (Barron and Ivers, 1998, Skomars, 1998; Butler, 1998). The World Wide Web, in particular, is a flexible environment for lifelong learning and has the potential to change the way curriculum is implemented and the way teachers teach (Stager, 1996; Quinlan, 1997). The uptake of the World Wide Web for educational use, however, is relatively slow in the field of Mathematics and there is a scarcity of literature in this area.

Although use of computers in mathematics education is not new (Hansen and Zweng, 1984), teacher practice in the use of the Internet for mathematics education is at best in its infancy. Despite this, there are a considerable number of web sites for mathematics on the World Wide Web. Among these are active sites maintained by reputable organisations, universities and schools. The sites offer information, activities, games and tasks that can be used to enhance Mathematics education from kindergarten to high school. But to what extent have teachers used them and in what ways are they being used?

For Mathematics to be meaningful, students need a varied and adequate range of examples and a global structure so that misconceptions and perception difficulties can be reduced. Pereira-Mendoza and Kaur (1999) suggested that teaching should focus on relational understanding and on providing a wider and more varied context for the application of mathematics. This call is not very different from the one made more than a decade ago by

Fuys, Geddes et al. (1988) for teachers to look beyond a page of text because of its limitations for manipulative exploration and discovery learning. It has been found that when confronted with mathematical tasks, students tend to think in associative ways rather than constructive ways and they tend to have compartmentalised knowledge structures and are reluctant to relate the concepts unless forced to do so by the problem statement (Evans, 1991).

Numerous types of software programs have been used for the teaching and learning of Mathematics since the 1980's (Hansen and Zweng, 1984). The late 1990's have seen newer and more sophisticated mathematical software, such as *Derive*, *Geometer's Sketchpad*, *Mathematica* and *Maple*, being used in schools as well as in institutions of higher learning. While these software packages are without doubt useful and effective in their own ways, their educational use is restricted by licensing procedures and costs as well as their availability in students' homes. In contrast most mathematical activities on the Web are freely available for educational use (Barron and Ivers, 1998; Skomars, 1998), and are a likely alternative for use in the mathematics classroom. At the time of writing, the author has identified more than 50 active web sites for mathematics teaching and learning, containing numerous associated web pages of colourful, animated and/ or interactive tasks and activities. Recent developments have shown that there are now available Web versions of *Mathematica* and *Geometer's Sketchpad*. *WebMathematica* is a new technology that enables *Mathematica* functionality over the Web. It is currently being trialed in Denmark by the Danish Ministry of Education for use in 24 high schools. The courseware integrated with *webMathematica* allows students to complete interactive lessons online and to submit their homework electronically upon completion through an intranet link (Wolfram Research, 2001).

The World Wide Web, with its myriad of information in written, audio and visual form is particularly suited to classroom use as a resource-based tool for a subject like Language Studies (Sexton, 2001). Characteristics of the Web such as authenticity, topicality, quantity, variety, hypertext links and searchability make it relevant to foreign language learning. What features in the Web would make it particularly relevant to Mathematics education?

An examination of these and other questions relating to the use of the Web in mathematics education requires an extensive research program. Such a program would identify and categorise useful "sites", provide a mapping of relevant "sites" to topics in the curriculum, describe effective teaching strategies that deploy such "sites", study their educational effectiveness and describe impacts on student behavior and motivation. The following outlines the stages of a research study that examines some aspects of the above program.

## THE STUDY

The focus of this study is to determine the extent teachers are using the Web for high school mathematics teaching and learning, the teaching strategies they adopt and the impacts on students.

### Design

This study will be conducted in 3 linked stages. Action in Stage 2 will be contingent to the results in Stage 1.

To determine the extent the Web is being used in the teaching of high school Mathematics, a broad paper-based survey will be conducted on mathematics teachers teaching Years 10 -12 in selected schools around South Australia. A stratified random sample of public and private

schools in urban as well as country areas will be taken. An online survey will be open to any individual who is a secondary Mathematics teacher and is interested to participate.

