

Building DMAD: A Distributed Mathematics Assessment Database for WME¹

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Abstract

Assessment of student understanding and performance is important in education. Hence we are building a Distributed Mathematics Assessment Database (DMAD) for our WME (Web-based Mathematics Education) system. DMAD consists of databases located at individual WME websites. Each local DMAD database collects assessment questions contributed by teachers to be shared with others. Teachers can search and import assessment questions, edit and revise them to use in tests and assignments. They can also author new assessment questions and contribute them to DMAD to be shared locally or widely. DMAD supports true-false, multiple-choice, short-answer, and essay questions. Correct answers are stored. DMAD provides online tests, immediate grading of student answers, real-time feedback, and statistics of student performance. Questions in a test can be displayed in various permutations automatically to enable test taking by students at close proximity, for example. Incorrect answers for questions can be connected, by the assessment author, to common misconceptions or missing background knowledge. DMAD can help correlate such diagnostic information with WME Topics Lesson Pages that can help students overcome difficulties exposed by assessments. DMAD is easy to use and allows questions to contain text, pictures, graphs, and formulas.

1. Introduction

Mathematics education using the Web is increasingly popular and important for many reasons including: ease of use, speed, flexibility, immediate response and

information sharing. At the Institute for Computational Mathematics (ICM/Kent), we are Developing WME (*Web-based Mathematics Education*) as a distributed system for supporting, enhancing, and delivering mathematics education at all levels [2]. A pilot project puts WME to in-class trial at Kimpton Middle School (Munroe Falls, Ohio) [1].

A critical area of mathematics or any education is assessment, the activity to measure the effects of education, student performance, and achievement of learning goals. Assessment tests should also diagnose learning difficulties and pinpoint knowledge shortfalls. The United States *No Child Left Behind Act of 2001 accountability components* include “performance on state designated assessments in reading and mathematics”. To support assessment within WME, we are developing a distributed system called DMAD. In addition to supporting WME, DMAD has the potential of becoming an important resource for mathematics education in general.

Many existing websites already provide various assessment materials for mathematics education. For example:

- The Math Forum [14] has the Internet Mathematics Library that provides various types of assessment suggestions and resources such as articles, books, and links to other assessment websites.
- The AAC (Alberta Assessment Consortium) is a non-profit organization [21], and provides assessment rubrics, materials, and publications.
- The Discovery School [26] provides a wide range of assessment and rubric information.
- The PBS TeacherSource [28] has many assessment techniques, ideas, and strategies over the Web.
- Other Assessment resources and programs are also available in [18, 27].

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Useful as these are, it is perhaps time to consider a more integrated and systematic way of supporting assessment for mathematics education. The *Distributed Mathematics Assessment Database* (DMAD), as part of WME, is an ongoing investigation in this direction. The functionality, usage, design, and implementation of DMAD are described.

2. What is DMAD?

DMAD provides an efficient, effective and systematic way to support the assessment needs of mathematics education and a platform for teachers at different schools to contribute and share assessment materials. It utilizes distributed database and Web technologies to achieve these functions. DMAD helps Mathematics teachers to quickly and easily author, edit, administer and manage tests. They can also easily import materials from or share questions with other teachers.

- **DMAD** is a distributed database with *local databases* at different WME sites. Within DMAD we have:
- **PTA** – A Per Teacher Assessment Database is provided for each mathematics teacher. It stores and manages assignments, tests, questions, student answers, grades, statistics and so on for each individual teacher.
- **PSA** – A *Per School Assessment Database* is created for each school as part of its WME site. A PSA connects PTAs within the school and PSAs at different schools through the DMAD system. The PSA performs a critical role in enabling the sharing of assessment materials within and without a school.

3. DMAD Organization Overview

As a distributed system, DMAD has three levels as shown in (Figure 1). Communications between levels support importing, exporting, sharing, and searching for assessment materials.

At each WME site, we have a single PSA and one PTA for each participating teacher in the school. The local PTAs communicate only with the local PSA to share information. The existence of other PSAs in the DMAD system is transparent to the PTAs and therefore no concern to the teachers. All they see is an easy and

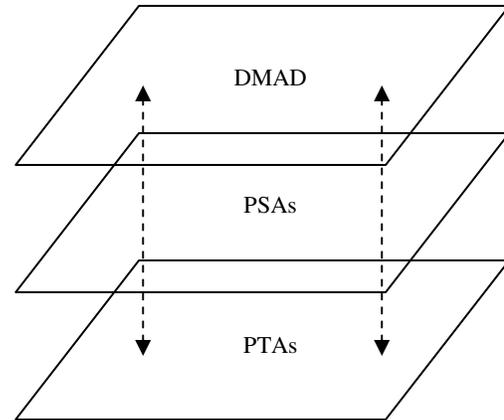


Figure 1. DMAD system levels

efficient user interface to import assessment materials, construct and manage tests, and make their own contributions. The PSAs interact and combine to form the whole DMAD system by making assessment materials from each school accessible, by classifying the information, and by making search quick and efficient (Figure 2).

