DESIGN AND IMPLEMENTATION OF AN ASSESSMENT DATABASE FOR MATHEMATICS EDUCATION

Saleh Al-shomrani
Department of Computer Science
Kent State University
salshomr@cs.kent.edu

Paul Wang
Department of Computer Science
Kent State University
pwang@cs.kent.edu

ABSTRACT

Assessing student performance and understanding is important in education generally and in Mathematics education in particular. DMAD (Distributed Mathematics Assessment Database) is an experimental Web and Internet based system to help assessment tasks that can be of great value to teachers and students of Mathematics. DMAD consists of local databases at individual school websites. Each local database collects assessment questions contributed by teachers in a particular school to be used and perhaps shared with others. DMAD is designed to work as one distributed database while providing power and convenience at each participating school. The system helps create, revise, administer, and grade exams that can contain various types of questions. Questions use a well-designed representation allowing correct answers, rubrics, formulas, multimedia as well as interactive content. DMAD supports two types of testing: online and paper testing. Tests taken online can be graded automatically and stored for teacher review and analysis. Because DMAD has been designed in consultation with middle school teachers and education experts, it provides features to support real-life test giving such as loss of power to a laptop and retaking of tests. DMAD is an open system implemented with standard Web/Internet technologies and easily interoperates with other online systems.

KEY WORDS

Assessment, DMAD, Online Testing, and Mathematics Education.

1. Introduction

Teaching and learning Mathematics on the Web are increasingly popular with school teachers, educational experts and even by normal people due to easy Internet accessibility, flexibility, and interactivity. At the Institute for Computational Mathematics (ICM/Kent), we are developing WME (*Web-based Mathematics Education*) as a 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].

Assessment, measuring the effects of educational concepts, student performance and comprehension, is a very important. Assessment tests should also diagnose learning difficulties and determine 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, we are developing a distributed system called DMAD. DMAD is a distributed mathematics assessment database that can support the assessment needs of WME [5] as well as work independently. 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 [15] has the Internet Mathematics Library which provides different types of assessment resources and ideas including: articles, books, and links to other assessment websites.
- The PBS TeacherSource [22] has various assessment techniques, ideas, and strategies on the Web.
- The WebCT [27] provides a wide range of assessment information and articles.
- The AAC (Alberta Assessment Consortium) is a non-profit organization [29], and provides assessment rubrics, materials, and publications.
- Other Assessment resources and programs are also available in [19, 25, 26, 28].

Such useful resources not withstanding, it is a good idea to consider a more integrated, flexible and systematic way to support assessment for mathematics education. In our previous paper [5], we have covered the goals and concepts of DMAD. Here we present the design and implementation of DMAD and many practical features including online tests and security.

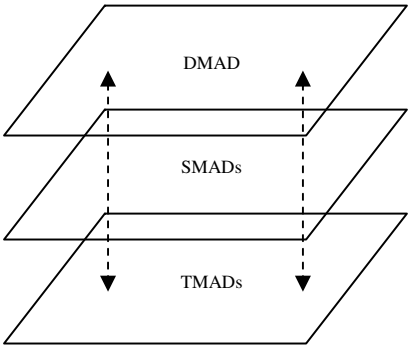

Figure 1. DMAD system levels

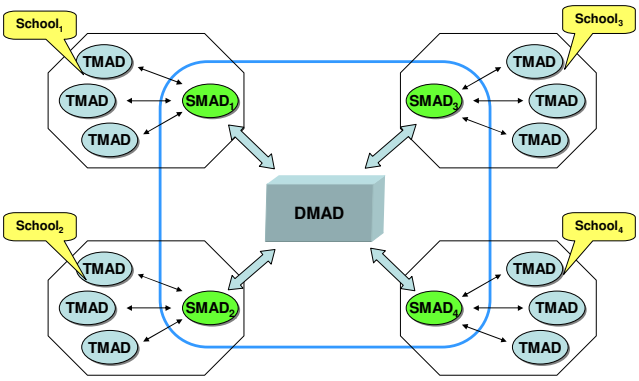

Figure 2. DMAD system structure

2. DMAD Overview

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 uses 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 (Figure 1).

- **DMAD** is a distributed database with *local databases* at different school sites. Within DMAD we have:

- **TMAD** – *Teachers Mathematics Assessment Database* is a database assigned to mathematics teachers of same school. It stores and manages assessment tests, homework assignments, questions, student answers, grades, statistics and other info for each individual teacher.

