MathFax: An Online Adaptation of the Elementary Learning Game "Math Facts"

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Abstract - *In the game "Math Facts", students are given up to sixty seconds to answer up to twenty elementary math problems. MathFax is an online adaptation of that game. Proposed by a local elementary school and developed by students in our Software Engineering class, MathFax goes far beyond the rudimentary paper and pencil version. It was developed for use on a WAMP server and offers many features: creating users, classes and tests and viewing test results. The paper describes these features in depth, details the database and discusses the current status of and future work for MathFax.*

Keywords: Software Engineering, Service Learning, Group Projects, Elementary Education, Innovations in Education

1 Introduction

For many of us, the days of elementary school are a distant memory. It was a time when our most pressing concern was "when is recess", not "when is my next deadline". Well, MathFax should serve as a reminder of that time. This software is an online adaptation of the elementary learning game often entitled "Math Facts" or "Math Fax." For those to whom this is unfamiliar, students are given a sheet containing twenty elementary math problems, consisting of addition, subtraction, multiplication, division or any combination thereof. The answer to any given problem is a non-negative integer, generally no greater than the low hundreds. Students are given sixty seconds to answer as many of these problems as they can, with the goal of improving their problem-solving skills over time.

MathFax began as one of several service-learning projects undertaken by our Software Engineering class, which was comprised of ten undergraduate students, during the Spring 2010 semester. Descriptions of service-learning projects and how these projects are managed can be found in [1][2][3][4][5][6][7]. The MathFax was proposed by St. Anthony's Catholic School, a local elementary school. The vast majority of the software was completed during that semester; however, a few students continued to refine the software after the semester ended.

This paper focuses on the software itself. Included are details on the chosen server and database: a WAMP server supporting Apache, PHP and MySQL. The bulk of the paper discusses the features which the software has to offer.

2 Server

For our development and hosting platform, we chose to use a WAMP (Windows Apache MySQL PhP) server. Using WAMP greatly eases the burden of installing and setting up the individual components. WAMP is an open source project created by Romain Bourdon and a team of PHP developers [8].

MathFax has been successfully tested on WampServer 2.1e with Apache, PHP and MySQL versions 2.2.17, 5.3.5 and 5.5.8, respectively. It has also been tested on WampServer 2.0 with Apache, PHP and MySQL versions 2.2.8, 5.2.6 and 5.0.51b, respectively.

3 Database

The database for our software consists of nine tables, each of which will be briefly described in this section.

3.1 User

This table contains information related to system access (login), and valid user permissions within the system. It contains four fields: 'userid', 'password', 'status' and 'privilege', which takes one of three values: admin, teacher or student.

3.2 Faculty

This table contains four fields: 'facultyid', 'first_name', 'mid_name' and 'last_name'. 'facultyid' uniquely identifies each teacher added to the system, and each 'facultyid' matches exactly one 'userid' in the user table.

3.3 Student

This table contains twelve fields: 'first_name', 'mid_name', 'last_name', 'gender', 'grade', 'time_goal' and six others. 'studentid' uniquely identifies each student added to the system, and each 'studentid' matches exactly one 'userid' in the user table. 'num_goal' holds the student's score goal (number correct within the time limit), while 'clock' holds the student's time goal (time taken if the student has

reached the maximum 'num_goal'). 'ada' determines if the student's test screen background is white or yellow, while 'show_clock' determines if the student's on-screen test clock is visible or hidden. Finally, 'ClassID' matches the student to a unique class.

3.4 Class

This table contains seven fields: 'classname', 'grade', 'classyear', 'status' and three others. 'classid' is a unique identifier assigned to each created class. 'facultyid' identifies a unique teacher who teaches this class. 'classsem' is the semester the class begins, either fall or spring.

3.5 Test

This table contains seven fields: 'name', 'status' and five others. 'testid' is a unique identifier assigned to each created test. 'type' is a description of the test. 'style' indicates whether the test uses a vertical question format or a horizontal question format. 'grade' identifies the grade for which the test was created. 'time_limit' is the amount of time students are given to take the test.

3.6 Assigned_test

This table contains four fields: 'testid', 'classid', 'taken' and 'studentid'. The significance of this table will be discussed in section 4.6.3, Assigning tests and taking them.

3.7 Complete_test

This table contains four fields: 'testid', 'studentid', 'questionid' and 'answer'. The significance of this table will be discussed in section 4.6.3, Assigning tests and taking them.

