Math on the Web: A Status Report

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Focus: Distance Learning

by Robert Miner and Paul Topping

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The six months since the last Status Report have seen steady incremental improvement in support for Math on the Web. There has been some progress with browser support, and more activity with authoring tools. However, some of the most notable developments have been in the area of support for math in distance learning tools.

In this volume of the Status Report, we begin with a brief survey of what people are doing with math and science communication on the Web, and the techniques they are using to do it. We will then take a look at some notable Math on the Web news and announcements from the last six months. Finally, we end by taking a closer look at what has been happening in the distance learning arena.

The Promise and the Problem of Math on the Web

The problem of communicating Math on the Web is really no different than communicating math via other media. Namely, authoring and displaying mathematical notation is difficult. On top of that, the Web is a dynamic medium, where users can interact with rich media documents in sophisticated ways. This introduces a whole new layer of challenges and possibilities for engaging, interactive communication between authors and readers.

In spite of the fact that math and science communication on the Web requires special skills and tools, along with a healthy dose of ingenuity, this has not stopped people from taking advantage of the Web's potential. Many innovative Web sites, some new, some old, show what is possible with today's technology.

New Resources for Students

One thing the Web is doing is greatly expanding the resources available to students. “Math Help” sites abound, often with tutors or moderators that answer questions posted by students. Others offer study and enrichment materials aimed at parents and mentors. Another interesting kind of site seeks to give students ways to help each other. For example, ThinkQuest[1] was created for fourth graders *by* fourth graders to work on word problem skills. Enabling this kind of interaction between students from around the globe is something that is hard to conceive of on a wide scale without an enabling technology like the Web.

New Ways for Students and Teachers to Interact

There has been tremendous growth in Web sites and services for coordinating interactions between teachers and students over the Web. Interaction over the Web offers a compelling blend of the thoughtfulness of written communication, and the immediacy and informality of spoken communication. The partial anonymity of interacting through the Web can have a liberating effect on shy students who might otherwise be too reticent to fully engage with learning. For adult learners, the ability to work at one's own pace and schedule can create an opportunity for ongoing training and education in situations where the pressures of everyday life won't permit more traditional pedagogical methods.

Distance learning is a very large area, but broadly speaking, distance learning platforms from various vendors generally seek to provide frameworks in which teachers can easily set up a class Web site where students and teachers can then interact. Such frameworks provide ways for teachers to post materials and announcements, message boards, real-time whiteboards, email, and other communication services, as well as online testing and assessment in some cases. Several distance learning vendors have recently taken steps to support math in their product offerings. See our *Focus: Distance Learning* section below for more details.

New Ways of Presenting Math

On the Web, documents don't have to be static. Web material can engage readers in a host of new ways, from embedding rich media such as sound and video, to interacting with readers through simulations, animations, and “live text” that alters in response to a reader request to see information in a different form, or in more detail.

One of the most exciting new technologies for dynamic mathematics is the World Wide Web Consortium's (W3C) Recommendation for Scalable Vector Graphics (SVG)[2]. SVG is an XML-based markup language that describes 2D graphics, rather like PostScript. It is displayed by a browser plug-in, and the scene can be modified on the fly from within a Web page by using JavaScript, for example. You can see some great examples of how this emerging technology can be used to explain mathematical concepts from Integre Technical Publishing[3].

New Tools for Research

Many projects are underway to make research publications available online to facilitate faster and more complete exchange of information between researchers around the world. While getting research articles online has been a major focus for some years, as the amount of information online has grown, the ability to find relevant material has become more and more important. While traditional searching and indexing techniques can do a lot, searching scientific material presents special challenges. One innovative research project seeking to address this problem is the SearchFor initiative[4] at the University of Nice and INRIA Sophia-Antipolis, run by Marc Gaëtano and Stéphane Dalmas.

They have built a prototype search engine that knows about math. Thus, for example, searching for x + y will also find y + x, when appropriate. Using these search techniques together with inference rules, it may soon be possible to answer questions such as “Is $x^4 - \sqrt{x^8 - x^7 + 9x^2} > 0$?” by searching the world's research literature. The result would not only be the answer (which in this case might be more easily found by simply graphing the function numerically) but also a pointer to where the *proof* of the answer could be found.

Many Technologies, None Perfect

While the promise of the Web for scientific communication is great, technical problems still remain. The thread that ties together all attempts to use the Web for math and science is the need to put mathematical notation in Web pages. There are basically four strategies for publishing technical material to the Web today, none without drawbacks.

