Customization and Interoperability in WME

David Chiu
Institute for Computational Mathematics
Department of Computer Science
Kent State University
dchiu@cs.kent.edu

Abstract

One of the advantages of the Web-based Mathematics Education (WME) system is flexibility. That is, freedom for teachers to customize lesson plans and lesson material. The customized components can then be shared and distributed to anyone else using WME. However, offering such flexibility demands self-sufficiency among WME site components. Reported within are the WME component structure and how they aid methods for handling customization and interoperation.

1. Introduction and Background

The Web contains a myriad of materials that can be used for educational purposes. With the advent of MathML [16] and its growing support, mathematical content (such as formulas) became easier to produce and distribute on the Web, which were, and still are, shown as infix notations or generated by mathematical formatting software (such as LaTeX) and then converted into graphical images for display. While MathML is set out to solve problem of mathematics display and context on Web pages, separating those content suitable for education from those that are not remains a problem that lays hidden in the Web's ubiquitous disposition. Searching and selecting useful mathematical content takes time, and integrating content into informative Web pages is strenuous even with intuitive visual XHTML editors such as Netscape Composer and Macromedia Dreamweaver.

These issues were identified, and the Web-based Mathematics Education (WME) Project became a focal point at the Institute for Computational Mathematics (ICM/Kent State University). The project began as an ambitious expedition that searched for ways to reveal a *Web for Mathematics Education* – one that would allow worldly contribution of mathematical lessons, assessments (e.g. question banks), virtual manipulatives (e.g. exercises or games to help strengthen mathematical concepts), and simplified integration of these elements to compose customizable Web-based lesson pages. It was a unilateral project focused on Computer Science aspects. Without discipline from an educational perspective, questions persist: *Who will be our audience, and will they find it useful? Will teachers and students benefit from WME?* The latter of these may take time to answer, but for now, an auspicious collaboration from the College of Education (Kent State University) provided the research project with educational expertise and connection a live audience.

An impromptu approximation of a goal-oriented WME site was initially constructed and deployed to a regional middle school in an effort for the continuous pragmatic assessment of the WME framework. Because the research group had been designing the framework blindly without educational background input, the goal was to uncover and address WME's deficiencies, incorporate new functionalities, and experiment with different ways for teaching mathematical concepts [1, 2, 15]. The result is a model WME site [3] that can be deployed onto any Web server through some guided installation process. In addition to the model site, the feedback information that was gathered allows us to correctly design and implement other projects within WME:

- *MeML and Woodpecker* --- MeML, the Mathematics Education Markup Language, is an XML application for the easy generation of WME lesson pages. Woodpecker is a prototype browser plug-in to render MeML documents [6].
- *GeoSVG* --- An SVG-based (Scalable Vector Graphics) [7] geometry tool, similar to *Geometer's Sketchpad* [14]. Its abundant predefined elements make interactive animations even easier to produce [4]. Its roots in SVG inherently allow for native integration into Web documents with W3C's intermixing profile for XHTML+SVG+MathML [8].
- *DMAD* --- Distributed Mathematics Assessment Database, a massive database that is integrated with all WME sites and provides content standard student assessment data (exam questions, etc) [5].

In the beginning, this ad hoc site consisted of only a few static lesson pages. Nonetheless, it was enough to expose many flaws within our design. One of these was the failure to provide school administrators and teachers with enough flexibility for customizing certain aspects. Because we were working with multiple teachers and classrooms, having only a single set of lesson pages became constraining. Teachers began longing for the ability to change the wording within pages, instantly block out and reorder page sections, edit manipulatives, and pose their own questions for students to answer. All of these alluded

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to a clear indication that customization is necessary within the WME framework. We propose to take this approach a step beyond, and suggest that the customized elements can then be further reused, shared, and able to be imported and exported from any other WME site as illustrated in Figure 1.

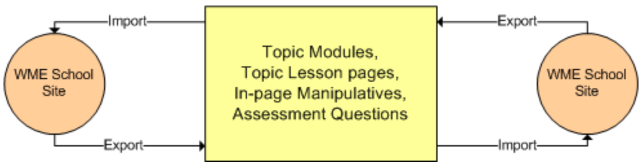

Figure 1. An Overview of WME Site Exchange

Undoubtedly, in order to capture the above requirements, not only do naming conventions and protocol standards need to be set, the Web site itself must be built on an information architecture organized in such a way that individual WME units, from Topic Modules (TM) to an in-page exercise, can be encapsulated into self-sufficient constituents. The following sections discuss this approach.

