WEBWORK –INTERNET DELIVERY OF HOMEWORK IN COLLEGE ALGEBRA[1]

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By way of introduction, WeBWorK is a program, free to educators, for delivering mathematics homework on the internet. The software, written by Mike Gage and Arnie Pizer at the University of Rochester under a DUE grand from NSF, won the ICTCM Award for Achievement and Innovation in 1999. Installed on either a unix of linux server, the program uses a combination of TeX, HTML, and Perl scripts to deliver mathematics, and then evaluate student responses. An overview and a sample, together with full download information and documentation are available at the WeBWorK home site, http://webwork.math.rochester.edu/docs/.

Project goals

WeBWorK was originally designed for calculus. After this author attended a minicourse conducted by Pizer and Gage at the National AMS/MAA annual meeting in January 2000, she shared the features of WeBWorK in a departmental workshop. Colleagues quickly saw that WeBWorK could be extended to other mathematics courses. In particular, WeBWorK seemed ideal for addressing our needs in College Algebra courses. Since we teach a large number of sections, mostly with temporary faculty, we needed some way of unifying and coordinating the curriculum. Without the resources of tutors or graders, we also needed a way of ensuring that students in all sections got adequate feedback on their homework. WeBWorK offers assistance to both students and instructors in a manner that is convenient for all users. Campus-wide surveys showed that students were less and less engaged with academic work outside class. Yet we all know the importance of reinforcing understanding of mathematics with individual exercises. Therefore our primary goal for WeBWorK was to get students involved in homework in College Algebra classes. This project was also funded by NSF as an adaptation of the original WeBWorK project.

Why WeBWorK?

The any time, any place delivery of homework and the instant feedback for students were two of the key features of a web-based homework system. We investigated several web-based systems such as Web-CT and some publisher-supplied web sites for delivering homework, quizzes, and tests. WeBWorK was our choice among all these options because of the following features:

- **control:** all software and copies of problems are run on our own web server, allowing each instructor to author and modify problems, design assignments, and manage rosters without depending on some remote site administrator.

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[1] See http://www.radford.edu/~cmett/ictcm2002/ for links to several topics in this paper.

- **text independent:** changing texts will never be a problem for WeBWorK users. Problem are organized by topics that are suitable for any text.

- **mathematical display formats:** the best that we have seen for displaying mathematics correctly on web pages. Moreover, the student has a "preview" option that takes a student's in-line entry, possibly containing square roots, exponents, parentheses, and fractions, and then returns the correct mathematical display for this entry.

- **documentation:** the home site at University of Rochester has very thorough documentation for site administrators, instructors, authors, and users of WeBWorK at any level. Both Pizer and Gage respond to a discussion group on a daily basis.

- **practice features:** the program offers an easy way for users who are not enrolled in a course to log in and do problems. This feature can be used for students to get extra practice or for review exercises for anyone anywhere.

- **individualized variations on problems:** a key feature for getting students to collaborate on homework, each student gets a different set of coefficients generated from a problem template.

- **multiple attempts:** students respond very favorably to this opportunity to learn from mistakes and to be rewarded for continuing effort. The likelihood that a student will revisit a problem done incorrectly is much higher with the instant feedback provided by the web.

- **answer-checking formats:** this feature is the best we have seen, with options of having text, numerical, list, interval, expression answers in addition to the more common multiple choice selections. The beauty of the WeBWorK program is that it recognizes the equivalence of a variety of correct mathematical expressions. For example, $x\^2$, $x*x$, $x**2$, $x\^2 + \sin(pi)$, are all evaluated as equivalent expressions, regardless of spacing.

- **expandability:** WeBWorK is easily extended to other courses and other departments such as physics or economics or even high school courses. Any instructors who would appreciate the presentation of mathematical problem on the web would find WeBWorK useful.

- **data collection for assessment:** since we administer WeBWorK on our own server, we have easy access to information such as number of logins, number of attempts, intensity of usage, for individual courses as well as collectively.

- **summary overview:** many of the other features (such as the feedback tool, the use of graphics) of WeBWorK are found in a summary at http://webhost.math.rochester.edu/webworkdocs/discuss/msgReader$0001220

Disadvantages of WeBWorK

After assessing all of the features of WeBWorK, we also must note some warnings to potential users.