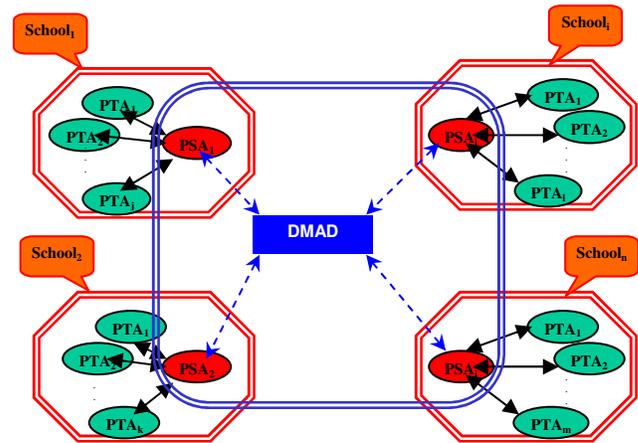


Figure 2. DMAD system overview

4. DMAD Requirements

As with any software project, the starting point is to specify the requirements for the system. In other words, we must first consider who are the users, what are the purposes and functionalities, and exactly what will be achieved by the software. Consulting with middle school mathematics teachers and mathematics education researchers, we have specified the following requirements for DMAD:

- Easy to access -- available on the Web and used through any Web browser.
- Easy to use -- having a simple and intuitive user interface for teachers and students.
- Safe and secure -- providing a secure environment in which to store and retrieve assessment information such as tests, answers and grades.
- Different types of questions -- supporting true-false, multiple-choice, short-answer, and essay (extended answer) questions.
- Rich data formats -- allowing questions to contain text, images, graphs, and formulas.
- Authoring support -- providing an effective environment for teachers to create new tests, locate relevant assessment materials, import, edit and customize questions.
- Testing support -- conducting interactive assessment tests online, generating and displaying tests, storing answers, providing automatic grading, and manual grading support.
- Diagnostic support -- supplying statistics of student performance, fast and immediate response, advice and hints for teachers regarding answers and mistakes.
- Remediation support -- linking specific mistakes to causes and difficulties and suggesting remedial lessons.
- Privacy -- making it possible to contribute assessment materials anonymously.
- Interoperability -- having a well-defined API (Application Programming Interface) to interact within the WME system [2, 7] and with other systems on the Web and Internet as an *assessment server*.
- Extensibility -- being flexible and easily extensible for adding new features and functionalities in the future.

5. DMAD features

The preceding requirements guide us in our ongoing efforts to design and implement DMAD. A combination of current and standard Web and database technologies are used to achieve DMAD. These include XHTML, MathML, XML, ECMAscripts, DOM, active page (PHP), and database support (MySQL).

Let's look at the basic and advanced features of DMAD.

5.1. Basic DMAD features

The most central feature of DMAD is test authoring. Teachers can *create new questions, view, edit (reword) and delete existing ones*. Four types of questions are available: true-false, multiple-choices, short-answer, and essay (extended answer).

- *Creating a new question* :
When a teacher chooses the *create new question* menu option, a pop-up dialog appears for choosing the question type. Depending on the question type, an appropriate question form (Figure 3) is displayed to enter the question content and any answer options. A question may involve texts, graphs, images, and formulas.

Question options (in case of multiple choices) can also have graphs, images, and formulas. For efficiency and responsiveness, these forms are implemented by dynamic HTML based on the standard Document Object Model (DOM) and Javascript. Images, graphs, and options can be added or deleted easily on the client side. Only the finalized form will be submitted to the server side.

The test author can also connect incorrect answer options to common mistakes, misconceptions, or missing background knowledge. DMAD can help correlate such diagnostic information with WME Topics Lesson Pages [10], that can help students overcome difficulties exposed by the assessments.

The author also identifies the correct answer, for true-false and multiple-choice questions, so such questions can be graded automatically. For short- and extended-answer questions, the author can, optionally, provide a sample answer/rubric to be stored and retrieved

along with the question. This info is used to guide manual grading.