Non-HTML Formats

The simplest way to publish a technical document created in a format that natively supports math (e.g. Adobe PDF, TEX/DVI files, Word documents) is to put the document online as is. This has the significant advantage that the author retains total control over the formatting. But it also has significant disadvantages: it requires the reader to have the software to display that format on his or her machine, and such documents can only be superficially integrated into the rest of the Web. Using Adobe's PDF format minimizes the software problem, since the Acrobat Reader is widely available. But the integration with the rest of the Web remains problematic. Most research articles are currently put online using this technique.

Browser-native HTML

At the other end of the spectrum, one can choose to use only the mainstream browsers' native HTML capabilities. That generally means images of equations for complicated material, or a combination of text, symbols, fonts, tables and stylesheets for more elementary material. The big advantage of this method is that it reaches the widest audience by far. It places almost no burden on the reader to obtain additional software, such as browser plug-ins. However, the downsides are that the quality tends to be lower, and such documents are quite difficult to author and maintain. This technique is most widely used for more elementary, expository educational material.

Although there are limits to what is economically viable, the best thing for the math and science community, obviously, is for mainstream browsers to add more support for native math rendering. The most important activity to watch in this area is the ongoing work on MathML in Mozilla.[5] However, there is some possibility of greater style support for math in future versions of the W3C's Cascading Style Sheet (CSS) specification.

HTML with Components

Even if native math support eventually makes its way from Mozilla into Netscape's browser, it is clear that mainstream browsers cannot build in all the dynamic math capabilities the math and science community might eventually need, not to mention features desired by other groups with specialized interests. For this reason, a great deal of work has been done on techniques for integrating special purpose components into Web pages. Browser support for component technologies such as applets, plug-ins and behaviors continue to mature, while several vendors now make various kinds of components for dynamic math and science Web pages.

The main disadvantage of the component approach to putting math and science on the Web is that it requires readers to install specialized components into their browsers. Also, authoring pages that make use of such components is generally quite difficult. A final factor that has hampered broader adoption of this strategy is that components have generally not integrated very seamlessly into the surrounding page, usually requiring ad hoc techniques for every browser. Therefore, the difficulty of creating pages that are robust across many browsers and operating systems has been substantial.

It is clear that this approach ultimately has, by far, the greatest potential for facilitating the creation of engaging, dynamic, high-functionality math and science content on the Web. It also has the advantage of competition, since component architectures are of necessity standards-based, with components coming from many vendors. At present, however, because of the technical nature of authoring, this technique has mostly been limited to professionally developed and maintained Web sites and pages created by commercial authoring systems.

Server-side Programming

One of the main difficulties in choosing a strategy for dealing with math in Web pages is that the criteria for what is best are typically controlled more by the reader than the author. If a reader is browsing a page using an old copy of Netscape on a Mac, a very simple browser-native HTML strategy is going to work best, while a reader with the latest version of Internet Explorer with a raft of specialized components and helper applications installed will most likely want content which takes advantage of the more sophisticated component-based HTML strategy.

The only real viable strategy to deal with this conundrum is programming the Web server to determine what kind of browser the reader is using, so that it can then send a page customized to work best in that environment. The advantage of this technique is obvious — readers get the highest quality, most engaging and dynamic version of a page that their browsers are capable of supporting. The downside is that server-side programming is quite difficult, and requires more access to the server software than is feasible to give a large number of authors. In other words, server-side programming requires expert knowledge and access; hence, it is generally limited to professionally developed and maintained sites.

Standards are Paving the Way to Better Solutions

While many in the math and science community have long been frustrated by the lack of a clear and effective strategy for putting math on the Web, if one steps back a bit, several important trends become visible that are cause for optimism.

A Clear Winner: HTML + Components

First of all, when thinking about the future of Math on the Web, the first and the last of the strategies discussed in the previous section can be ignored. Like a modest baseline level of unemployment in a healthy economy, there will always be a place for putting non-HTML documents online in their native formats. For one thing, the sheer mass of legacy documents in the world gives value to the ability to share them directly in their native format. Also, in many situations all that is wanted or that is appropriate is the electronic transmission of paper documents. But apart from special narrow communities with a strong vested interest in a particular format, such as $\TeX$, it is clear that the mainstream of electronic communication lies with the Web.