- **SMAD** – A *School Mathematics Assessment Database* is created for individual school as part of its school site. A SMAD connects TMADs within the school and SMADs at different schools through the DMAD system. The SMAD performs a critical role in enabling the sharing of assessment materials within and without a school.

3. DMAD General Views

DMAD system as a whole consists of two views/levels that can be considered completely different and served various purposes:

3.1. Global View

This view represents a general picture of the whole DMAD system. More specifically, we consider the DMAD system as a huge bank/collection of assessment questions. This includes:

- Importing and exporting questions:
  DMAD user can *import questions* of interest simply by marking (selecting) them, choosing the destination assessment, and then all selected questions will be copied to the teacher's TMAD database. Imported materials can be customized and used in assessment tests, homework assignments, and quizzes. Changes made on an imported item do not affect the original copy. On the other hand, Teachers can select questions from his/her personal TMAD and *export them* either to the local SMAD or to the public DMAD.

- DMAD search:
  A teacher can easily *search for assessment questions* on particular subjects and at specific grade levels. The search covers the local SMAD and transparently the rest of DMAD. The search can be narrowed by subjects, topics (for example, fractions, algebra, geometry, and measurement), keywords and grade levels.

- Adding/Deleting TMADs/SMADs from the DMAD :
  Since DMAD system consists of different participating schools (SMADs) and Teachers Assessment Databases (TMADs) in different locations or sites, adding a new participating school site (new SMAD) or deleting existing one is an essential to the DMAD structure (Figure 2). Unlike central systems, the distributed nature of the DMAD system adds an extra burden on the DMAD Search engine to successfully handle issues of adding new site or removing existing

school sites from the collection in such good and transparent way.

3.2. Local View

This is related to doing Assessment in schools locally, which may include:

- Authoring Tool:
  Teachers can *create new questions, view, edit (reword) and delete existing ones*. There are different types of questions that DMAD can support: true-false, multiple-choices, short-answer, essay (extended answer), and two-menu-matching questions (Figure 3). 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 school Lesson Pages [7], which can help students overcome difficulties exposed by the assessments.

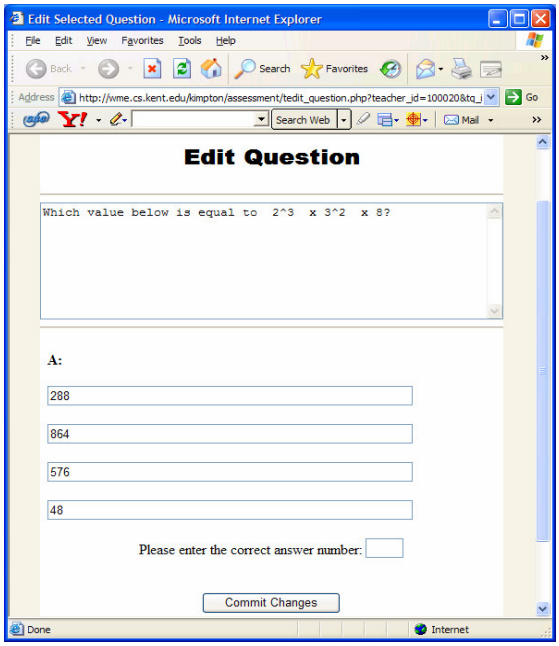

Figure 3. An Example of Edit question form

- Managing Assessment Test :
  Teachers can prepare/generate their own assessment tests, homework assignments, or quizzes either from scratch (by authoring their own questions) or by importing questions from the DMAD bank and then the teacher can store assessment test for future use. The default status of these assessment tests (questions) is hidden from students. That is for additional security purposes and also the teacher can prepare her test long before class time. Hence the teacher has to clearly make her assessment test public to be shown to students.

- Conducting Assessment tests -- DMAD provides teachers with two testing options: *online testing* and *paper testing*. Automatic grading and other useful statistics are only supported for the online testing. However, teachers can have hard-copies of their assessment tests for in-class testing at any time. Teachers also have control over students who can/can't take assessment tests and who is eligible for test retake.

