The Online mathematics course – Can it work?

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Abstract. This paper contains discussion of four aspects of online course design and deployment for mathematics. Addressed are several of the most asked about issues of online courses. Included as well is a discussion of the issues pertaining to online mathematics presentation, typography and computation. General topics range from basic course design considerations such as content issues to advanced features such as streaming multimedia. The emphasis is on what can be done without extensive training. Because there are so many facets to course development, learning curves are unavoidable. Their number can be controlled but at the expense of scope. Overall the reader may view this article as a review of the terms, the features, and the software needed for creating and operating such a course.

Web-based and Web-assisted courses

The grand scope of an online course sweeps from creation of the course to interactivity to assessment. Since no one has more than a few years experience at online teaching, an essential part of course design is redesign. But, before the redesign must come the original course creation, and this prospect can be daunting.

Many online courses have humble beginnings, just as Internet itself. Less than ten years ago the first online course homepages emerged; they contained basic information such as the text and syllabus and not much more. Most students didn't use them; many didn't even know they were there. Gradually instructors enhanced their course homepages by adding useful links and then homework assignments and labs. Those more adept at math-on-Web skills added practice exams and homework solutions. In the very early days, the LaTeX2HTML converter was widely used as the only alternative to massive math content on the Web. In recent times, alternatives have appeared, and together with the typography we have seen more and more course content with full math-on-Web features, graphics, animations, online assessment and interactivity. It is not uncommon to see course Websites with full streaming media lectures. (See [Oblinger, 1991], [Brusilovsky, 2000], and [Cunningham, Francis, 2001].) Today, few students will risk **not** looking at the course page for fear of missing essential course features. Today, many online courses are designed from the ground-up, the net result being a complete Internet-based mathematics course. This is not to say it will used for distance learning, which is another subject altogether.

Aside from distance learning there is the important distinction between Web-based and Web-assisted courses. The former is a full measure more extensive and should be considered a complete package. The latter emphasizes certain aspects of the course, whether applets for interactivity or special examples, or even a bulletin board; Web assisted courses are best distinguished by the continuing presence of the lecture or classroom activity.

To create an online course, one must consider the scope of design, software tools, student deliverables, and security as major factors, each with multiple sub-factors. As for any educational publication, style is extremely important, and for the Web, especially so. See [Lynch, Horton, 1999]. Each should be considered thoughtfully, even though not all can be resolved right off. In this paper, we highlight a few of them.

The scope of course design must address among others the content and interactivity issues. Content is the most important. One shortcut used by many authors is to use a print textbook as the sole source of mathematical content. Remarkably, irrespective of the modern mathematics textbook design, extensive editing, and multiply colored production, few are written for self-study. They are written to be the print-companions of the traditional lecture course. Indeed, it is for this traditional lecture/recitation environment that almost all textbook authors write. For the online course, over reliance on any textbook to convey mathematics content may well produce disastrous results. One alternative, that of writing the complete contents oneself, may require too much time and of course there is no guarantee of the results there. For additional discussion on tools and methods see [Bogley, Dorbolo, Robson, Sechrest, 1996, 1998] and [Robson, 1999].

However, a blend of a print text with personally generated supplements can work well. Consider the following three supplements. Generate a news-type page with full-rich mathematical content that is aimed at answering individual inquiries in a more general way for all students to read. This is relatively easy to produce and easy to maintain. Another is to post complete solutions to homework problems, and additional examples that illustrate some particular point. In both cases supply more than the usual detail found in the text. The third supplement, and a surprisingly important one, is posting practice exams. Students, it appears, have unusual tenacity about working these problems out. It may be that they feel that while homework has theoretical importance, practice exams have significant and practical importance. A lengthy practice exam may provide the student with an important learning instrument. Other methods including threaded discussions and chat rooms have merit, as well. These require continual monitoring, and that translates into additional, possibly substantial, instructor time.