2. Site Organization and Architecture for Interoperability

According to Katila and Wang, "Website information architecture (IA) deals with the structuring, the relationship, the connectivity, the logical organization, and the dynamic interactions among the constituent parts of a Web site [10]." In other words, site architecture is a blueprint of an infrastructure for Web content placement. It is clear that a stable and standard site architecture must be maintained to handle the interoperable data encapsulation and exchange shown in Figure 1. But before we discuss the model site architecture itself, we present some insight into the model site's top-down organization.

Figure 2 illustrates the per-user view of the organization of the model WME site. A user navigates from the homepage to some guided step-by-step process that begins by identifying the user's grade level, math course under that grade level, and finally narrowing down to the user's instructor and registered course section. For a student or teacher, this process leads to a dynamically generated page listing Topic Modules (TMs) and their respective Topic Lesson Pages (TLPs). Simply put, TMs are a collection of related TLPs that convey some mathematical concept (e.g. Fractions). A TLP delivers a specific point within the module (e.g. “Fractions and the Whole” might bring across why 4/4 is equal to 1, and provides manipulatives that strengthen this concept). TMs are selected for use by the instructor and should probably abide by some standard proficiency (Number Operations, Pre-algebra, Geometry, etc.) as recommended by, perhaps, the NCTM [11].

The generalization of Figure 2, however, is deceptive in the way that it does not show a clear relationship between the WME components. After much deliberation among ICM, the College of Education, and most importantly, our middle school math educators, it was agreed that, for our purposes, the design of the WME site architecture should be one that is built around usability and interoperability by providing a sound physical and logical organization that can allow for [3]:

- Support for customization. As we had previously experienced with the pilot WME project, once a TM, TLP, etc. is imported, it is unlikely that every teacher will be satisfied with the default lesson content. Modifications of these components should be allowed on a per-teacher and per-classroom basis.
- Easy means for importing and exporting TMs, TLPs, and other constituents (such as in-page sections, and manipulatives) to any other WME site. The model architecture should also be able to preserve page styles, file inclusions, graphical images both before and after importing/exporting these components. This is the way that WME envisions the simplicity of public math education contribution.

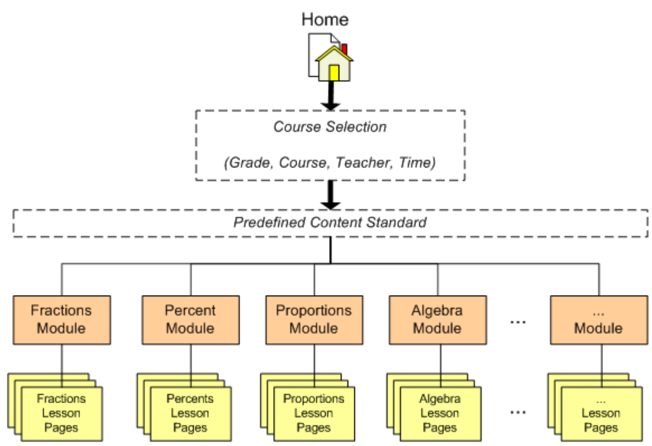

Figure 2. A Top-down View of the WME Model Site

Figure 3 depicts the resulting architecture. First, notice the connection to a WME database. Because logical descriptors such as grade levels, teachers, and their courses taught are variable across educational institutions, a persistent storage is necessary to capture and associate these values with concrete WME components. For instance, one such relationship is the mapping of a classroom to a TM with customized TLPs pertaining to that teacher's specifications. It can also be seen that the architecture calls for quite an extensive file structure. That is, each TM (e.g. percent) is contained within its own directory, which includes directories for graphical images, style sheets, and ECMAScript files (not shown). Delving further into the TLP level (e.g. meal and pizza_slicing) we see that Topic

Lesson Pages are in fact file directories rather than *pages*. Again, these directories encapsulate the content, graphical images, etc. used (not shown). *But why is this file structure overkill necessary?* Recall from the above that our architecture strives for an *easy means for importing and exporting TMs, TLPs, and other constituents*. Packaging these TMs, TLPs, and others can be done effortlessly at the directory level. Deployment and installation of these packages enjoy the same simplicity. Moreover, the architecture promises to preserve site navigation and all possible page manipulation controls such that they are seamlessly integrated into the WME site with minimal effort from its users.

