# Paper Title: Web-based Mathematics Education Pilot Project

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# Web-based Mathematics Education Pilot Project

**Abstract**
The Web-based Mathematics Education (WME) framework aims to create a Web for mathematics education where education content and support services are interoperable on the Web and can be created, deployed, and maintained on a distributed basis. To test the feasibility, practicality, and effectiveness of WME as a way to enhance mathematics education in schools, a pilot project at Kimpton Middle School (Munroe Falls, Ohio) has been launched. The pilot generated positive feedback from students and teachers. Described are the WME approach, the pilot website, teaching experiments with 7th grade students, lessons learned, and future plans.

## 1. Introduction and Background

Web-based learning can extend the reach of education and significantly broaden its impact and influence. Given the state of mathematics education in the United States and other countries, an effective way to deliver and enhance mathematics education via the Web holds much promise.

While various methods have been used to display mathematical formulas in Web pages and to make simple mathematical computations accessible via CGI programs or X Windows [12], a general and effective system for accessing, producing, and delivering mathematical content is still the subject of research and development.

Investigators at the W3 Consortium (W3C) and elsewhere are working to make *publishing* mathematical materials on the Web easy. *MathML* [14] is an XML application for markup of mathematical expressions that supports both presentation encoding (display layout) and content encoding (computation semantics).

The IBM digital publishing group has released the experimental *Techexplorer* [11], a Web browser plug-in that dynamically formats and displays documents containing scientific and mathematical expressions coded in TeX/LaTeX. Some MathML are also supported. Techexplorer also allows a user to send expressions to a fixed compute server for evaluation. *MathType* [18], from Design Science Inc., supports interactive creation of mathematical notations for Web pages and documents. The same company also offers *WebEQ* [18] that provides a Java applet to display WebTeX and MathML in a browser. The W3C *Amaya* Web browser demonstrates a prototype implementation of MathML which allows users to browse and edit Web pages containing mathematical expressions [17]. Together with the rest of the Web page, these expressions are manipulated through a visual interface. Netscape 7.1 offers native support for MathML provided that the required fonts are installed. The increasing acceptance and software support for MathML were evident at recent *MathML International Conferences* [15].

*Mathematical content viewing* on a Web page is static. On the Internet, end-users, especially educational applications, can make good use of *dynamic access to mathematical computing*. ``Internet Accessible Mathematical Computation" [6] has been the subject of the *IAMC Workshops* that underscore the on-going interest in making mathematical information and computation easily available in the new communication age [5, 9]. For more background and related activities, please refer to the Proceedings of the IAMC Workshops [10], and the IAMC homepage [13].

Researchers have begun to make attempts to deliver mathematical education materials over the Web/Internet. Already, we can find many Web sites providing courses and tools for mathematics education. Such sites include WIMS, Livemath, Mathwright, WebMathematica, Calc101, AcitveMath, Maple, and MathWeb. Linda Beccerra [1] gave a good summary of Web tools for interactive computation. Please refer to the website `icm.mcs.kent.edu/research/wme.html` for more background information.

Generally, ad hoc server-side programming is made to support a narrowly defined set of topics. Authoring educational content within the scope is awkward, and outside of the scope is almost impossible without substantial new back-end Web programming.
The most serious flaw of such ad hoc approaches is that the components, content pages, and server-side programs do not combine to form a larger system within which to interoperate and to mutually reinforce.

In 2001, our group at the Institute for Computational Mathematics (ICM/Kent), together with collaborators, began research on the *Web-based Mathematics Education* (WME) framework [7]. Starting in January 2004, Ohio Board of Regents (OBR) Research Challenge funding provided for a pilot project to put WME to trial at Kimpton Middle School.

An overview of the technical aspects of WME is given first. The discussion will then focus on the pilot project.

## 2. What is WME?

The goal of the Web-based Mathematics Education (WME) framework is to establish a modern distributed system on the Web for mathematics education. The framework conforms to open standards, works with regular Web browsers, makes authoring simple, allows systematic access to server-side support, and enables these independently developed components to interoperate seamlessly. In short, WME seeks to create a *Web for Mathematics Education*.

## 3. WME Architecture and Components

Figure 1 (top) illustrates the concept of the WME framework. We hope to achieve Web-based mathematical education through a combination of standard technologies.