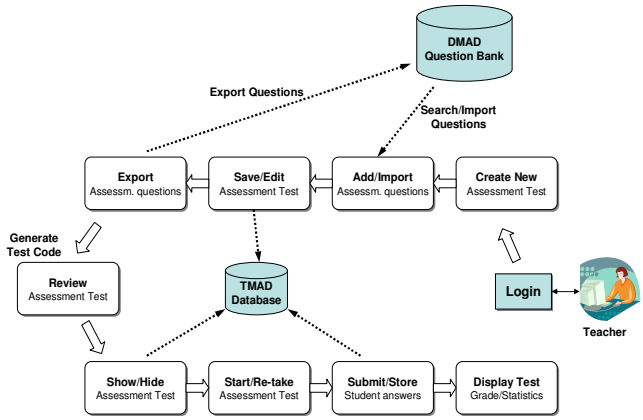

Figure 4. Teacher Interface (Assessment Test steps)

4. DMAD Assessment Testing:

DMAD system enables teachers to author, store, and conducts assessment tests either in class or as homework assignments. It supports the two types of testing: online testing and paper testing (Figure 4). It also supports an *accumulative submission and storage* of student answers on question-by-question basis. Moreover, it allows some specific students (controlled only by their teachers) to *Retake* assessment tests if needed. This is very important in case of unpredictable computer errors or student mistakes: closing a test browser window is an example. In such cases, already student submitted/stored answers will show up and the student can complete the test. Thus, a teacher can have options to conduct her assessment test online or in-class (as hard copies) or can be both.

4.1. Online Test Security

Security is a basic requirement of assessment testing in general and in an online testing more specifically. In previous paper [5], we have implemented student login system as a standard and secured login system using student username and password. But interestingly and after consulting Mathematics teachers and experts, we found the following problems:

- Students usually forget their usernames, passwords, or both especially at the lower grade levels which has been considered time

consuming or class time wasting by their teachers helping students to login.

- Using already known usernames and passwords is considered not secured enough and vulnerable. Because students may give their login personal information to friends or even to classmates to help them in heir tests.

4.2. Special Test Codes

For the reasons mentioned earlier and other security concerns, we have come to conclusion that we have to avoid such types of standard login systems and find a better way as an alternative. So we have decided to use an easier yet more secure login system using *per-test codes* generated by teachers through an API (Application Programming Interface (Figure 5).

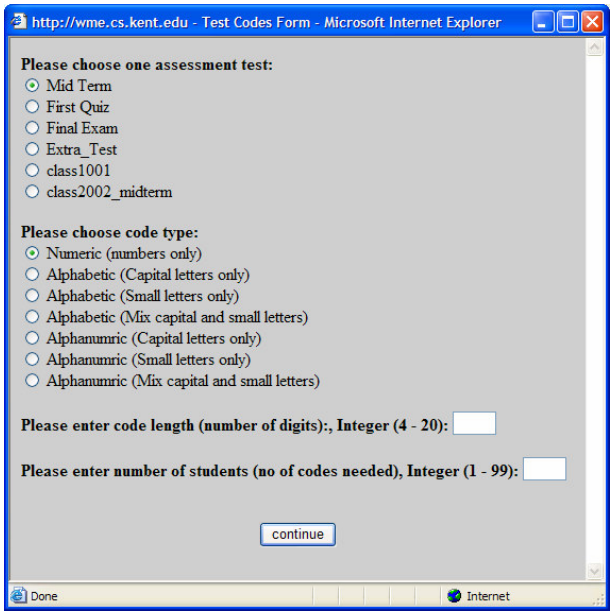

Figure 5. Test code form

These test codes are generated randomly and uniquely for each test and to be used by students for login system. As you can see in (Figure 5), teachers can specify the *code type*: Numeric, Alphabetic, and Alphanumeric and also can choose various *permutations* (Capital letters, small letters, and Mixture). Additionally, they determine the number of digits (code *length*) and finally the number of codes needed for a test (as a *number of students* taking the test). Teachers then can store these codes along with already prepared assessment tests in their TMAD database for future use.

To make students take an assessment test through DMAD system, a teacher must first publish/show the test (change test status to public) to students through publish test API provided by the system. Now for students taking the test, they have to go the teacher's assigned Web page URL either by clicking its link from school Website or by typing the URL into browser address. Every participating teacher has her own *assessment test page* with a unique assigned URL. The assessment test page allows at most one test at a time to be shown to students. Teachers should hide their test from the public using hide test API after finishing the test. Students taking the test need to enter theirs name and test codes (distributed in class by their teachers) to login (Figure 6). For student retaking the test, they need to check *Re-take test* checkbox and enter second code given by teachers so they can login.