A completed question can be added to an existing test or stored in a new test. Editing can be aborted anytime before submission.

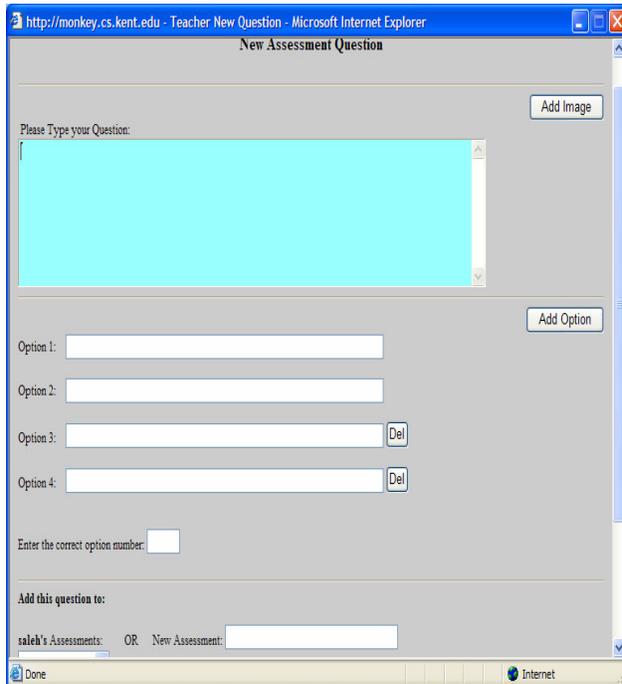


Figure 3. New question form

- *Modifying an existing question :*
A teacher can retrieve an existing assessment question and *make changes to the question content and any answer options*. Changes can be made on text, images and graphs in any part of the question. The process is very similar to creating a new question, except the form is initially filled with data from a question stored in the teacher's PTA (Figure 4).
- *Viewing existing questions :*
Assessment questions and tests can be displayed for *viewing and checking*. It is important for teachers to proofread questions after making changes, or before importing and exporting.
- *Question and test administration :*
Other features support creating *new tests, copying, renaming and deleting existing tests or questions*.

- *Conducting Tests online :*
A test can be deployed by a teacher to be taken by specific students. Tests are displayed in standard Web forms. Answers are immediately stored for later use.
- *Managing test results :*
DMAD stores test answers from students for easy retrieval. Automatic grading of multiple-choice and true-false questions is supported. Manual grading can also be done online through DMAD which can display standard answers and grading rubrics alongside each question. Grades can be saved, displayed in tabular form, and statistics can be generated.

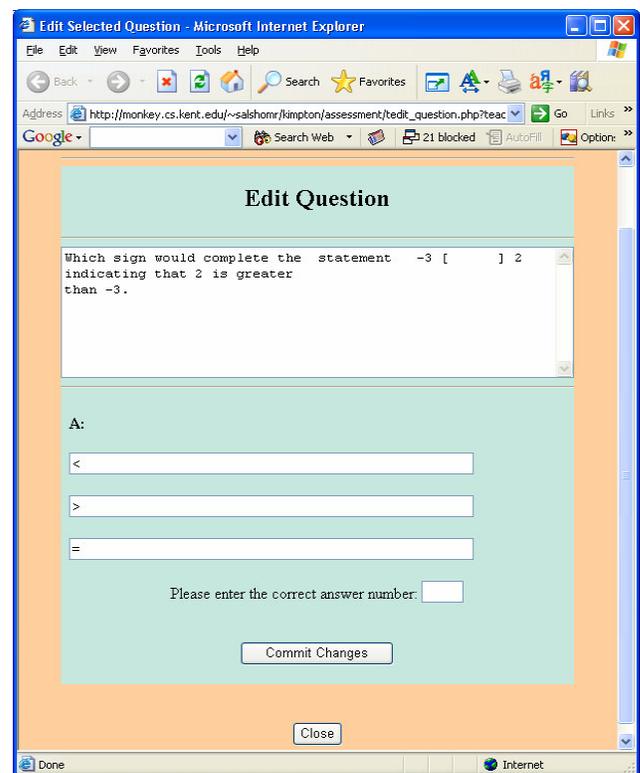


Figure 4. Edit question form

5.2. Advanced DMAD features

A variety of advanced features make DMAD more powerful and comprehensive. These include question search, importing and exporting assessment materials between PTAs and PSAs, making the same test appear different, retrieving students answers in different ways, obtaining student performance statistics, and linking wrong answers to remedial materials. Let's look at some of these in more detail.