- *Content-markup support*---The *Mathematics Education Markup Language* (MeML) [8] is used to encode Mathematics education content pages. MeML provides well-defined *mathematics computation elements* and *mathematics education elements* that can be used together with regular HTML and MathML elements for easy content markup.  MeML also provides elements designed to access *WME services* that supply various mathematics education capabilities.

- *Regular Web servers*---MeML pages, with the `.meml` suffix, originate from normal Web servers with the content type `application/xml`.

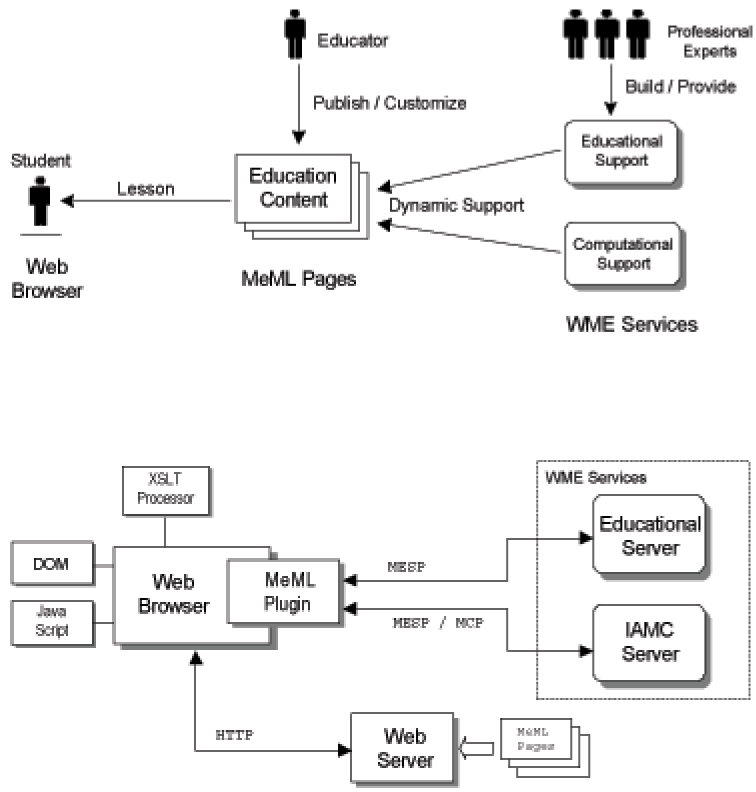


**Figure 1: WME Concept and Architecture**

- *Client-side support*---On the user side, common Web browsers can be used.  A *WME Page Processor* in the form of a browser plug-in (the *MeML Plug-in*) provides control and processing for the MeML content, using the browser as a Graphical User Interface.
- *Server-side support*---On the Web server side, regular active page and database capabilities support site operation, administration, customization, and configuration.
- *Distributed support*---MathChat [2] and other WME services such as plotting, terminology dictionaries, and computations for different areas of mathematics can be supplied to MeML pages from anywhere on the Internet.  The WME Page Processor can access WME services through the *Mathematics Education Service Protocol* (MESP) and through the *Mathematical Computation Protocol* (MCP) [6].

Thus, the WME architecture involves these major components: the Mathematics Education Markup Language (MeML), educational content pages written in MeML, standard Web servers and browsers, the WME Page Processor, server-side support, and distributed WME services. Figure 1 (bottom) shows the WME framework architecture. In the WME framework, an online courseware consists of a group of MeML pages with dynamic back-end support by WME services that can supply a rich set of computational and educational functionalities useful in many different MeML pages.

WME will allow teachers to create or choose from many types of environments for their students. Examples of these are: specifically designed tutorial programs for assisting students in reviewing mathematical procedures; creating investigations for students to explore and gather data; interacting with real data to collect, organize, analyze, and explain. One of the major blocks in implementing reform in mathematics education is the lack of an easily accessible context that captures the interest and challenges students with a variety of mathematical abilities. Research indicates that technology has the capability to help ALL students learn much more significant mathematics than they might otherwise be able to learn without its use [16].