Similarly, the expedient of server-side programming to customize content for different browsers is currently so important mostly as a short-term consequence of the explosive growth of the Web. The issue of backward compatibility is inherent in computer software, and a large part of what software vendors do for their customers is try to shield them from the worst aspects of the problem. In general, the requisite server-side programming to handle backward compatibility with older browsers has already begun migrating into the infrastructure of the Web, and will likely become increasingly transparent to casual authors. Indeed, in many of the distance learning systems we will be looking at in more detail later in this report, some degree of server-side adapting of content to browsers is already built in. Increasingly, authors will be able to interact with higher-level Web management software that takes care of the gritty details of browser compatibility for them.

Consequently, the future of Math on the Web is really tied up with browser-native HTML and component-based extensions to it. While proprietary systems occasionally claim to solve the problem of Math on the Web by creating a parallel, proprietary, Web-like architecture, the success and pervasiveness of the Web is already so total, these efforts simply aren't credible in the long term. While they may appear to be attractive “complete solutions” in the very near term without any messy integration problems, in the long term they are apt to be expensive mistakes.

The HTML Platform

The groundwork for powerful browser-native HTML capabilities, together with a flexible, component-based extension mechanism, has been slowly but steadily emerging over the last five years, in large part as a result of the standards process taking place at the World Wide Web Consortium. While to mainstream users the technical details are a confusing alphabet soup of new technologies — HTML, XML, XSL, DOM, CSS, SVG, MathML and so on — one by one these W3C Recommendations and related standards have mapped out an architecture for a powerful, extensible way of communicating via rich, dynamic Web documents.

That framework, which taken altogether we call the “HTML Platform,” has made great strides in the last year or two, and is finally getting to the point where it is sufficient for math and science communication. In particular, there has been substantial progress on component embedding technologies in the last year or so. In response to the technical advances, a component architecture workshop is currently being organized at W3C to set about creating the standards necessary to insure robust, cross-platform implementation of these promising new techniques. Most veteran standards activity watchers in the math software community now agree that enough pieces of the HTML Platform are really there and fit together well enough to start building what we have always wanted to build.

MathML in Browsers is Important but not Everything

One part of the HTML Platform deserves special attention from the math and science community. MathML 1.01[6] and MathML 2.0[7] are the W3C

Recommendations for encoding mathematics for the Web. When MathML was first adopted in 1998, there was a backlash of frustration when MathML failed to be the “silver bullet” that suddenly made math work right in browsers. However, the real success of MathML has been more behind the scenes. The mere existence of MathML has had a substantial influence on the ultimate shape of the HTML platform. In working out how different markup languages, style mechanisms, and component architectures should all fit together in the HTML platform, there were many occasions where there was a temptation to choose a simpler, more text-oriented design, instead of a more complicated and powerful design that could accommodate mathematics as well. Because of MathML, those pitfalls have largely been avoided.

At last count, there were 18 MathML implementations in various released products and tools. While it remains frustrating that the last thing of all to fall into place is sufficient browser support for the HTML Platform to do the math, it is indubitably on the way. Internet Explorer 6 and Mozilla 1.0, when they are released later this year, will both have far superior native and/or component-based support for math than ever before. We look forward to seeing what people will have managed to do with MathML technology by the time the next Status Report comes out.

News Round-up

The last six months have seen quite a bit of MathML adoption activity. The following sampling of news items highlights some of the more notable events.

- **MathML 2.0 Recommendation Adopted.** MathML 2.0[7] was adopted as a W3C Recommendation on February 21, 2001. The main improvements over MathML 1.0 are a much improved listing of mathematical characters newly standardized by the Unicode consortium, a DOM interface, extensions to MathML content markup, and provisions for equation numbering in presentation markup.

- **Rechartering of W3C Math Working Group**[8]**.** The W3C announced it would renew the Math Activity on June 9, 2001. The new Working Group will be working on maintaining the MathML 2.0 Recommendation, continuing liaison with other W3C working groups and other standards bodies, and more generally continue the task of facilitating the use of mathematics on the Web.

- **Maple 7 Adds MathML Support, Incorporates WebEQ.** On June 7, 2001, Waterloo Maple announced[9] that it will introduce enhanced Web math functionality using WebEQ technology from Design Science. The new functionality will be an integral part of Maple 7, slated to begin shipping on June 29. Maple 7 will feature a comprehensive MathML 2.0 implementation, providing import and export of MathML-encoded math expressions, as well as the ability to save Maple worksheets in HTML+MathML format for display in Web browsers.

