Pedagogical Issues in web*Mathematica* Applications In Distance Learning Mathematics

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Abstract

Web*Mathematica* is a new web-based technology developed by Wolfram Research that allows the generation of dynamic web content with *Mathematica*. It combines the computational engine of *Mathematica* (the *Mathematica* kernel) with web pages that are written in the HTML language and creates a synergism that is a useful tool for enhancing teaching mathematics and mathematically oriented topics. With this technology, the distance students should be able to explore and experiment with some of the mathematical concepts. Technology is no longer an issue as we have more technology than we know how to use and the focus must now be directed towards what matter most - effective learning and good teaching. The learning experiences must be well organized and integrated in a comprehensive modular approach to facilitate for continuous and student-centered-learning. The design of instruction is by far the most important parameter in an effective teaching and learning equation as the discipline approaches higher orders of learning skills. This paper will elucidate the pedagogical issues in the application of web*Mathematica* in the distance learning environment and the shape of the future "classroom" as well as relevant educational strategies towards improving mathematics education.

Area of mathematics education: use of technology
Relation to the theme: making mathematics accessible to adult distance learners

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Introduction

The demand for 'anytime-anywhere' education is now a common feature in the current educational background and thus further enhances the application of distance education technologies in the shift towards networked learning in the creation of a knowledge-based society. Distance education is planned learning that normally occurs in a different place from teaching and as a result requires special techniques of course design, special instructional techniques, special methods of communication by electronic and other technology, as well as special organizational and administrative arrangements [1]. The growth of Internet-based distance learning will have a significant impact upon traditional education and is now finding its way into high school and university. The growth of Internet-based distance learning will influence traditional education as the availability of sophisticated software that everyone can use, in school and out. As suggested by Dunn [2], this occurrence will blur the distinctions between distance learning and traditional education.

With the advancement of ICT, innovative use of technology at early tertiary level can motivate and enliven the students in the learning of mathematics especially in distance learning environment. Recent trends in improving mathematics teaching at tertiary level include the use of computer algebra system. Computer algebra system such as Scientific WorkPlace, LiveMath, MATLAB, Maple and *Mathematica* has the capability of doing

1. numerical and symbolic computations
2. approximate numerical solutions
3. graphic manipulation

The versatility of *Mathematica* computer algebra system in particular makes it more attractive to be used as a tool for teaching as well as in research. At IYTE, *Mathematica* was integrated into the first year Calculus course in order to provide engineering and science students with a sufficiently deep knowledge of mathematics and science [3]. Effective use of *Mathematica* requires training the mind to formulate problems in new ways and not just apply new syntax to old methods. An initiative was also made to use *Mathematica* in teaching mathematics to distance learners and giving the final year students a wider scope for doing final year project [4]. The usage in distance learning mode was however very limited due to the cost of software and hardware and difficulty in teaching students the necessary skill in using the programs at the distance.

One significant change in distance education is the increasing emphasis on the student learning, rather than the institution teaching. Web-based instruction is student-centered and students control the pace of learning, they make decisions when and where to study. One of the most exciting new technologies for dynamic mathematics on the World Wide Web is a web*Mathematica*. This new technology developed by Wolfram research enables instructors to create web sites that allow users to compute and visualize results directly from the web browsers. This is achieved by integrating the *Mathematica* computer algebra system with the latest web server technology. The students use the existing Internet browsers such as Internet Explorer or Netscape as an interface to web*Mathematica* and they do not need to know *Mathematica* and install the program in their machine to use it. Web*Mathematica* is based on a core technology called

Mathematica Server Pages (MSP) [5]. MSP technology allows a site to contain HTML pages, which are enhanced by the addition of *Mathematica* commands. When a request is made for one of these pages, which are called MSP scripts, any *Mathematica* commands are evaluated and the computed result is placed in the page.
Through web*mathematica* the instructors and students can fully utilized the computational power of *Mathematica* for pedagogical applications. In view of the emergence of this new technology, there are some important issues that relate to the instructional design of on-line material with web*Mathematica* for effective learning.