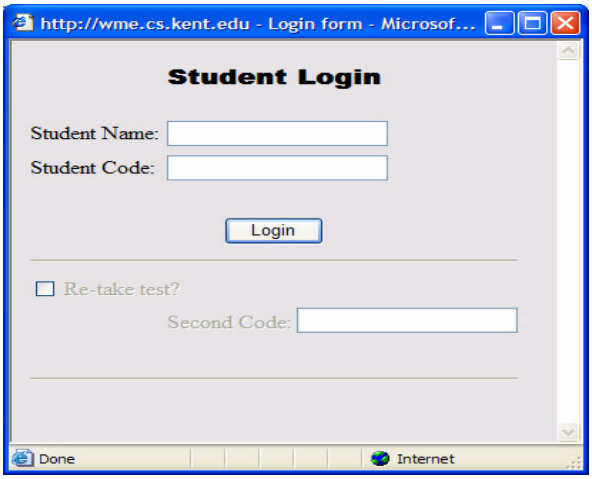

Figure 6. Login system Interface using Test Codes

4.3. (Re) Take Test Implementation

For a student to start or retake an assessment test, she has to have at least one code to do that. The DMAD system will do the following tests (Figure 7):

1. Check if the student code1 is *valid* (exists and matches the one in the TMAD database), if not then exit.

2. Check if it was *already used*, if not then it is a new student taking the test. Otherwise, go to 3.

3. Check if this student is *allowed* by her teacher to retake the test, if not, means code is already taken by a classmate and exit. If so, test if second code (code2) matches the TMAD correspondent one given by the teacher, if not exit, or successfully logged in.

From teacher's point of view, the Retake test feature is set to *Disabled* by default meaning that a student will use code1 to start a test for the first time. Thus, teacher has to clearly set the Retake test property to *Enabled* to allow certain students to retake the test.

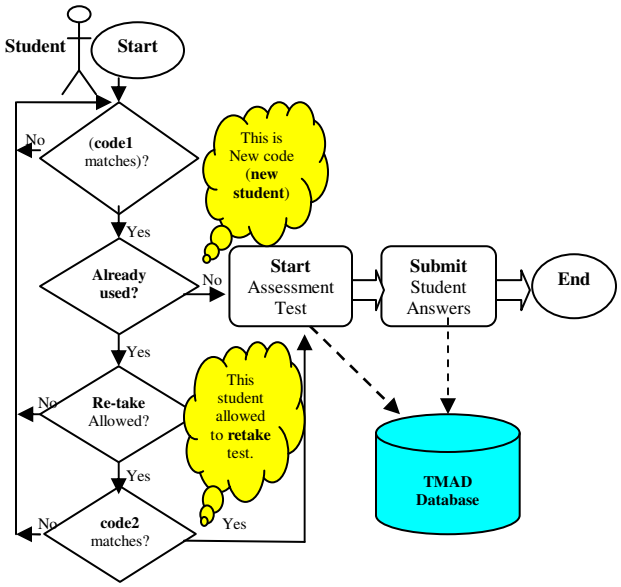

Figure 7. Test code Algorithm for (Re) Take Test

The Assessment program will generate another code (student code2) for such student to be used in the login system (Figure 8).

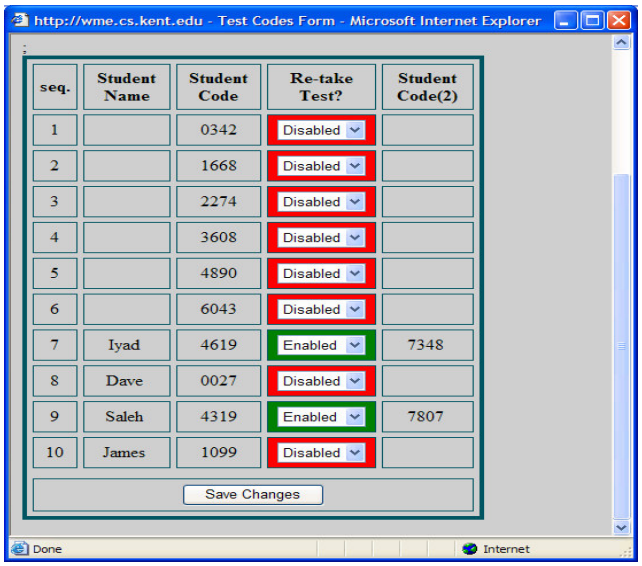

Figure 8. Retake Test code form

5. Assessment Markup and Interoperability

The DMAD system aims to support interoperability and inter-communications with other applications on the Web. Thus, many DMAD functionalities are accessible as Web Services. Consequently, a well-defined API (Application Programming Interface) is needed to communicate and serve other applications on the Internet to achieve this goal.