- **Blackboard Licenses WebEQ.** Blackboard, Inc. concluded licensing arrangements with Design Science in March, 2001 for incorporating WebEQ math editing and display technology into their e-Learning products. As of this writing, details as to when math support will be available within Blackboard have not yet been announced.

- **WestWords**[10] **Announces Plans for MathML Support in MathMonarch.** MathMonarch, the content transportability tool for math publishing, is keeping pace with Design Science's development of MathML features. MathMonarch 4.0 converts Microsoft Word documents containing MathType equations into its intermediary language, WWdoc, which is then imported directly into Quark with the PowerMath or Mathable extension loaded. The resulting Quark files can then be exported back out to WWdoc, which can then be imported back into Microsoft Word with MathType. MathMonarch is extending its capabilities to the MathML environment by combining the ability to transport design information, as well as content. Both are crucial to display math correctly on the Web.

- **MathML Support in Mozilla Matures.** Work on adding native MathML support to the Mozilla Open Source browser has progressed substantially over the last six months. While MathML support is not enabled in routine nightly builds of Mozilla, precompiled binary versions of Mozilla with MathML and SVG support turned on are available from several sources[11]. The current version is 0.9.1. The commercial Netscape 6 browser is based on Mozilla version 0.6, without MathML support.

- **Design Science Releases MT Extra Font under Open Source License.** Fonts are a key issue for enabling MathML generally, both in Mozilla as well as potential future versions of the commercial Netscape browser. As an open source project, Mozilla can only bundle open source fonts with it for distribution. However, without fonts, MathML support will not work, and consequently, fonts are a major obstacle to turning on MathML support by default. To address this problem, Design Science announced in February that it had released its MT Extra font under an Open Source license with the specific goal of helping Mozilla get to the point of turning on MathML support by default.

- **IBM Techexplorer 3.1 Released.** IBM released version 3.1 of its Techexplorer scientific browser in June, 2001. The new version offers full MathML 2.0 support, as well as support for Internet Explorer 5.5 behaviors.

- **MathML to Braille Converter Announced.** Taking advantage of MathML's ability to encode mathematical semantics in a structured way, a MathML-to-Braille converter, called BraMaNet[12], was released early this year. It has a user-friendly Visual Basic interface and can be used together with MathType to translate Microsoft Word documents into Braille for printing. Other related projects are investigating ways of combining MathML, and a speech rendering technology called VoiceXML, to further enhance the accessibility of mathematics.

- **Beta: MathType 5.0 with MathPage Technology.** This new version of Design Science's MathType equation editor adds an important new feature: the ability to save Microsoft Word documents containing equations into Web pages that really work. The equations and math symbols can be embedded in the Web page as either GIF images (for maximum browser compatibility) or as MathML 2.0. MathType 5.0 is in beta test. Final release is expected in August, 2001.

- **Beta: WebEQ 3.0.** This new version of WebEQ, Design Science's Java-based suite of tools for building dynamic math Web pages, features improved and more intuitive editing, content MathML generation, customizable user interfaces, powerful new scripting capabilities for programmers using the DOM, sophisticated math line-breaking of long expressions, and MathML 2.0 support.

- **Coming: MathPlayer**. Design Science is working on a software component that will enable Microsoft's Internet Explorer Web browser to display MathML. It is based on Microsoft's Behavior technology and will work with Internet Explorer 5.5 or later. It is planned that a version of MathPlayer be available free-of-charge to anyone requiring MathML display. Release is expected in Fall, 2001.

Focus: Distance Learning

What is Distance Learning?

According to the USDLA (United States Distance Learning Association[13]), distance learning is “the acquisition of knowledge and skills through mediated information and instruction. Distance learning encompasses all technologies and supports the pursuit of life long learning for all. Distance learning is used in all areas of education including Pre-K through grade 12, higher education, home school education, continuing education, corporate training, military and government training, and telemedicine." The Web is a perfect medium for distance learning. It enables the delivery of educational materials within seconds to anyone with access to a computer. And since science, engineering, and technology play such a crucial role in our modern economy, the ability to work with mathematical notation is an important component of distance learning over the Web.

Besides education in colleges and universities, the U.S. military is also very interested in distance learning. In 1997, the Advanced Distributed Learning (ADL)[14] initiative was created to "ensure access to high-quality education and training materials that can be tailored to individual learner needs and made available whenever and wherever they are required." The ADL organization is responsible for producing SCORM (Sharable Content Object Reference Model), a set of standards that define a Web-based learning content model.