Pedagogical Issues

Essential to all types of learning is the pedagogy, which is the art and science of teaching. Designing and developing on line learning material with web*Mathematica* presents special challenges. The instructional design process is particularly more important in distance education as instructor and students share limited common background and typically have very minimal face-to-face-contact. The online learning material need to be structured and communicate the knowledge in ways that enable students with diverse learning styles to understand and apply the knowledge that has been learned. Most often, the instructors are called to be a one person architect-designer-builder for producing online material. The development of effective online learning environment require a course team approach that should include instructional designer, subject matter expert, programmer in web*mathematica* to identify and consider the crucial elements of course design, learning theory and learning strategies. The issues concern with the goals/objectives, content, design approach, methods and strategies of using web*Mathematica* in distance learning mathematics as well as in the traditional face-to-face teaching.
Web*Mathematica* is easy to use but not quite straightforward to set up and develop. What type of learning material is suitable to develop with web*Mathematica* for effective learning? Though with web*Mathematica*, interactive calculations and sophisticated visualizations can be added to virtually any web page, the instructor has to be selective in developing online material with web*Mathematica*. With web*mathematica*, we can do virtually all the mathematics like differentiation, integration, plotting graph etc. But the important questions do the students understand the process and the underlying concepts? Some students might just use it like calculators to get quick answer and not much of mathematics is learned. Not everything can be done should be done with web*Mathematica*.
The current uses of computers in learning is often driven by technology issues rather than learning issues. It is not so much of the technology that being used but rather how the problems being posed using web*Mathematica* and how it works in a particular mathematics curriculum. The instructors need to consider carefully topics that best represented by web*mathematica* to maximize learning. It is well known that visualization has a major impact on the understanding of mathematical concepts. With web*Mathematica* to do on line computation and interactive on line visualization of *Mathematica* graphics in web pages, it can make learning mathematics among adult learners more fun to learn. Besides textual descriptions, images can be used as a communication medium to convey mathematical ideas/results in a comprehensive way to

the students. Examples of this aspect is using web*Mathematica* to graph the Ode's that model dynamical system and requiring the students to make interpretation based on the graph. The students are expected to be able to make conclusion and deduction of the stability and of the long-term behavior of solutions.

Rapidly changing world continuously demand new skills and new thinking skills which make adult learning and lifelong learning increasingly important. The majority of students at any distance learning institutions are working adults and between the age of 28-35 years old. Learning mathematics at a distance can be a daunting experience among adult learners. Having left formal education for several years, they approached the course with anxiety. High level of anxiety can impair student's performance. It is one of the main tasks of the instructors to eliminate fear of mathematics and to make the subject more fun and friendly. Well designed interactive "virtual manipulatives" of mathematical concepts like limits and graphing with web*Mathematica* can reinforced their understanding and can be fun.

Another important issue is to determine the types of instructional activities needed with web*Mathematica* for the learning processes and learning outcomes to foster critical thinking. Mathematics students need to acquire higher order skills to be able to think mathematically and be able to apply what they learn to new situations. How can web*Mathematica* be used to teach high order thinking skills such as puzzles, reasoning and problems solving. Instructors can use the various e-learning methods and strategies that include presentation, demonstration, drill and practice, tutorials, simulations, discussion, interaction, modeling, facilitation, collaboration and motivation.

We recognize that learning mathematics at a distance using technology without technological and instructional support is not easy and less likely to be successful. Feedback from students and constant consultation are through electronic means. An important component of web-based learning is computer-mediated communication (CMC) which is capable to re-humanize distance learning. The effective use of asynchronous CMC like e-mail, listserves and discussion forums will ensure effective interactivity which is fundamental to online pedagogy.

With the increase number of student's population, the lack of individualization is seen as the root of today education system. All students are different with different background, interest and learning styles. With the current learning model, every student tends to be provided with the same learning environment. New approach should be explored to incorporate the use of highly interactive computer-based learning material with software capable of combining learning and assessment into one seamless activity [7]. Assessment could then be used to determine what material is to be presented next. Online tutorial and testing using web*Mathematica* could be designed to help diagnose student's mathematics skills and create personalized study plan based on student's test results.

Examples of web*Mathematica* Scripts

Examples of interactive learning material developed with web*Mathematica* for Calculus and Differential Equation courses can be accessed respectively at

- http://gauss.iyte.edu.tr:8080/webMathematica/math/index.html and
- http://gauss.iyte.edu.tr:8080/webMathematica/MSP/faisal/sistemlinear.

The instructors design the web page that discusses particular idea or concept and Gagne's conditions of learning theory serve as the basis for designing the instruction [8]. The typical material is organized in modular form with the instructional objective clearly spelled out at the beginning of the lesson. The topic of discussion is the concept of limit. Adult students as well as first year traditional students face difficulty understanding the basic concept of limit. With web*Mathematica*, a visual representation might be useful in the form of animation and interactive to gain student's attention. It invites students to explore many interesting questions about limit and to gain insight by computation and visualization. The answer to what is the limit of a function is not the main instructional goal. Here is the source code for the animation of limit.

```
<HTML> <HEAD>
<TITLE>Animate Limit</TITLE> </HEAD>
<BODY bgcolor="#faff00">
<H1><CENTER>Animate Limit</CENTER></H1>
<FORM ACTION="AnimateL" METHOD="POST">

Animation of lim x->xo f[x]=L. <br>
<%Mathlet SetSecurity[]%>
<%Mathlet Clear[a,l,f] %>
Input xo, x->xo:
<INPUT TYPE="TEXT" NAME="xo" ALIGN="LEFT" SIZE="8" >
Input a function:
<INPUT TYPE="TEXT" NAME="fon" ALIGN="LEFT" SIZE="15"> <BR>
<%Mathlet
      MSPBlock[ {$$fon,$$xo},l=Limit[$$fon,x->$$xo]] %>
<%Mathlet a=MSPToExpression[$$xo]%>
<%Mathlet f[x_]=MSPToExpression[$$fon]%>
<%Mathlet <<Graphics`Colors` %>
<%Mathlet MSPShowAnimation[Table[
      Plot[f[x], {x, a - 4, a + 2},
        Epilog -> {{Blue, PointSize[0.04], Point[{a, l}]}, {Green,
              PointSize[0.03],
              Point[{a + (10 - k)/10, f[a + (10 - k)/10]}]}, {Green,
              PointSize[0.03],
              Point[{a - (10 - k)/10, f[a - (10 - k)/10]}]}, {Red,
             PointSize[0.03], Point[{a - (10 - k)/10, 0}]}, {Red,
              PointSize[0.03], Point[{a + (10 - k)/10, 0}]}},PlotRange-
>{-10,10}], {k, 0,9}]]%>
<HR>
<INPUT TYPE="Submit" NAME="btnSubmit" VALUE="Evaluate">
</FORM>
</BODY>
</HTML>
```