## 4. The Kimpton Middle School Pilot Project

Having made substantial progress in the design and implementation of the WME framework, our group is eager to perform trials to see how well WME works when deployed in real educational situations. With OBR Research Challenge funding, our group begun a pilot project to study how the WME technologies can best be tailored and applied for actual mathematics education in schools.

Participants include Professors Paul Wang (ICM/Kent) Michael Mikusa (School of Education/Kent), graduate students, and middle school teachers Grace Dorene Ellis and Kim Yoak (both at Kimpton Middle School, Munroe Falls, Ohio). Both Kim and Dorene are experienced and technology oriented mathematics teachers.

Consulting with the middle school teachers, our team created a pilot website to experiment with the WME ideas and techniques, to gain experience and to obtain feedback.


**Figure 2: The 7th Grade Percent Module Entry Page**

**5. Overview of the Pilot Website**

There are two major aspects to building this pilot website:

1. The architecture, navigation, and support techniques for the site
2. The mathematics education content pages that go into the site

The first item must be designed and implemented in a general way to be a model for other WME sites and to allow content pages and materials to be easily configurable, customizable, and interoperable among sites of similar design. Server-side support details can be found in a separate paper [3].

The initial content for our pilot website focused on 7th grade mathematics to be used for a number of mathematics topics by Dorene and Kim at Kimpton Middle School. We wanted the content pages to provide ``tangible'' perspectives to the middle school students by including interactive activities that pertained to the everyday life of a 7th grader-- in other words, helping to answer the ever-celebrated question: ``Why do I need to understand this?'' (Figure 2).

The first task was to generate some Web activities suitable for complementing lectures on the topic of percentages. To make it interesting and relevant, the *7th Grade Percentage Module* starts with the introduction page entitled ``*What Does LeBron James Have to Do with Percents?*'' and ends with a page asking students to compare top NBA 3-pointer player percentages with that for LeBron. The *7th Grade Percentage Module* incorporates activities that help inspire and enhance the students' understanding of percentages and how they are applicable to a breadth of daily activities including dining (Figure 3), shopping, traveling, money, and sports.

The module can be used by multiple teachers in different classes at the same time. Teachers can customize each page to add questions, exercises, or other activities and to collect student answers. This ability is also important for assessing students' understanding and appreciation of these activities. A password-controlled administrative area of the website, admitting only authorized personnel, provides access to page customization and student answer retrieval.

The *7th Grade Percentage Module* currently offers a dozen or so different topic pages. New topics can be added easily by using existing pages as templates. The new pages can be plugged into the module by listing them in the module index page.

Completion of the percent module sets the stage for in-class trial, the first ever ``test drive'' of the WME concept and technology by the teachers and the students. The trials provided valuable feedback and insights into how and where WME can be made more effective and user-friendly.

## 6. In-class Experiences

In our initial visits, the teachers expressed concern about students' ability to make sense of percentages conceptually and computationally. We began to design a set of tools that could be used by students to inquire about various aspects of percents. In this development stage we used research [4] to help guide the design of the tools. Our tasks and activities were aimed at taking advantage of students' intuitive conceptual notions of percentages and help them to build on these ideas.

For example, students were introduced to 3 different models where they could click on sections of a shape (a pizza and various grids) and the page would represent the percent of pizza (or grid) that was selected and the percent that was unselected. Students were asked to translate this experience on paper by creating a variety of representations of given percents (25%, 50%, ...).
We also created a series of tools to help students estimate what we called benchmark percentages (50%, 25%, 75%, 10%) of any given number. For example, students can enter a value in a spread-sheet like table tool and it calculates and displays these percentages. The students were asked to describe patterns they observed in these generated tables. From other pages students were to select meal items from a menu and the Web page would total up their ``meal order'' (Figure 3), but students would estimate labor costs (50%), tips (10%), and tax (5%). The Web page would tell students if their estimates were good, incorrect, or exactly correct.