3.8 Question

This table contains seven fields. 'questionid' is a unique identifier assigned to each created question. 'operand' is an operator (+, -, /, *). 'first_val' and 'sec_val' are the values upon which 'operand' operates. 'answer' is the answer associated with a this question. 'grade' identifies the grade for which the question was created. 'testid' indicates the test on which this question will appear.

3.9 Score

This table contains seven fields: 'studentid', 'testid', 'num_correct', 'num_goal', 'time_take', 'time_goal' and 'date_taken'. The significance of this table will be discussed in sections 4.6.3, Assigning tests and taking them and 4.7, Viewing test results.

4 Software

4.1 Compatible browsers

MathFax is fully compatible with the most up-to-date versions of Google's Chrome internet browser and Apple's Safari browser. In addition, Mozilla's Firefox browser is supported, though the layout may not always appear the same as it would in Chrome or Safari. Microsoft's Internet Explorer is not supported: the buttons do not function.

In each of these supported browsers, it is necessary to turn off the "AutoFill" feature. Since students taking a test must enter their answers in a text field, this browser feature must be turned off so the distracting "AutoFill" pop-ups do not disrupt the students' concentration.

4.2 Users and their privileges

There are three user types in MathFax: administrators, teachers and students. Each of these user groups has its own specific functions that form the whole of the software. For user support, three user's guides, one specific to each type of user, are included with the software and are accessible on-screen once a user has logged in. These guides may also be printed if necessary.

4.2.1 Administrators and their privileges

Administrators are responsible for setting up the system and maintaining the information contained therein. A default administrator account is provided with the system, but it is the primary administrator's responsibility to create new administrator(s) and delete the default account, for security purposes. Next, administrators have sole responsibility for adding teachers, classes and students to the system, and deleting those entries if necessary. They have access to all test results contained within the system and access to all three user's guides: administrator, teacher and student. When the end of the year comes around and students need to be promoted to the next grade and year, administrators have access to a feature that performs that function.

4.2.2 Teachers and their privileges

Teachers are responsible for testing and monitoring students' progress. First, an administrator must create accounts for them to access the system, assign them to classes and put students in those classes. Teachers then have the ability to create and administer tests, view all test results contained within the system and modify student specifics as necessary. In addition, they have access to two user's guides: teacher and student.

4.2.3 Students and their privileges

Students are the users for whom the system is designed, and they will comprise the majority of users. Once they are created, they will have access to the four following features: take an assigned test, take a practice test, view their own

results and view their own score and time goals. Students have access to the student user's guide if they require assistance.

4.3 Logging and sessions

MathFax uses a fairly simple logging system. Someone wishing to access the software is required to enter a username and password. If the username and password match a user's respective information stored in the 'user' table, that person is granted access. If the information entered is incorrect, the user will remain on the login screen, and that information will be cleared from the screen.

If a login is successful, the following three actions will occur. First, the user's 'userid' will be stored as a session variable for use within the software. Next, the user's 'privilege' will be stored as a session variable for access purposes within the software. Finally, the user will be brought to the appropriate main menu, determined by his or her 'privilege'.

Sessions are terminated under only two conditions. If a user selects "logout" once he or she is logged in, the session will terminate. Also, if a user closes the browser while logged in, the session will terminate.

4.4 Main menu and side menu

When a user has successfully logged in, he or she is presented with a main menu. In addition, users are provided with a left-aligned side menu on all screens, except those where a student is taking a test. As shown in Figure 1, the side menu gives the user easier access to the different software functions, without having to return to the main menu. However, if the user wishes to return to the main menu (like the one shown in Figure 2), a "Home" button is provided in the upper left corner of every screen on which the side menu appears. The contents of both menus are determined by the user's privilege, assigned at login.