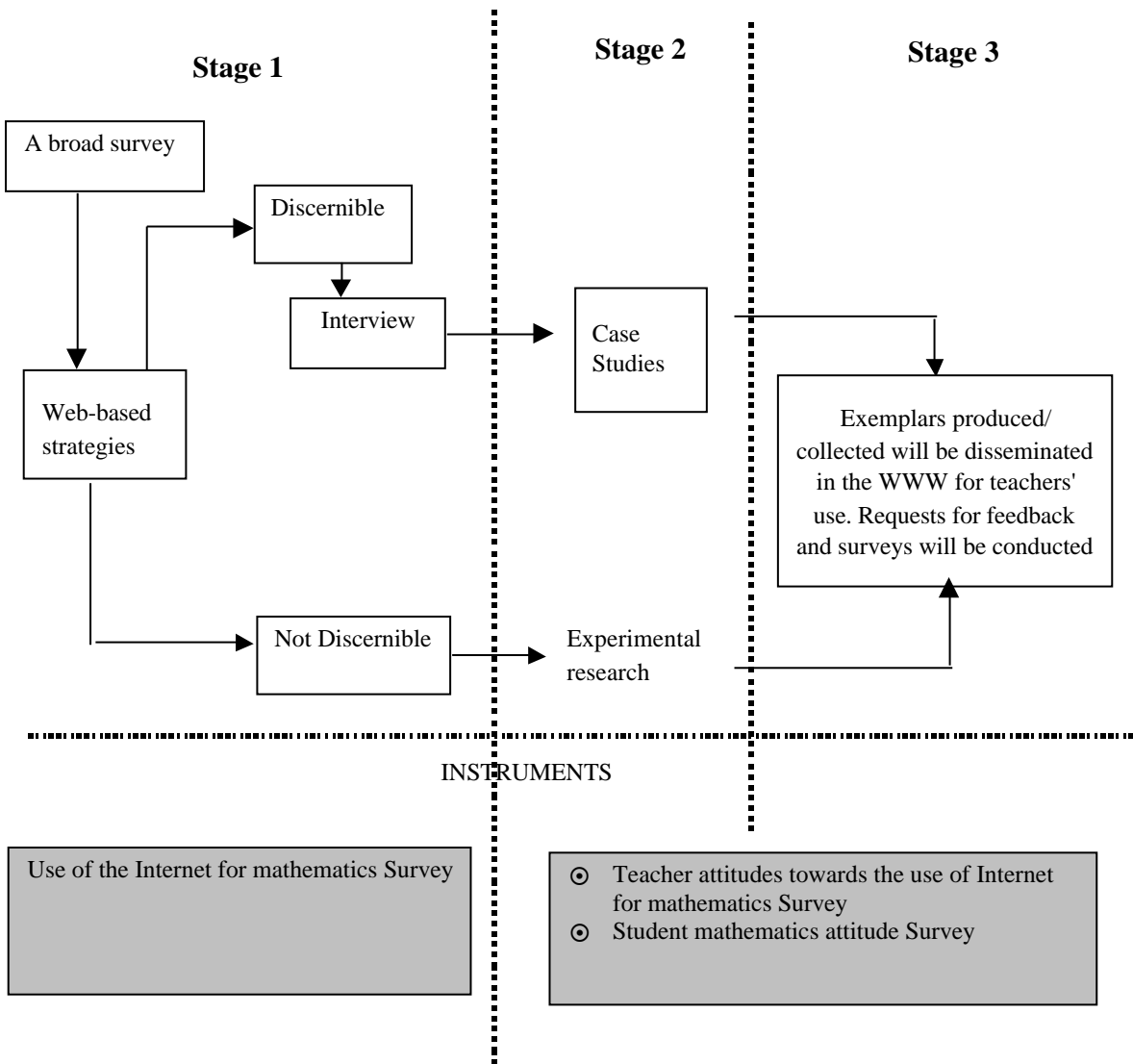


Figure 1. A diagrammatic representation of the methods to be used

It is anticipated that interviews (with teachers who use the Web for mathematics education) will take place to discuss the strategies they have used or are using. Collaboration and observation will begin with interested parties in their respective settings. If there are no discernible strategies, an experimental approach, which incorporates a Web-based unit of work, will be introduced and tested for its effectiveness.

Pre- and Post- attitude surveys and achievement tests will be conducted with samples of Year 10 students whose teachers use the Internet for teaching Mathematics. Year 10 teachers and students have been used because this is the entry level from which many of the concepts of higher mathematics will be introduced. Pre- and Post teacher attitudes' surveys will also be administered.