Interactivity

Interactivity is the Internet buzzword these. What is it? And how can anyone put it into his or her Web-based course? A wide scope interpretation would define interactivity as anything that *communicates* with the student beyond mere text and static images. This includes animations – animated GIF images, for example. Animations, while simple to create for the web are not that easy to simulate in class. Most of us can remember trying to show our classes how the secant line may approach the tangent line by "moving" a fixed chalk line to the (chalk) tangent line. The result is not always convincing. With simple animations, these motions are both possible and effective. If the student cannot attend the lecture to see your simulated animation, he or she can see the real thing on the Internet. Well-crafted animations, and by the way brilliantly colored graphics, have a certain fascination for many students. Animations are easy to make with tools like Maple, Mathematica, and MATLAB, MathCAD, Flash, Java, and JavaScript. With respect to the CAS (Computer Algebra System) tools such as Maple, however, some postproduction may be necessary to render the animation more convincing. (The Web site www.academicsolutions.com/workshop gives a brief discussion, demonstration, and tutorial on various ways to create animations for mathematics courses and discusses the post processing of Maple animations. The interested reader may also view Larry Husch's home page at http://www.math.utk.edu/~husch/ for some interesting animations using Flash and Java. A general animation tutorial from the Webmonkey site is available at http://hotwired.lycos.com/webmonkey/multimedia/animation/tutorials/tutorial1.html. It emphasizes general graphic design for commerce and therefore has limited utility for mathematics courses.)

The next level of interactivity requires the student to interact in some meaningful way with the computer, most often by using the keyboard or mouse. For example, the student may enter the acceleration of gravity and elasticity of a ball to study how it bounces. Such interactivity almost always requires programming. Whether one uses Java, JavaScript, Flash, Mathematica, or MATLAB, special skills and/or services are needed. Each can be programmed (all in different languages of course) to generate remarkable interactive and truly educationally valuable applets. Java remains the most powerful tool available today. JavaScript, which lacks Java's powerful graphics API, is also very useful. However, it is Flash[1] that is coming on as a strong competitor. The newest version, Flash 5, contains a full scripting language. This together with its vector graphics capabilities and relatively shallow programming learning curve may give a broad base of instructors a powerful animation and interactivity generator.

Two CAS engines, Mathematica and MATLAB, also allow interactivity over the Web[2]. However, the user needs special Web components and CGI-bin access on their server. Neither is learned quickly. For these and all interactivity creation tools, it is strongly recommended that the user take a course. For example, the MAA and ICTCM both offer short summer workshops on various software tools and Web course design.

Lastly, there is one type of interactive applet that everyone can construct, have working, and uploaded, all in the same day! Using active-X components generated by FrontPage 2000 or 2002, it is easy to create interactive applets involving almost anything possible with a spreadsheet and a graph or graphs based on the spreadsheet. For example, it is easy to create an interactive applet allows students to see changes in the graph of a quadratic as the student enters its coefficients, or roots. Important drawbacks are that users need Internet Explorer running in a Windows environment and editing the active-X script is virtually impossible. For example, the code for the graph of quadratic equation with user input coefficients is more than 600 lines – all generated by FrontPage. We mention, for completeness, LiveMath (Review of LiveMath Maker 3.0, by Marcia Tharp, College Mathematics Journal, May 2001) and MathCAD, both excellent programs. Both allow some interactivity and ease of use with the Web. Indeed, MathCAD exports documents in HTML format making graphics and mathematics as GIF images, all by selecting the Save As button.

Overall and notwithstanding FrontPage convenience, the more intensive the programming required to produce an interactive applet, the more browser sensitive it becomes, a daunting drawback for which we have no time to discuss here.

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[1] Flash, a product of Macromedia, is priced at about $100 for educators.
[2] We emphasize that for interactivity, we imply that the client does not need special software. Plug-ins we allow if they are free or have low cost.

Finally, it is most important to use the interactivity in some meaningful way. Most students, perhaps already over stimulated by the world around them, have little use for visual curiosities in their college courses. When designing interactive functionality pay special attention to its purpose, its appearance, and ease of use. The serious developer should be willing to combine several tools together to obtain the animations and interactivity he or she desires. For mathematics courses, using a CAS engine, if only for its graphical imagery, is nearly essential.