To transmit assessment questions to and from DMAD, we are creating an XML markup language MAML (Mathematics Assessment Markup Language) to represent assessment questions and exams. MAML defines markup elements and attributes such as question head, type, classification, body, rubric, and so on. DMAD Web services receive and return MAML encoded data. The following example shows the markup of a *multiple-choice* assessment question:

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet                    type="text/xsl"
href="maml.xsl"?>
<dmad>
<question type="multiple_choice">
<q_head>
  <author>Johe Doe</author>
  <keywords>Measurement,      Area,      Rectangle
</keywords>
  <classification>Plan Geometry</classification>
  <answer>choice 2</answer>
</q_head>
<q_body>
  <q_text>What  is  the  Area  a  rectangle  with
  height=h and base=b?</q_text>
  <q_diagram>
     <svg  xmlns="http://www.w3.org/2000/svg">
       <rect    x="100"    y="20"    width="40"
       height="60" />
     </svg>
  <q_diagram>
  <q_choices>
     <choice id="1">
       <math
xmlns='http://www.w3.org/1998/Math/MathML'>

<mi>h</mi><mo>+</mo><mi>b</mi></math></choice>
     <choice id="2">
       <math
xmlns='http://www.w3.org/1998/Math/MathML'>

<mi>h</mi><mo>*</mo><mi>b</mi></math></choice>
     <choice id="3">
       <math
xmlns='http://www.w3.org/1998/Math/MathML'>
         <mi>h</mi><mo>-
</mo><mi>b</mi></math></choice>
     <choice id="4">
       <math
xmlns='http://www.w3.org/1998/Math/MathML'>

<mi>h</mi><mo>/</mo><mi>b</mi></math></choice>
  </q_choices>
</q_body>
</question>
</dmad>
```

The XSLT style sheet for MAML (maml.xsl) is responsible to translate MAML markup into XHTML + SVG + MathML.

6. Using DMAD in WME

The DMAD system has been used in WME. It interoperates and interacts with other parts of the WME components such as Lesson Pages (Figure 9). It provides WME Lesson Pages with *pre-assessment* and *post-*

assessment set of questions to prepare students and measure their understanding of lesson concepts.

For example, a teacher logging in into WME administration interface can click pre or post assessment link to trigger DMAD system to author or import assessment questions that can be included in her particular lesson pages. Teachers using WME can also make their own assessment tests, probably independent from any specific Lesson Page such as Midterm exams, using DMAD and have them automatically stored and graded. In such cases, DMAD system can give useful performance statistics and provide diagnostics and suggest some remedial Lesson Pages and materials.

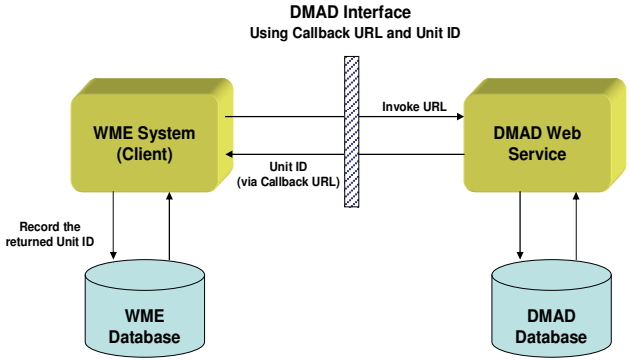

Figure 9. DMAD as a Web service in WME

7. 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 authoring, importing, customizing, and exporting assessment materials can help create an environment in which usage and experience can accumulate and mutually reinforce.

In fact, we have long way to go to add features and more improvements to DMAD system 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.

Our goal is to put DMAD under extensive trial in schools and collecting feedback and suggestions from teachers, students, school administrators and education experts to help us evolve DMAD. As more schools adopt WME and DMAD, the distributed nature of DMAD will be demonstrated in realistic situations.

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