Figure 1: Side Menu (pictured on its side at a 69% zoom)

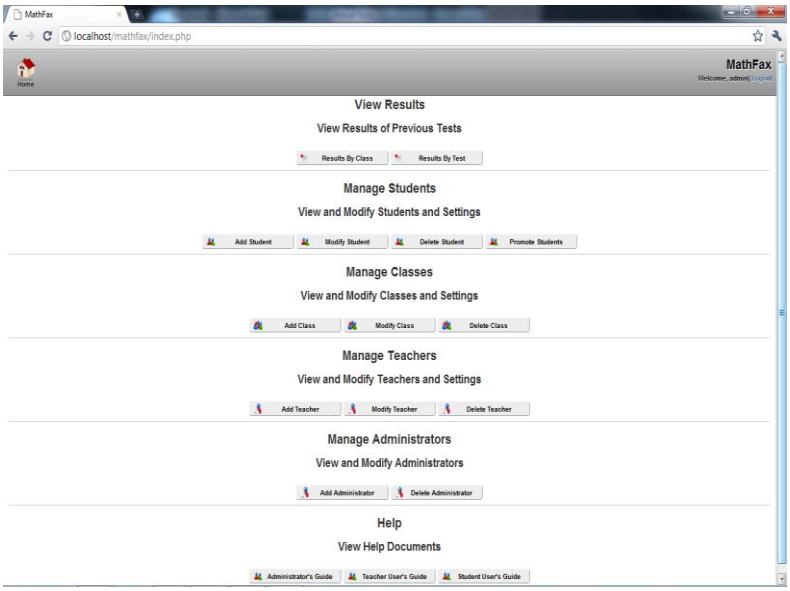

Figure 2: Administrator's Main Menu (pictured at 83% zoom)

4.5 Managing users and classes

This section discusses adding, modifying and deleting the following: administrators, teachers, students and classes. Only administrators have access to these features; however, teachers do have the ability to modify students as well.

A noteworthy feature of the software applies to user account creation. Since 'userid' is the primary key field of the 'user' table, no duplicates for this value can be stored in the table. However, multiple users may be assigned the same 'userid' value during account creation. To solve this problem, the software simply appends the next available digit to the desired name. For example, suppose there exists an account with a 'userid' of "NewUser". The next user to request the 'userid' of "NewUser" will be assigned the 'userid' of "NewUser1". The next one will be "NewUser2" and so on. The significance of this feature will be discussed in later in this section.

4.5.1 Managing administrators

Adding administrators is a simple process. The new administrator chooses his or her username and password and enters a confirmation password. The account is created and inserted into to the 'user' table.

Deleting administrators is also a simple process. A drop down box lists all administrators. One of these is chosen, and the account is deleted from the 'user' table. Administrators can delete themselves, though they will remain logged in. Also, the last remaining administrator cannot be deleted from the system, a feature that is hard-coded into the PHP.

4.5.2 Managing teachers

4.5.2.1 Adding teachers

When creating a teacher, five fields are requested. A first name and last name are required, but a middle name is

optional. Also, a password must be entered and confirmed. Upon successful completion of all required fields, the new teacher's 'userid' is generated and added to the 'user' table. In Figure 3, the teacher "New School Teacher" is created, with a 'userid' of "NewTeacher".

Figure 3: Teacher Is Successfully Added

This teacher's 'facultyid' (same as 'userid') and first, middle and last names are inserted into the 'faculty' table.

4.5.2.2 Modifying teachers

The first action allows an administrator to search for the teacher by last name, as shown in Figure 4.

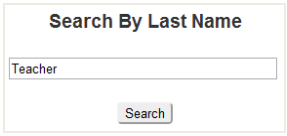

Figure 4: Search By Last Name

The software matches the entered phrase to any last name that contains that phrase and lists those names in a drop down box. If the search field is left blank, all teachers will be listed in the subsequent drop down box.

Once a teacher is selected, that teacher's first, middle and last names can be modified, though the 'userid' cannot be changed. Also, the password can be changed by entering a new password, confirming it and selecting "Yes" from the "EditPassword?" drop down box. The same fields required when creating a teacher are required here, though a password is not required if the "EditPassword?" box states "No". A confirmation screen appears if the modification is successful.

4.5.2.3 Deleting teachers

Deleting teachers works the same way as deleting administrators. A teacher is selected from a drop-down list and deleted from both the 'user' and 'faculty' tables. All teachers can be deleted.

4.5.3 Managing students

Students can be managed in the same way as teachers. There is also an option to "Promote Students."

4.5.3.1 Adding students

There are six requested fields. The four fields 'First Name', 'Last Name', 'Grade' and 'Class' are required. The fields 'Middle Name' and 'Gender' are optional. Upon successful completion of all required fields, the new student's 'userid' and 'password' are generated and added to the 'user' table. An example is shown in Figure 5.