**Figure 3: Connecting Mathematics to Real Life**

The percent module was put to use in two 7th grade classes, each with about 20 students, at Kimpton for a week in March 2004. As was mentioned previously, the students in both classes were very engaged in these activities. The use of the computer and the Web page did not seem to cause them any distraction or difficulty. After we completed our first unit we had students respond to questions regarding their use for learning mathematics. One student commented ``The games were fun and the questions really challenged you to use your brain''. A pair of students working together said ``These Web pages were kind of neat to see it helped clear up a few fuzzy spots when it came to EASY percents.'' These were typical comments made by students in our first attempt. We believe that this shows we were successful in creating pages that captured the attention of the students, provided an environment for them to explore important mathematical ideas, and helped them to make sense of a very important idea that can be difficult for some, in middle school mathematics.

Our pilot project also revealed important requirements from the teachers. They liked having a rich set of pages and tools from which to choose the right combination for their classes. Also, the ability to take the same Web-based lessons and tools and apply them to different classes by different teachers is critical. Teachers must be able to easily add different types of questions to the pages and collect student answers for later review online. Certain textual materials and tool parameters (such as the number of rows and columns of a grid) in a page must be made easily customizable. In response, we built a Web-based administrative interface to satisfy these requirements. As our pilot project continues, the site/page customization mechanism and the administration user interface will evolve and mature.

## 7. Additional Modules

We are adding three 7th-grade Topic Modules at the present time:

- *Proportions*---using party planning (apples and guests), recipes (making lemonade), and scale models (model airplanes) to illustrate the concept.
- *Probability*---employing coin tossing, card playing, and numbered cube throwing to guide students.
- *Algebra*---visualizing equivalence using a simulated balance, showing straight line equations and their plots, experimenting with active plots to show the difference between points on and off the line.

The experience will guide us in building more advanced modules for high school and college levels.

## 8. Lessons Learned

The pilot project so far has generated the much needed first test drive experience for our project team and for the teachers and students alike. The positive reactions from teachers and students are very encouraging.

An amazing amount of information on the practical use of WME was collected. The requirements generated from a real education environment are very valuable. We list some major WME site requirements identified here.

- A site consists of self-contained units called *Topic Modules* such as the 7th Grade Percentage Module.
- Each topic module may have an entry page, a set of lesson pages, one or more module index pages, and a final concluding page. Individual lesson pages can be easily reusable to quickly create different variations of the same Topic Module through mix-and-match.
- A lesson page ``provides a discussion point'' or ``illustrates an idea'' with descriptions, graphics, demos and hands-on experiments, and further discussions.
- A lesson may be customized to include questions interactively entered by the teachers and to store answers from students. A class period may cover one or a few lesson pages.
- Topic Modules are easily moved from one site to another and can be customized according to schools, grade levels and individual classes, and instructors. The WME site forms a dynamic *site context* within which Topic Modules and lesson pages (coded in

MeML) run. A site context may customize modules and pages through CSS, replacement graphics, and configuration parameter values.

- Lesson pages are configurable and customizable dynamically through a password-protected Web-based admin interface provided by the site context.
- Customization includes adding, deleting, and sequencing in groups of questions on any lesson page. Answers to questions are stored with student, class and teacher names for later retrieval through the same admin interface.
- Customization also includes simple modification of text and replacing pictures on the page through the admin interface. (In addition, an authoring tool can import any page for extensive editing and revision.)
- Lesson pages can provide hands-on demo and specialized tools with user interactions. Tools and demos are supported on either the client side or the Web. These demos and tools must be easily reusable in different pages.
- Pages must work on newer browsers for major platforms (Windows, Mac, and UNIX)
- Storing and retrieving persistent info for the site such as school, class, teacher and student names, configuration settings, customizations, work/answer from students, and comments for student work from teachers. The site context should handle this.
- Online discussions among class participants (students and teachers) may be supported by a chat service with Math display capability and lesson awareness. This is an option that can be added easily for any WME site.

## 9. Future Plans

Much work remains for the WME framework project. As the WME site requirements come together, we will define the WME site architecture and its interactions/interface to its modules and pages. MeML support for customization and interoperability will be revisited and improved. Woodpecker, the browser plug-in for MeML, will be modified and improved accordingly. The pilot website will expand to include topic modules at different levels for different schools. And more in-class experiments will be conducted.

As the pilot website evolves into maturity, we plan to have implemented many mathematical modules suitable for not only seventh grade math classes, but a larger classification of discipline including high school and even college-level mathematics. Web-based chat supporting the display and transmission of mathematics shall also become useful in our website in order to provide remote interaction.

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