Assessment

The third component of the Web-based course is the set of student deliverables. What you ask your distance or local students to deliver will certainly impact your course design. If the course is supplementary to lectures, there is wide latitude on what can be done. Most likely traditional homework, quizzes, and exams, all synchronously ordered and arranged will be the assessment methods of choice. For a distance or Web-based course, the deliverables are not as clear. For graduate courses, where the students are all adult learners, the use of homework, class projects, and take-home exams have worked very well. [Allen and Pilant, 2002, 2003, and Allen 2001a, 2001b]. Others use windowed exams to be taken over the Web and delivered to a database using a course management system. For reference, a windowed online exam is any online exam available to the student only for a certain *window* of time. Within the WebCT course management system, the add-on tool *Respondus*, is an effective exam generator.

However, for undergraduates, exams must be given. Local and distance Web-based courses are now usually differentiated. Local courses have on campus students. Naturally, this makes exams, help, and peer associations easy to resolve. Distance Web-based courses are very much different. With classes diverse in almost every way, the tasks of assessment are more difficult. Exams must be proctored, and they must windowed. Therefore remote proctors need to be identified and engaged. Security is a key issue, but is too complex to discuss here. Course management systems are an important tool for many online courses. For locally administered Web-based courses, where the scheduled class period takes place in a computer lab and there is no lecture, the traditional exam type schedule is used. However, to keeps the students on task, many more quizzes are given each semester. This has served to keep students on task on a daily basis. [Allen, Stecher, Yasskin, 1999]. Nonetheless, comparative work has been done on giving online examinations to traditional lecture classes. (Hall, Pilant, Strader, 1999])

Tools for creating online assessments are available. Within every course management package such as Blackboard, WebCT and about forty others there are extensive tools for online exam creation – and online grading. All are unsuited to the mathematics environment. Quite a number of freely available tools can be downloaded. For example D.P. Story of the University of Akron has developed the ExerQuiz package that uses PDF files and JavaScript. (URL: http://www.math.uakron.edu/~dpstory/webeq.html). Another, rather intuitive quiz generator, Quizmaker 1.2 can be downloaded or used directly from the Web. (URL: http://www.academicsolutions.com/workshop/javascript/mq12/quizmaker12.htm)
Neither of these can be described easily, but both allow for mathematics symbols. Quizmaker allows the inclusion of any valid HTML code. So, whether MathType or

Scientific Notebook, or even LaTeX2HTML is used to create the native HTML code for mathematics display, it can be pasted directly into the quiz question, answer, or feedback entry boxes.

Math-on-Web

Many online course authors are using methods that will attract the students to learn from the online materials. The proper medium for readable mathematical content is excellent mathematical typography. While mathematicians can get along with most any "fortran-esque" script, learning students cannot. It is one task to learn mathematics but another of compounding that with inadequate or obscure mathematical notation. Much has been written about how to do this. [Allen, 2000] This note, to be of manageable size, cannot do much more than mention the basic options. They are: (1) PDF, (2) Converters, (3) Graphics, (4) Plug-ins, and (5) MathML.

The simplest way by far to put math online is to use acrobat files. The Adobe Acrobat portable document format (PDF) is by now ubiquitous. It does by far the very best job of rendering your mathematics page exactly as it appears in print. Indeed, the Acrobat Distiller operates through the print daemon meaning that user may focus completely on the creation of the content itself. One needs to be mindful of font embedding problems. The course creator needs only make a link within the Web. The principal criticism is that PDF documents are more-or-less static, not yielding simply to dynamic changes. Several fine efforts have been made, however.

Among the several converters on the commercial or free market are (Microsoft) MSWord and LaTeX2HTML, though the later is strictly a converter. Both can be used convert an existing native document to HTMLfds. This has meant in recent years that mathematical constructs are rendered as GIF images with the converter aligning them with the text. Converters have steadily improved by increasing the number of Web features allowed. Full links, bookmarks, tables of contents, and the like are certainly possible. For TeX/LaTeX users, the book by Goossens and Rahtz contains a wealth of information on integrating mathematics into Web pages The MSWord conversion is done with many XLM constructs, making the file size quite large and moreover making post conversion editing difficult. The Word Perfect conversion yields a somewhat cleaner HTML file. A companion program to Word and Word Perfect is MathType, which has been the full-featured mathematics-typesetting alternative to the native equation editor. Now in version 5, MathType can create output in the GIF imaged style or MathML. The instruction manual is one of the very best you will ever read.