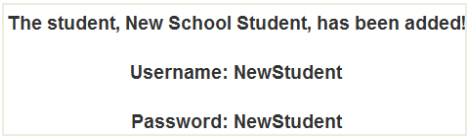

Figure 5: Student Is Successfully Added

Also, the new student's 'studentid' (same as 'userid') and other completed information will be inserted into the 'student' table. Note that a student can't be created until a class is created, since there will be no 'Class' option to select.

More options are available for students and are described in the following section.

4.5.3.2 Modifying students

First, a student is selected. This process is performed the same as it is for modifying teachers.

Once a student is selected, the same information that was used to create the student can be modified. The student's password can be modified here as well, using the same process as is used in modifying a teacher. All fields except for 'Middle Name' are required, though a password is not required if the "Edit Password?" drop down box is set to "No". Four new fields: 'Number Goal', 'Time Goal', 'Yellow Screen' and 'Show Clock', are presented.

A student's 'Number Goal' is the number of questions he or she is aiming to tie or exceed when taking an assigned test. It must be given a value zero through twenty, inclusive. A student's 'Time Goal' only applies if the student has a 'Number Goal' of twenty. Once a student has reached this level, the new overall goal becomes to finish the twenty questions in a shorter time, denoted by 'Time Goal'. It must be given a value one through sixty, inclusive.

The 'Yellow Screen' feature allows students to take their tests with a yellow, as opposed to white, background. Selecting "Yes" in the drop down box indicates that the student wishes to use a yellow background, while "No" indicates a white background. This value is stored in the 'ada' field in the 'student' table: 1 for yes, 0 for no. The 'Show Clock' feature allows students to hide the on-screen clock while taking tests. Selecting "Yes" in the drop down box displays the clock, while "No" hides the clock. This value is stored in the 'show_clock' field in the 'student' table: 1 for yes, 0 for no. It must be noted that both of these drop down boxes are set to "No" when the modification screen appears. They must be set to "Yes" every time a student is modified, if the student prefers it. An example of these options can be seen in Figure 8: Example Test Screen.

4.5.3.3 Deleting students

This feature is performed using the same process as is used when modifying a student. A search by last name is performed and then a student is selected from the subsequent drop down box. The selected student is deleted from both the 'user' and 'student' tables, and that student's assigned tests, completed tests and scores are deleted from their respective tables. All students can be deleted.

4.5.3.4 Promoting students

When the end of the year comes around and students will be moving to the subsequent grade and year, this feature allows for easy movement of all students from one class to another class. The process is as follows.

First, a current class is selected from a drop down box listing all classes. Next, one of two processes can occur. If the selected class is a sixth grade class, the administrator is presented the option to delete the students in that class along with the class. If the selected class is a first through fifth grade class, the administrator is presented with another drop down box listing all classes that are one grade and one year ahead of the selected class. The second class is then selected.

Students graduating to the seventh grade will no longer have access to the system, so they are removed. For those who will remain in the system, the first through fifth grade students, several things happen behind the scenes. The selected class to which the students will be promoted cannot already contain students; therefore, this selected class must be cleared of all students, another class must be selected or a new class must be created. If the selected class is empty, the students being promoted to that class will have their 'grade' and 'classid' fields updated to match their new class. And finally, those student's tests and scores from the current year will be removed from the system.

4.5.4 Managing classes

When adding a new class, five fields are requested: 'Class Title', 'Grade Level', 'Year', 'Semester' and 'Teacher'. All fields are required. Note that classes require a teacher, so teachers must be created first. This information is stored in the 'class' table, and a distinguishing auto-number is generated for the 'classid'.

When modifying a class, all classes are listed in a drop down box. Once a class is selected, the modifications can be made. The same fields present when adding a class may be modified, and again all fields are required. The current teacher is listed on-screen. If this teacher has been deleted, a message will indicate such in place of the teacher's name, and a new teacher must be selected. The 'classid' cannot be changed.

When deleting classes, a "Search Type" and "Search Term" are requested. Search types consist of the following: "Year", "Grade", "Name" and "Faculty User Login"; one of these must be selected or the search will not be processed. The software matches the search term to any phrase contained within the search type and lists those matches in a drop down box. All students must be removed from a class before it can be deleted, and once this is done, the class is removed from the 'class' table and all tests assigned for the class are deleted from the 'assigned_test' table.