The distance learning market is expected to grow to $5.2 billion by 2004 according to Frost & Sullivan[15] (as quoted by the Federal Learning Technology Resource Center[16]). There are many companies already in this growing field and more are entering it all the time. Colleges and universities are also looking seriously at becoming vendors of distance learning services as a way to extend their reach and as an important source of revenue (see "EduCAUSE president discusses future of distance learning in education"[17]).

Where Does Math Fit into Distance Learning?

Although most distance learning content does not contain mathematical notation, lack of it limits the utility of distance learning whenever there is a strong technical component to the material. Many college departments have at least some material that makes use of math.

Mathematical notation may appear in online material in much the same way as it does in traditional educational materials. However, there are a few applications that are of special interest to the distance learning marketplace:

- **Courseware** — This includes materials containing static math (technical papers and tutorials) as well as dynamic math (interactive pages demonstrating a mathematical or scientific concept).

- **Assessment (testing)** — Math notation is used in the presentation of test questions. In addition, students can use interactive entry of math (using tools like Design Science's Equation Input Control[18], for example) to answer questions. The use of MathML to represent answers enables automated evaluation of correctness. Also, it enables the variable names and numbers to be algorithmically customized on a per-student basis to prevent cheating.

- **Course-oriented Bulletin Boards** — The Internet enables students and teachers to communicate as never before, without the restrictions imposed by the traditional professors' office hours. In this application, students and teachers post messages to a Web-based bulletin board. MathML allows mathematical notation to be part of such communication.

Progress in Distance Learning

There are many companies and organizations involved in providing distance learning products and services. Although this marketplace continues to grow by leaps and bounds, it is just now maturing to the point where the ability to handle mathematical notation is becoming an important requirement. Below, we list some highlights in this growing trend. In most cases, we have quoted representatives of each organization directly. We apologize in advance for this list being somewhat Design Science-centric but this is the work with which we are most familiar.

Blackboard

In March of this year, Design Science concluded a license agreement with Blackboard Inc. that allows it to use WebEQ technology in its future products. We expect the company to release more details as they become available.

Blackboard Inc.
http://www.blackboard.com

Carnegie Learning

"We develop curriculum, including software and print materials, for high-school level mathematics. Currently, our main products are Algebra I, Geometry and Algebra II. We sell directly to high schools, who use our materials as the main class curriculum. Students typically spend 40% of their class time in a computer lab using our software and 60% of the time in the classroom, doing projects and activities based on our print materials.

"The software is based on research done at Carnegie Mellon into how students learn mathematics. It traces students' actions in a problem-solving activity, providing hints when necessary. In addition, the software tracks students' growth in knowledge throughout the school year. It forms a model of each student's strengths and weaknesses and then selects problems for each student to solve based on that student's skill profile. This 'knowledge tracing' enables students to work at their own pace. They receive more problems if they are having difficulty and need to master each section of the curriculum before moving on.

"Our products were initially developed in Lisp and are in the process of being ported to Java (the interfaces are all in Java; Algebra 1 has a Java back-end as well; the others use a Lisp back-end). We use WebEQ to display formatted mathematical expressions in all of our interfaces (including problem text, symbolic algebra tools, spreadsheets, etc.).

"Our products are not currently accessible over the Web; students use them in a lab at the school. We are currently piloting a new course, Quantitative Literacy through Algebra, which is a college-level course using the same technology. For this course, we've configured the software to save student records over the internet."

Steve Ritter, Ph.D.
Senior Cognitive Scientist
Carnegie Learning, Inc.
http://www.carnegielearning.com

IQMind.com

IQMind.com is a Singapore-based education service provider that offers software and hardware services to schools in Asia. These services include software applications that are aimed at improving productivity of teachers and administrators, and enhancing communication, collaboration and interaction among students, teachers and parents, hardware infrastructure, and enrichment/training programs.

"Distance learning for IQMind.com entails students doing their assignments from home (e.g. weekends, holidays, etc.). Most of the time, students will engage the teachers directly in school. Design Science's WebEQ product has been integrated with IQmind's e-learning platform, specifically in the area of online quiz and assessment, so that teachers can present their questions in a seamless manner. No longer do they have to cut-and-paste mathematical symbols and equations from Word documents or other specimens in the process of creating questions for students to tackle in an online realm.