Another motivation for the deep structure is that it creates a much desired content separation. The organization is necessary to capture not only default page contents, but also customized results. The more separation that we can achieve, the more control teachers have over their lessons without influencing those of others.

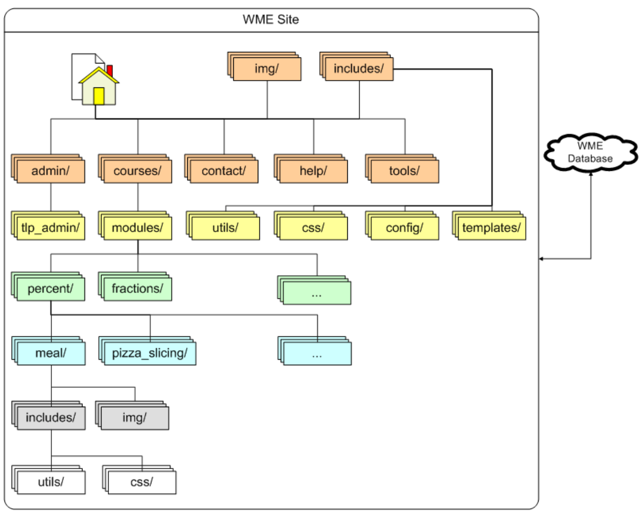

Figure 3. The Model WME Site Architecture

3. View-Sections for Content Flexibility

Save for some auxiliary Web pages for providing some institutionally related information and back-end administration, the educational substance of a WME site is essentially a composition of one or more TMs. *It is appropriate, after all, since TMs provide the lesson material!* TMs consist of TLPs packaged in the file structure as mentioned in the previous section for easy deployment. TLPs are lesson pages that convey some mathematical concept. Like TMs, TLPs are themselves product of arrangement of even smaller entities, known as *View-Sections* or *VSecs*. Each VSec contains the actual page content (page markup), and can be appended with question sets (again associated per teacher, per class). Below, Figure 4 shows one teacher's version of a TLP conveying a lesson in statistics. Notice the separation of VSecs for content flexibility, which allows our teachers to:

- Display and hide VSecs to students at any given time for page focus.
- Instantly modify and save VSecs' wording, graphics, and manipulatives.
- Rearrange VSecs' ordering within the TLP.
- Add or delete VSecs from TLPs at will.
- Share and reuse VSecs that may or may not have been customized by teachers.

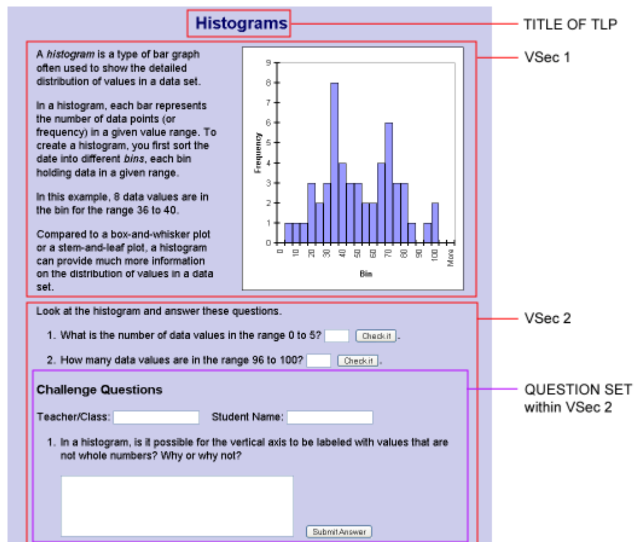

Figure 4. TLP and Inner Elements

Because VSec manipulation happens per teacher, their "factory" versions will always remain unchanged. In fact, whenever a TM is requested by a teacher, copies of VSecs are created from default versions. Therefore, any content overwriting is avoided, and if mistakes were made, it is easy to replace VSecs with its original content. The next section discusses VSec customization.

4. Customization and Instructor Control of TLP Components

As teachers and classes are added to the WME site, opportunities for customization become available. Although teachers are welcome to use the content as provided by the TM distributor, elements such as choice of wording, graphical images, and assessment questions may be personalized through the back-end administration area provided by the model WME site. The administrative section supplies dynamic menus tailored for three types of users: *student, teacher,* and *administrator*.