Scientific Notebook [Wilkin 1998] has been available for several years; it has been improving steadily. With it, not only is mathematics painlessly simple to create, it can be displayed over the Web and is inherently live with the Maple engine running in the background. Not strictly a plug-in, clients need the program to view the native TeX files. However, the latest version, 4.0, does allow HTML export. Operating similarly to LATEX2HTML, it renders mathematics as GIFs shown inline with the HTML text portion.

A quite remarkable (and inexpensive) plug-in type product is Tech Explorer. With it TeX and LaTeX files are rendered accurately within Netscape or IE. Hyperlinks, footnotes, and a number of other normal html features can be inserted directly into the

TeX file. Tech Explorer is robust, coming in versions for Windows, Macintosh, Linux, and Unix operating systems. It is certainly the first choice (with PDF) for the display of legacy LaTeX files, where little time is available for technical modifications. For mathematicians that need to give presentations and are a bit tired of being showed up by the glitzy PowerPoint presentations from nonmathematical colleagues, Tech Explorer offers hope. Within the Windows system Tech Explorer allows the input of LaTeX and MathML scripts as objects that the user can insert directly. It's quite simple. Just paste or type the TeX codes from your LaTeX file into an input field; it is displayed instantly. One can even adjust the colors of the fonts to accommodate various styles. MathCAD files can also be exported to an html format for use with Tech Explorer. Math Type also works with Power Point, and has for some time. This list is by no means exhaustive.

Course Operation

Online courses can reach a vast population of students for whom collegiate mathematics courses are otherwise unavailable. Web-based and Web-assisted courses give students resources not available in the traditional format. It is worth noting that the revered lecture format is the centuries' old compromise to teach the many by the one. In an age where we have identified verbal, visual, and tactile learners, traditional teaching methods have been abandoned in favor of newer face-to-face teaching methods. There are constructivist and instructivist methods; there are normal and dynamic learning communities. The impact of philosophy of postmodernism has changed the world of teaching and even the definition of learning. See [Wilson, Teslow, Osman-Jouchoux , 1995] [Berry and Sharp, 1999], [O'Malley, Scanlon 1990], and [Berry, Nyman and McIntyre, 1999].) The point we emphasize is that Web-based materials offer another and possibly very important channel for information delivery. Moreover, they can offer options and venues beyond the scope of classroom teaching. Closer to home but not exactly within the world of technology, Laubenbacher and Pengelley [1996] have reported successes in teaching mathematics with original source materials.

To be specific, we assume that the Web-based course is offered without a lecture and that some of the students are not on campus. Furthermore, we will assume that the all students have been certified to be reasonably independent learners without reading difficulties. Qualifications are important; a sure way to defeat a new instructional enterprise is to admit students with learning difficulties. As we all know, teaching reluctant learners is a formidable challenge and one for which many of us fail. The type of course should favor mathematical training as opposed to mathematical concepts. To be sure teaching Web-based undergraduate courses in advanced calculus, topology, or abstract algebra without a lecture may not work well. On the other hand, when many of the theoretical foundations of numerical analysis, cryptography, and matrices have previously learned, these courses can work well as Web-based. Nonetheless, we have only just begun to explore the scope of Web-based learning of mathematics.

To operate a Web-based course requires an active strategy. Communication with students, bulletin board and chat, feedback quizzing, online testing, news, assessment, online help, homework collection and return, and proctoring examinations are many of the considerations. As always, good communication channels to students are key. We consider the critical channel of online help.

Students will have questions; answers must be provided. If the questioner arrives during office hours, normal procedures are in play. When the question comes by email or fax, the instructor's teaching experience is critical. Here you must interpret the question and decide just what about the question the student needs answered. Answers should be relatively complete, with full details supplied. Often the student will simply read a problem wrong. This is easy to handle. Yet, all of these questions – easy, hard or in between, take time.