4.6 Tests and practice tests

Tests are created or generated, assigned and deleted by teachers. Students take the assigned tests and can also generate their own tests for practice outside of class.

4.6.1 Creating tests

This feature consists of two parts: creating the test and creating the questions on the test. Creating the test involves the following. Five fields are required: 'Test Name', 'Grade', 'Description', 'Question Style' and 'Time Limit'. 'Question Style' allows teachers to choose whether questions will appear in a vertical or horizontal fashion, as shown in Figure 6, respectively.

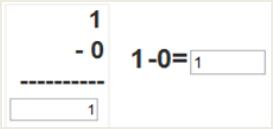

Figure 6: Question Style

Next, the teacher can manually create questions for the test. There are twenty fields for the teacher to create up to twenty questions. A sample field is presented in Figure 7.

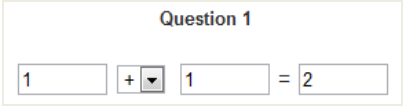

Figure 7: Question Field

Any integer value can be entered in the three text fields. The drop down box contains the four operators: addition (+), subtraction (-), multiplication (X) and division (÷). The answer field is not checked for accuracy; therefore, it is the teacher's responsibility to ensure that correct information is entered. The test is stored in the 'test' table and the questions are stored in the 'question' table.

4.6.2 Generating tests and practice tests

These two features are essentially the same, though when a teacher generates a test, he or she must also name the test, assign it to a grade and describe it. The remaining fields apply to both teachers and students: 'Type of Questions', 'Question Style', 'Time Limit', 'Max Addition and Subtraction Value', 'Max Multiplication Value', 'Multiplication Fact Restriction' and 'Max Division Value'.

The 'Type of Questions' can be addition, subtraction, multiplication, division or any combination of those four. The four max values must be greater than zero, though there is no upper limit. The 'Multiplication Fact Restriction' requires more detail. This feature allows the user to generate tests where the first value in a multiplication problem is limited to the value selected from the 'Multiplication Fact Restriction' field. The options are: zero through ten and no restriction.

Once the information is entered and submitted, the software randomly generates problems within the chosen parameters. Addition and multiplication problems are easily generated. Their only restriction is that the operands cannot be greater than the max specified value (for addition problems, this also applies to the answer); multiplication problems must also follow the specified fact restriction (if any). Subtraction and division are a bit more difficult. Subtraction problems

can't yield a negative answer, and each operand cannot be greater than the max specified value. Division problems must yield an integer answer, and the divisor can't be zero. Again, the max specified value must be followed.

4.6.3 Assigning tests and taking them

To assign a test, the teacher selects a grade. All tests created for this grade are displayed in a drop down box; a drop down box listing all of the teacher's classes is also displayed. This allows teachers to assign tests created for varying grades to varying classes, i.e. harder tests can be assigned to lower level classes and vice versa. If that specific class has already been assigned that particular test, the teacher will be given the option to reassign that test. If not, the assignment will complete. In either case, the 'assigned_test' table will be appropriately modified, with 'taken' being given the value "No" for each 'studentid' in 'classid' which has been assigned 'testid'.

When a student wishes to take an assigned test, he or she selects one from a drop down box. When a test is selected, the test screen will be generated according to the student's preferences and test specifications, and testing will commence. An example test screen is presented in Figure 8.

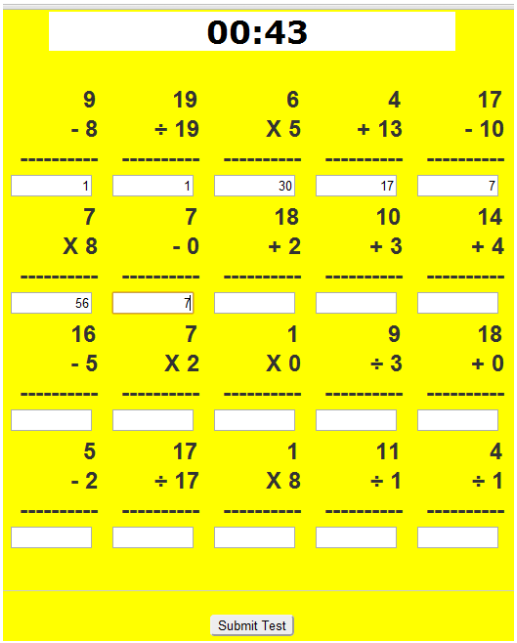

Figure 8: Example Test Screen

All answered questions will be stored in the 'complete_test' table. The student's score and time taken on the test will be stored in the 'score' table, and his or her score and/or time goals will be appropriately updated to reflect his or her performance on the test. Figure 9 shows an example of a performance report, presented after completion of an assigned test:

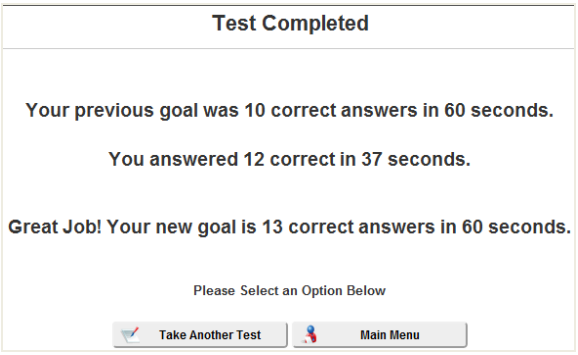

Figure 9: Performance Report

4.6.4 Deleting tests

The teacher selects a grade, and all tests created for that grade are listed in a drop down box. Once the teacher has selected a test, that test and all of its questions are deleted from the 'test' and 'question' tables.

4.7 Viewing test results

All users have access to test results. Administrators and teachers can view test results by class or by test. Students have access to their own test results, though no results are stored for practice tests. Test results can be viewed by two different methods: textual and visual. The information is retrieved from the 'score' table.

4.7.1 View test results by class

This option is available for both administrators and teachers, though the scope of results available to each user type differs. Since administrators are not assigned a class, they are given access to all results for all classes. Teachers are assigned to a class (or classes); therefore, they only have access to the results for their assigned classes. Both must follow a similar process to access results.

First, administrators and teachers must choose between textual or visual results. No matter which option is chosen, the user then selects a class for which he or she wishes to view results. Class results are displayed based on which type of display and which class the user chose.

4.7.2 View test results by test

Administrators and teachers also have access to this function for viewing test results. First, they select a grade, first through sixth. All tests created for the selected grade are listed in a drop down box. Currently, the results for this option are only displayed using the visual method.

4.7.3 View test results for a student

Students have access to this option. It works much the same way as "view test results by class" works for administrators and teachers, with the exception that students do not have the option of selecting a class. They only see results for all assigned tests they have taken.

4.7.4 Textual results

Textual results displays score results as pictured in Figure 10.

Date: 2011-06-09 || Test Name: New Test || Goal: 10 || Number Correct: 12 || Number Incorrect: 8 || Percentage of Goal: 120%

Figure 10: Textual Results

Percentage of goal may not be explicitly clear. It is calculated by equation (1).

$$percentage\ of\ goal = \frac{Number\ Correct}{Score\ Goal} \times 100 \qquad (1)$$

4.7.5 Visual results

Visual results displays score results as pictured in Figure 11.

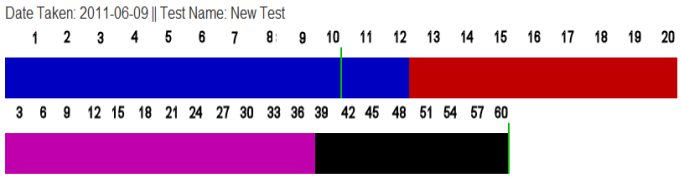

Figure 11: Visual Results

The top visual bar represents the student's score performance for that test. The section of the bar from the left indicates the number of questions the student answered correctly, and the remaining part indicates the number of questions the student answered incorrectly. The thin line extending above the bar (at 10) indicates the student's score goal going into that test.

The bottom visual bar represents the student's time performance for that test. The section of the bar from the left indicates the time taken on that test, and the remaining part indicates the time remaining for that test. The thin line extending above the bar (at 60) indicates the student's time goal going into that test.

5 Current status and future work

MathFax is currently undergoing final modifications and testing. A beta version of the software has been installed at St. Anthony's Catholic School, where students, teachers and administrators at the school will be testing the software for bugs and ease of use. We plan for the software to be fully functional, installed and ready for use before the 2011-12 school year. As is our policy with all of our service-learning projects, after this final testing phase is complete, we will make the software available to any school that wishes to use it.

6 References

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