All surveys are available online in a Web site created for this study. The uniform resource locator (URL) of the site is [www.education.unisa.edu.au/elearn/w3mathsed/default.htm](http://www.education.unisa.edu.au/elearn/w3mathsed/default.htm).

## DISCUSSION

### Towards a typology

As teacher use of the World Wide Web for mathematics teaching and learning is relatively new, it is necessary to consider carefully the types or kinds of learning objects. Differing learning objects need to be categorised and typified. The concept of learning objects is used to ensure a link between the utility of the resource in teaching practice and the features and properties of the object. In some cases a learning object may correspond to a web page, in others it may be correspond to more than one page, in still others a single web page may have a number of learning objects useful for mathematics teaching.

It is instructive to consider an example. The following Web page [http://www.exploremath.com/activities/Activity\\_page.cfm?ActivityID=40](http://www.exploremath.com/activities/Activity_page.cfm?ActivityID=40), entitled “Reflections of a quadratic function” has been classified as interactive and exploratory. The user can explore and compare the graphs of  $y = f(x)$ ,  $y = -f(x)$ ,  $y = f(-x)$ , and  $y = -f(-x)$  for quadratic functions of the form  $f(x) = ax^2 + bx + c$  in the applet on the right hand side of the screen. The parameters  $a$ ,  $b$  and  $c$  can be changed on the sliders and the user can view the corresponding changes on the graph. Comparisons of the different functions are available by clicking on the required box and a resultant graph will be shown in a different colour. This enables any one of the four graphical functions to be displayed individually or collectively for comparisons and investigations to be carried out. There is also a “calculation/copy” function where values of the different functions mentioned above can be calculated for values of  $x$  in step sizes of 1. Cross hairs values of the graphs (necessary for inflection or intersection points) can be obtained by clicking on the “show/hide cross hairs” icon. The graphs produced or the entire screen can be copied on to the clipboard for use in other applications. This page is also linked to a lesson plan, which is available in lab version or lecture version. The lab version is for use in a networked computer classroom whereas the lecture version is for use with a single computer and overhead projector. There is also a corresponding worksheet for student assignment. Clearly interactive engagement with student and discovery learning is supported by such a learning object.

Extensive examination of the some 50 sites suggests a number of groupings of learning objects. Figure 2 shows in graphical form a typology of learning objects on the Web. Two groupings emerge, the first are what might be called “resources” to assist in teaching, and the second comprises “communications” possibilities for mathematics teaching. This diagram shows that apart from having most of the features that are available in stand-alone mathematics software packages, the World Wide Web offers additional features that are peculiar only to it due to its communicative nature.

### *Interactivity*

Interactivity of resources is the key discriminator in their educational usefulness and student activity. The interactive resources can be further categorized as having functionalities which: gives feedback to the user, have exploratory and investigative functionalities, and those, which feature game play.

There are also a comparatively large number of non-interactive sites of mathematical value. These are mainly rich in various types of mathematical information. These consists of articles of historical aspects of mathematics, current mathematics and research issues, archives of topic-categorised word problems, math-related stories, jokes and cartoons and information on free downloads for mathematical use. The other category of non-interactive resources on the Web is the flat 2 or 3-dimensional graphic representations of mathematical objects in areas such as Geometry and Statistics. These are usually colourfully presented and in some cases animated. Most of these graphics are presented in conjunction with explanatory notes and further links.