Special software tools can also transact online lectures and help. Net meeting (Windows only) is an example. Students and teacher can interact with voice and software tools. While not perfect, acceptable results obtain. Other software tools include NetTutor, TutorsEdge, Interwise, Centra, and many others. Here's how these tools work. Synchronous hours are arranged. At the appointed time the instructor logs in to a specific URL, students wishing to participate in the day's session log in as well. Each participant sees the list of those logged in. The heart of the communication is by whiteboard or voice. The instructor has the master controls. He or she can allow or deny privileges such as writing on the white board or speaking. Students can (electronically) raise their hands to ask questions; the instructor answers questions privately or in class format. All can participate in the session. Interestingly, the instructor can give an entire lecture this way, using prepared slides, taking questions, answering questions, and making comments. It's not too much different than a lecture, except more preparation is required. Online office hours can be conducted the same way.

The tricky part is how to help with the math, symbols and all? First of all, most students don't write mathematics during office hours. Usually they ask a question about some homework exercise or some derivation. The instructor can respond with words, though often some mathematical explanation is necessary. With the exception of NetTutor these tools do not allow mathematical notation on their white board – the common drawing and writing area. So, using another mathematical preparation tool such as MathType or Scientific Notebook, the instructor typesets the appropriate mathematics, captures it and pastes it to the white board. With the mouse and various drawing tools, the instructor can annotate the math while both student(s) and instructor discuss its meaning.

Mathematical typography is the greatest drawback. The instructor must have the skill to create math, virtually on the fly. There are a couple of shortcuts, for example using a commercial whiteboard product (e.g. Aiptek) to actually write mathematics and then capture that. Another way is for the instructor to actually write the math on paper, scan it to a graphic file, capture and display that. One good feature of these online communication products is that the online sessions can be saved. Student unable to log in during the session can gain the full benefit of it later. Faculty can refer students to such sessions. The timesavings of not having to give multiple sessions for answering the same question are altogether new to education. Its value alone will almost certainly have a future regardless of the progress of online education.

Summary

It hardly seems appropriate to write a summary for an article that has merely touched upon many facets of such a large subject. However, assuming that the reader is already an accomplished mathematics instructor, and wishes to become aware of the bare essentials for online course creation, we do offer a few keywords. The overarching consideration is this: The software tools you select will have a direct bearing on the quality of your results. In addition we cite five principles:

1. Learn what software works and works well. Use a professional quality HTML editor. Use animations. Use interactivity. Experiment with multimedia.
2. Provide enough information for your students to learn. Too little is equivalent to nothing. Too much causes confusion.
3. Design your materials modularly.
4. Observe what others are doing; adopt the best of it.
5. Note the strengths of emerging learning technologies, particularly those that offer advantages beyond live instruction.

It is not necessary to fully embrace the new technologies to your instruction, but many new tools are available that can supplement and improve even your very best teaching efforts. As a final remark, these methods and ideas will help us through this, the first phase of online education. The next true wave of innovation will come from those that have actually learned mathematics from online sources.

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The following appendix is not a part of the paper, but serves to illustrate the many topics of this new mathematics educational methodology.

Appendix A

Online courses – the grand scope

1. Creation
    a. Scope of design
        i. Content
            1. Textbook
            2. Online content
        ii. External links

        iii. Interactivity/animations/
        iv. Streaming media
    b. Software tools
        i. Creating mathematics typography
        ii. HTML editor
        iii. Graphics editor
        iv. Multimedia
        v. Reference tools
    c. Student deliverables
        i. Projects
        ii. Book reports
        iii. Research papers
        iv. Homework
        v. Exams
    d. Security
2. Deployment
    a. Server
        i. Departmental
        ii. Campus
        iii. Commercial
        iv. Developer access
    b. Course management
        i. WebCT
        ii. Blackboard
    c. Student access (password vs. open)
        i. Online access
        ii. CD Rom
3. Operation
    a. Communication with students
    b. Bulletin board and chat
    c. Feedback quizzing
    d. Online testing
    e. News
    f. Assessment
    g. Online help
    h. Homework collection and return
    i. Proctoring examinations
4. Results
    a. Survey results
    b. Anecdotal results
    c. Future student performance
5. Continuing development
    a. Improving existing features
    b. Adding new features