The same instructional strategy is used in introducing the qualitative method for the autonomous differential equation. Using the graphics capabilities of *Mathematica* computation engine, animation of the flow and the graph of the ODE are produced. The students will experiment with various autonomous equations and study the patterns of the generated graph by web*Mathematica*. Students will then investigate and make a conjecture about a pattern of the generated graph and relate them to the eigen values of

the system equation. Here is the source code for the computation of eigenvalues and the generation of phase plane graph.

```
<!--
 This MSP demonstrates the use of page scoped variables and
MSPToExpression.
-->
<%Mathlet
      aygen = Null;
      If[ MSPValueQ[ $$expr],
            aygen = MSPToExpression[ $$expr]] ;%>
<HTML>
<HEAD>
<TITLE>Eigen</TITLE>
</HEAD>
<BODY background="back.gif" >
<H1>Linear Systems</H1>
dx/dt=f(x,y) <p>
dy/dt=g(x,y) <p>
 This is the system you are going to work on <p>
In this problem f(x,y)=ax+by and g(x,y)=cx+dy
<FORM ACTION="dys" METHOD="POST">
<%Mathlet <<Graphics`PlotField` %>

Enter a function f(x,y)=ax+by:
<INPUT TYPE="TEXT" NAME="fun" ALIGN="LEFT" SIZE="6" VALUE =
   "<%Mathlet MSPValue[ $$fun,  "3x-2y"] %>"
>

Enter a function g(x,y)=cx+dy:
<INPUT TYPE="TEXT" NAME="gun" ALIGN="LEFT" SIZE="6" VALUE =
   "<%Mathlet MSPValue[ $$gun,  "x+y"] %>"
>
Now write down the coefficients of f and g as a matrix A:<br>
<INPUT TYPE="TEXT" NAME="expr" ALIGN="LEFT" SIZE="15" VALUE =
   "<%Mathlet MSPValue[ $$expr,  "{{3,-2},{1,1}}"] %>" >
<%Mathlet f[x_,y_]=MSPToExpression[$$fun]%>
<%Mathlet g[x_,y_]=MSPToExpression[$$gun]%><BR>
<INPUT TYPE="Submit" NAME="btnSubmit" VALUE="Evaluate"> <p>
The coefficient matrix you have typed is: <p>
<%Mathlet MSPBlock[ {$$expr}, MatrixForm[$$expr]] %><p>
The characteristic equation is <p>
<%Mathlet MSPBlock[ {$$expr}, Det[$$expr-r IdentityMatrix[2]]] %>
The eigenvalues of A are <p>
<%Mathlet MSPBlock[ {$$expr}, Eigenvalues[$$expr]//N] %><p>
The eigenvectors of A are<p>
<%Mathlet
If[ aygen =!= Null, MSPBlock[ {$$expr}, Eigenvectors[$$expr]]//N] %>
<%Mathlet MSPShow[ PlotVectorField[{f[x,y],g[x,y]},{x,-2,2},{y,-2,2},
PlotPoints->10,ScaleFunction->(.5#&),ScaleFactor->None]] %><BR>
<tr><img src="webMathematicaFooter.gif" width="550" height="100"
align="right"></td></tr>
</FORM>
</BODY>
</HTML>
```

Conclusions

It is well known that students learn more quickly, and with less pain, when concepts can be demonstrated interactively. This can be achieved with Web*Mathematica* which is web-based learning facility that is intended to help distance learners to study mathematics at a time and place which is suitable to them. However, there is a limitation of the web*Mathematica* as a teaching tool and if not properly plan it can potentially be a major cause of wasted time. Problems that require visual representation like graph, diagrams, animations and moving images is great with web*Mathematica* that respond to students questions, answers or commands. Another potential set back is slow connection and frequent server problems which can cause frustration to students accessing web*Mathematica* from their home and in turn can further affect time efficiency.

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