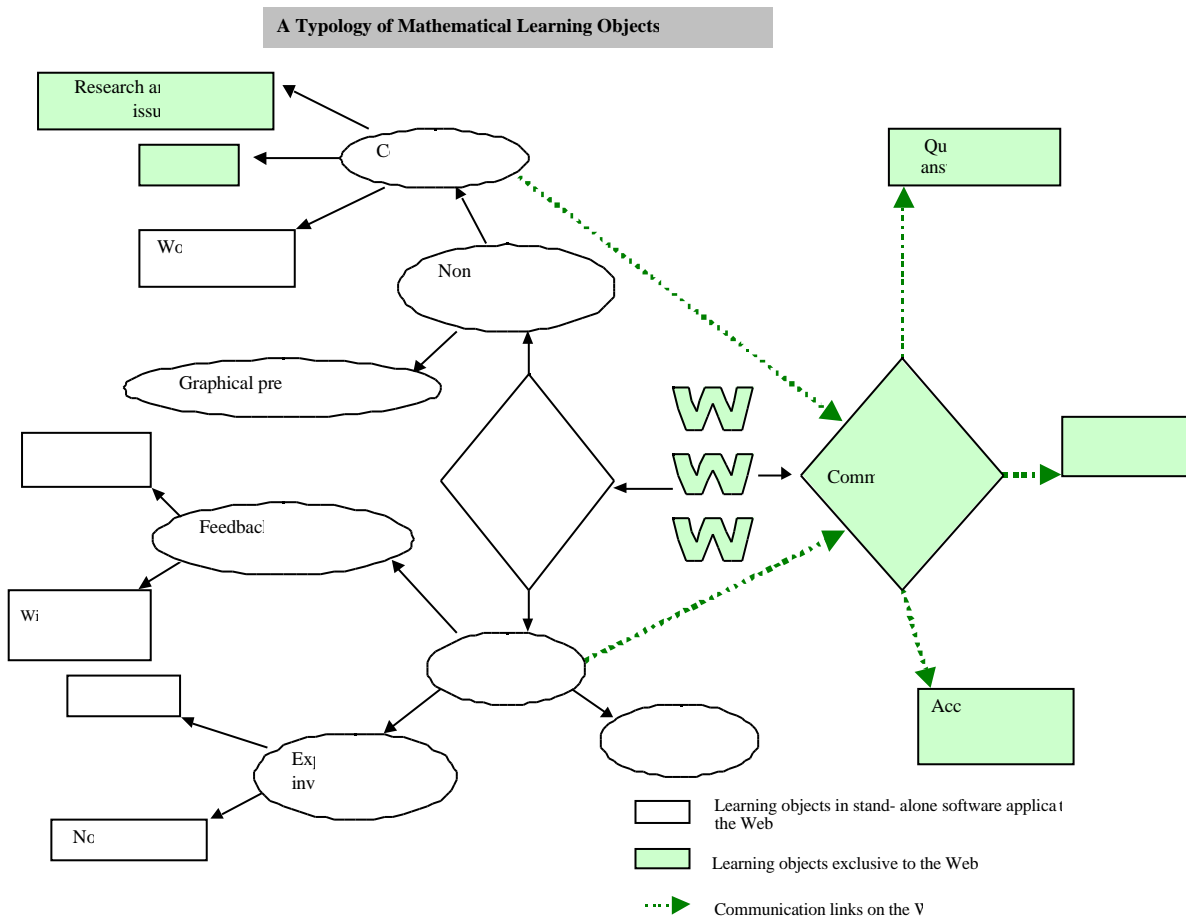


Figure 2. Towards a web typology of mathematical elements

The other grouping features in the communications aspect of the Web. Here the user can participate in online discussions locally or globally; or expect an answer to a mathematics problem from a panel of mathematics educators. These communications are usually made available from the web sites or web pages as links to a forum, a discussion group or Ask an ‘expert’ (for example, Ask Dr Math).

Some exemplars of these elements can be found in the uniform resource locaters (URLs) presented in Table 1.

### Strengths of the World Wide Web

Most software package caters to a particular branch of mathematics; for example, *Geometers' SketchPad* is used for Geometry and *Mathematica* or *Maple* for Algebra. However these are limited by several factors such as licensing procedures and accessibility. On the other hand, the World Wide Web offers a plethora of activities similar in kind to those in stand-alone packages and many of these are public domain. It is a mode of delivery that allows for 'one-stop' accessibility to various forms of mathematical information and activities.

In addition the communications aspect of the Web broadens the possibilities for student learning by allowing the student to extend beyond the limits of the software to gain access to expert opinions, peer discussions and opportunities for obtaining answers to questions.

The World Wide Web is a rapid and relatively cheap means and place to publish educational material. Educational material, such as research and current issues on Mathematics and education, mathematics related jokes and graphics such as cartoons and tried and tested lesson plans, so readily available on the Web, are not correspondingly available in mathematics stand-alone software packages. The vast amount of educational information available on the Web is

something that is not possible within a single CD ROM. The potential also exists for Web based learning environments analogous to WebCT to be built specifically for mathematics teaching.