- **Question search:**
A teacher can easily search for questions on particular subjects and at specific grade levels. The search covers the local PSA and transparently the rest of DMAD.

The search can be narrowed by subjects, topics (for example, fractions, algebra, geometry, measurement), keywords and grade levels.

- **Importing and exporting questions:**
After searching, a DMAD user can import questions of interest simply by marking (selecting) them, choosing the destination assessment, and then clicking import button (Figure 5). All selected questions will be copied to the teacher's PTA database.

Imported materials can be customized and used in tests. Changes made on an imported item do not affect the original copy. Teachers can select questions from his/her personal PTA and export them either to the local PSA or to the public DMAD. A contributing teacher's name can be withheld from the public for privacy purposes.

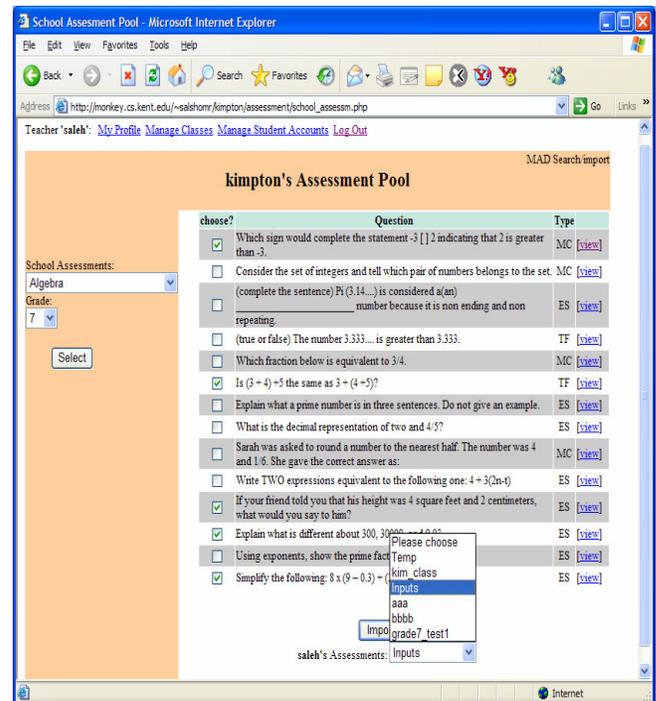


Figure 5. Importing questions in DMAD

- **Tests scoring:**
A test author may assign scores to each question or leave the scoring to DMAD. In that case, all un-scored questions in a test are weighted equally.
- **Controlling access to tests:**
Tests are sensitive information. Any stored tests are considered hidden until exposed by the author/teacher. The author/teacher can show or hide tests at any time, before or after test was given. For each teacher, there is at most one test visible at any given time. This visible test can be seen by students at a standard Web address assigned to the individual teacher.
- **Randomness in test Display:**
DMAD can make the same test look different by random question sequencing together with random answer option ordering. Some questions may have several different ways of wording that are interchangeable. These features help test taking by students at close proximity.

- **Retrieving test answers in different ways:**
A teacher may display test answers by student or by question. Seeing answers from students of a specific question can be very useful. DMAD system can also generate performance statistics and provide suggestions or advice for teachers. If 60% of students got the same wrong answer on some question, the teacher needs to know and take appropriate action.
- **Linking diagnostic information to remedial materials:**
By allowing test authors to specify diagnostic information connected to wrong answers, DMAD can connect wrong answers to common misconceptions or missing background knowledge exposed by student answers. By accessing WME lesson page meta information, DMAD can further link the diagnosis to lessons that can help students with their difficulties.

6. Conclusions and future work

The DMAD system aims to be an effective and easy to use assessment tool for mathematics education. A systematic way of importing, customizing, and exporting assessment materials can help create an environment in which usage and experience can accumulate and mutually reinforce.

To make assessment materials ready to deploy on the Web, to conduct tests online, to provide grading help, to generate performance statistics, to provide diagnostics and to suggest remedial materials, while making tests and scores private and secure, controlling access to tests and results, is a tall order and our work on DMAD is by no means completed.

Putting DMAD to extensive trial in schools and collecting feedback will be our next goal. Comments from teachers, students, and school administrators will help us evolve DMAD. As more schools adopt WME and DMAD, the distributed nature of DMAD will be demonstrated in realistic situations.

7. Acknowledgements

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