The *student menu* is quite simple because they have limited access to WME sites. Its main function consists of a course schedule that takes them directly to their course materials. Other functionalities include the set of omnipresent account configuration settings including change of passwords, names, etc.

The *teacher menu* is quite a bit more complex. A link takes them to a list of all the courses they are teaching (Figure 5). From the schedule, the teacher can then manage lessons or retrieve a list of enrolled students.

MATH-134 Pre-algebra

Section	Time	Location	
4	8:00am - 8:50am	111	[manage lessons] [list students]

MATH-432 Geometry

Section	Time	Location	
7	2:00pm - 2:50pm	345	[manage lessons] [list students]

MATH-222 Intermediate Math

Section	Time	Location	
8	3:00pm - 3:50pm	129	[manage lessons] [list students]

Figure 5. A Teacher's Course Listing

If "manage lessons" is selected, the user is brought to a page where he/she can select which TMs to use for the course in question. Further penetration allows teachers to choose which TLPs to use for the course and providing page customization (Figure 6). When changes to these pages are made, they are made immediately. This allows instructors manipulate lesson content on-the-fly that may involve any of those VSec facilities discussed in the previous section.

The *administrator menu* is geared towards school administration. These users have menus that allow them to add/delete courses, user accounts, and supply server-related technical configuration values such as database connectivity, and those involving the file system. It should be noted that user status types are stackable, that is, teachers may very receive administrative or even student statuses.

5. Conclusion and Future Work

The support for this concept of creating *and* promoting mathematics education material makes WME different from other systems - not so much in the way that we think it is necessarily *better*, but certainly more flexible. The support and facilities for lesson contribution may ambitiously lead to a Web for Mathematics Education on a global scale [12].

But to do this, WME must be fully interoperable. That is, anything designed for WME is guaranteed to operate with any other WME component. While the hierarchy and site architecture is certainly a step towards the right direction, provisions for full WME interoperability is still being investigated. One such exploration involves even deeper infiltration, past into VSec markup, seeking to allow customizable manipulatives. Other projects include:

- A *terminology finder* that links mathematical terms to definitions, manipulatives, and perhaps even TMs that supplies activities to help aid the understanding of the concept.
- *MathBoard*, a bulletin board with mathematics support (perhaps by MathML) for posing questions and responses.
- Completing implementation of *MathChat*, a live interactive forum where students can socialize with other students and teachers about mathematics in a virtual environment that simulates a physical classroom [13].
- A visual MeML editor for the intuitive creation of mathematics educational pages suitable for WME.

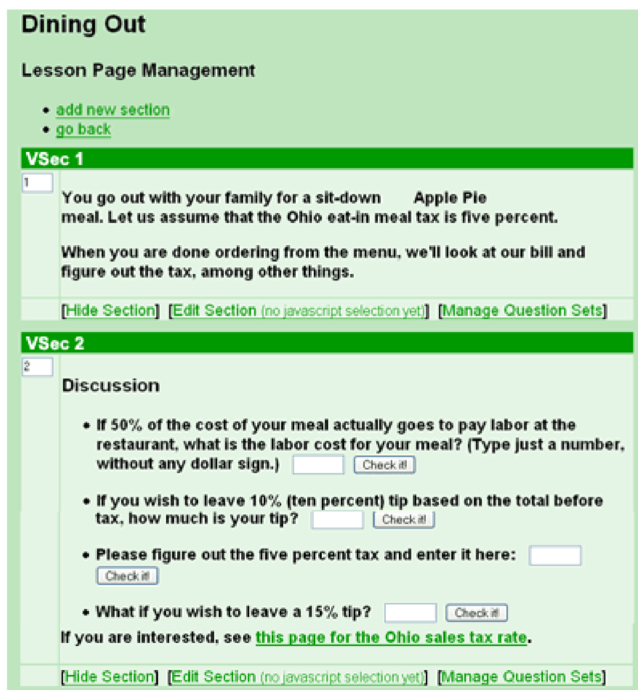

Figure 6. TLP Customization Interface

6. Acknowledgments

This material is based upon work supported in part by the National Science Foundation under Grant No. 0201772. Any opinions, findings, and conclusions or

recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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