*Table 1. Exemplars of mathematical learning objects on the WWW*

Interactive Resources		URL
Feedback systems	With follow-up	<a href="http://www.mathcounts.org/GoFigure/Main.taf?function=levels">http://www.mathcounts.org/GoFigure/Main.taf?function=levels</a>
	Without follow-up	<a href="http://cne.gmu.edu/modules/dau/math/dau1_frm.html">http://cne.gmu.edu/modules/dau/math/dau1_frm.html</a>
		<a href="http://cne.gmu.edu/modules/dau/algebra/exponents/exponents_frm.html">http://cne.gmu.edu/modules/dau/algebra/exponents/exponents_frm.html</a>
		<a href="http://cne.gmu.edu/modules/dau/algebra/exponents/exponents_frm.html">http://cne.gmu.edu/modules/dau/algebra/exponents/exponents_frm.html</a> <a href="http://www.calculus.net/ci2/practice/?tag=9200438920658">http://www.calculus.net/ci2/practice/?tag=9200438920658</a>
Exploratory investigations	Animated	<a href="http://www.mathcats.com/explore/xpl/explosion.html">http://www.mathcats.com/explore/xpl/explosion.html</a>
	Non-animated	<a href="http://www.exploremath.com/activities/Activity_page.cfm?ActivityID=40">http://www.exploremath.com/activities/Activity_page.cfm?ActivityID=40</a>
		<a href="http://library.thinkquest.org/3288/myojulia.html">http://library.thinkquest.org/3288/myojulia.html</a>
		<a href="http://www.mathforum.org/sum95/ruth/sketches/algcalc.sketches.html">http://www.mathforum.org/sum95/ruth/sketches/algcalc.sketches.html</a> <a href="http://www.coolmath.com/graphit/index.html">http://www.coolmath.com/graphit/index.html</a>
Games		<a href="http://www.coolmath4kids.com/games/">http://www.coolmath4kids.com/games/</a> <a href="http://www.mathgoodies.com/puzzles/polygon_cw.shtm">http://www.mathgoodies.com/puzzles/polygon_cw.shtm</a>
Non Interactive Resources		URL
Information-rich	Word problems	<a href="http://www.mathforum.org/library/problems/">http://www.mathforum.org/library/problems/</a>
	Math information	<a href="http://www.c3.lanl.gov/mega-math/gloss/knots/knots.html">http://www.c3.lanl.gov/mega-math/gloss/knots/knots.html</a>
		<a href="http://www.cs.uidaho.edu/~casey931/new_knot/pix_ropes.html">http://www.cs.uidaho.edu/~casey931/new_knot/pix_ropes.html</a>
	Research and current issues	<a href="http://www.mathforum.org/social/index.html">Http://www.mathforum.org/social/index.html</a>
		<a href="http://www.mathforum.org/mathed/index.html">http://www.mathforum.org/mathed/index.html</a>
	Lesson plans	<a href="http://www.exploremath.com/lessonplans/">http://www.exploremath.com/lessonplans/</a>
	Freebies for web site	<a href="http://kosmoi.com/Science/Mathematics/Graphs/Encyclo/">http://kosmoi.com/Science/Mathematics/Graphs/Encyclo/</a>
	Math related-Humour	<a href="http://www.csun.edu/~hcmth014/comics.html">http://www.csun.edu/~hcmth014/comics.html</a>
Graphics presentations	<a href="http://library.thinkquest.org/3288/mandel.html">http://library.thinkquest.org/3288/mandel.html</a> <a href="http://www.coolmath.com/polyhedra.htm">http://www.coolmath.com/polyhedra.htm</a>	
Communications		URL
Question and Answer Panels	<a href="http://www.mathforum.org/dr.math/">http://www.mathforum.org/dr.math/</a>	
Discussion Forums	<a href="http://www.exploremath.com/forum/threads.cfm">http://www.exploremath.com/forum/threads.cfm</a>	
Access to Expert Opinions	<a href="http://www.mathforum.org/dr.math/">http://www.mathforum.org/dr.math/</a>	

## CONCLUSION

The literature shows that there is much research on the use of the Internet and the World Wide Web for teaching and learning in higher institutions of learning as well as for distance education. However little is known about its use in high school mathematics education. This is evidenced by the lack of publications thus far in this area. The intention of this paper has been to whet the appetites of mathematics educators, especially middle and high school teachers or home schooling parents, to seriously consider the usefulness of the Web as a useful resource for extending mathematics teaching and learning. Further study will yield some insight into how the Web has been used or will be used in this area. The typology presented is expected to evolve with time and developments of the World Wide Web.

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