"The real benefit is the dilution of manual effort on the part of teachers. WebEQ is very easy to use and requires no rocket-science methodology to unravel. The time taken to piece all these symbols together in the past is now channeled towards the creation of more value-added questions and solutions."

Jansen Lim
IQMind.com
http://www.iqmind.com

Prometheus

Prometheus uses Design Science's WebEQ technology to allow courseware developers to incorporate math in online courses and to allow students to incorporate math in discussion areas.

Prometheus
George Washington University
http://www.prometheus.com

Question Mark

"Question Mark assessment software enables educators and trainers to write, administer and report on assessments via PCs, local area networks, the Internet and intranets.

"Many users of Question Mark wish to include mathematical and scientific equations within questions, and it's now possible for authors to enter or paste equations as MathML into questions as they write them. Question Mark then uses Design Science's WebEQ MathViewer applet to display these within the student or participant's browser.

"The advantages to authors of using MathML is that it is easy to author, and much easier to manage and edit than a separate GIF or JPEG graphic file, which is the most obvious alternative mechanism. Good questions take a long time to write and check, and people want them to have lasting value. A strong advantage of using MathML rather than a proprietary solution is that questions should be usable into the long term future, even if technology changes.

"The advantage to Question Mark of using WebEQ is that it works on all major browsers and seamlessly displays maths equations within questions. It's easy to deploy within the package and users can simply create MathML using WebEQ itself or another tool, and put them within questions, and they then run and display correctly without the user needing to set up or deploy anything.

"For a demonstration of Question Mark displaying MathML with WebEQ, see http://www.questionmark.com/links/tryit.htm."

John Kleeman MA MBCS C.Eng
Managing Director
Question Mark Computing Ltd.
http://www.questionmark.com

Wiley

Wiley has two products, eGrade and Math Machina for Calculus, both of which use Design Science's WebEQ technology. eGrade is available now, Math Machina is a future product.

"Wiley eGrade is a software product that allows instructors to assign homework and assessments to students in technical disciplines. It gives instructors the ability to create and modify questions and exams that are mathematically rich. One can create questions from multiple choice to fill-in-the-blank to matching and essay questions. Algorithmic problems are available as well as multi-stepped problems.

"The program is ideal for distance learning programs in that it addresses a variety of needs, from self-paced practice for students to fully proctored online testing. Students are given automatic feedback and grades are recorded in the instructor's grade book. It is also well suited for homework which is graded automatically. This product is offered in conjunction with several Wiley textbooks in math, physics, chemistry and engineering.

"Math Machina for Calculus is a Web-based, intelligent software tutorial for calculus. Math Machina solves and documents calculus problems in real-time. Students supply solutions in step-by-step detail for a wide variety of calculus problems. The student's answers are then analyzed and graded. Math Machina is able to also automatically solve problems and reveal the detailed step-by-step answers. This intelligent software supports extensive graphical activities to aid in the understanding and use of calculus concepts.

"Math Machina employs algorithms that use the rules of algebra and calculus to solve calculus problems. The algorithms produce customized content to document 'how' and 'why' problem steps progress as they do, inserting specific pieces from the student's own problem into examples steps. The software also links to pages of the student's calculus book where the relevant content is covered."

Ruth Baruth
John Wiley & Sons, Inc.
http://jws-edcv.wiley.com/college/egrade/

The Future of Distance Learning Technology

The future for distance learning is very bright. As success in education is crucial for the health of our society and as society becomes more global and less local, demand for technology that connects students with educators and educational material will only increase. Within the context of this report, we see two trends:

1. There will be a continuing move away from static math to dynamic math in distance learning materials. It is well known that students learn more quickly, and with less pain, when concepts can be demonstrated interactively. MathML enables interactivity in mathematics. Currently, most dynamic math materials must be created "by hand", requiring the author to have knowledge in several programming languages and Web technologies. We expect this situation to change with the advent of interactive, point-and-click authoring tools for dynamic math content. Design Science is very active in this area.
2. To date, distance learning has largely been directed at providing educational materials to those who cannot attend face-to-face classes. In the future, we see the technologies employed in distance learning used for all kinds of learners, not just distance learners. In no way should this be taken to indicate that the value of face-to-face student-teacher interaction is diminishing. Instead, interactive online materials free the teacher to spend more time with students. The power of interactive content enhances, rather than replaces, face-to-face teaching.

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