- Unix or Linux: for security reasons, the WeBWorK download is designed to run only on unix or linux operating systems. Even with the well designed and well documented software, there are often some tweaks that must be

implemented by a unix-savy system administrator. Nobody will claim that installation is as easy as loading commercial software on your personal PC.

- visual esthetics: the WeBWorK software is designed to deliver homework, not dazzle the user with media. Therefore the pages are often rather plain and sometimes a bit text-intensive. Instructors sometimes need to break up a lengthy piece of text into smaller, more manageable pieces.
- entry challenges: particularly at the College Algebra level, students sometimes struggle with the correct entry of an answer that they might have written correctly by hand. The combinations of parentheses, fractions, and roots are often intimidating. However, this is where the students should be reminded to use the "preview" tool, to check that their entry matches the answer they had intended.
- local administration: while having full local control is a blessing, it also comes with the demands on somebody's time to maintain the server. There are upgrades to install, about once a year. And each semester, a system administrator needs to archive old courses, create new courses, and upload student rosters. It is possible for individual instructors to upload a roster, but most institutions find that it is easier to write a script to take electronic data from the registrar and covert it to a text file in WeBWorK roster format.
- learning curve: as with any web-based system for instruction, there is some initial challenge in learning how to use the system. However, the minimal role for instructors, described below, is pretty simple. Authoring problems and writing new scripts, the ultimate challenge, is more difficult to learn. However, the documentation at the University of Rochester WeBWorK home site is certainly adequate for users who want to tackle writing new problems and modifying the local implementation of WeBWorK.

Instructor's role

The free download of WeBWorK includes a large database of problems for trigonometry, calculus, differential equations, statistics and probability. Additional libraries of problems in college algebra and finite mathematics are being written at other institutions and added to the CVS library at the University of Rochester home site. New problems are easily appended to the existing set. Therefore the instructor's role is primarily to select problems from the existing set and build an assignment. When an instructor login is initiated special professor's tools appear, along with the typical features that a student sees. A simple text file, constructed from a professor's web page, dictates the deadline for the assignment, problems selected, and the point value of each problem. If desired, the professor can restrict the number of attempts (default is unlimited number of attempts).

Other than building an assignment, the instructor will likely want to download grades into a personal grade program. WeBWorK homework scores are easily downloaded from a web page into a text file, and thus easily pasted into a spreadsheet or other grade software. Even before an assignment is complete, WeBWorK professor's tools provide excellent information about students' progress on an assignment.

Importing a class roster at the beginning of a semester is relatively easy, since the class list need only be a text file with fields arranged in a particular order. However, most institutions find that it is also easy to write a short script to convert the roster from the registrar to a format that is easily copied into the desired WeBWorK courses. WeBWorK has also provided tools for allowing an instructor to "drop" students from a course. Another nice feature of WeBWorK is that more than one person can have "professor" privileges for a course, and TA involvement or recitation sections in WeBWorK are easily implemented.

On additional feature that instructors might use is an email tool, which allows individual data to be merged into a letter template.

Tips
After our initial experiences with WeBWorK in College Algebra courses, we have summarized some tips for users. At the outset of a semester, instructors need to think about how they want to deal with multiple sections of a course. They can be treated as individual courses, or merged into a single WeBWorK group. It is easier to manage a single large group, assuming that the instructor can coordinate the same assignments with the same deadlines for all sections. It would be difficult, but not impossible, to construct different assignments or different deadlines for different groups within a single WeBWorK course.

It is very important to introduce WeBWorK to students with some careful explanation of its features and its advantages for the student. We have found that it is best to hold a class in a setting where students have access to computers and can experience early success with the program. Students who understand that they have opportunities to correct mistakes will appreciate the need for doing their work early. A first assignment should be designed to help students understand the variety of formats, feedback, and answer checking procedures in WeBWorK. We tell students about the "practice" logins, we emphasize our reasons for choosing WeBWorK to help them get engaged in homework, and we encourage them to collaborate on assignments since they each have their own individual version of a problem. Finally, we remind students of the "preview" tool so that they may find assistance with the syntax difficulties with some answer entries.

Assessment
Response from both students and instructors has been very favorable. Studies show that the time spent on homework in a WeBWorK class was significantly greater than that in a non-WeBWorK control group. Instructors have helped sort out problems that were too awkward or cumbersome for students, and have greatly appreciated the assistance in managing homework in large classes. Surveys of student attitudes showed that students are very positive about the opportunity for multiple attempts at getting a problem correct, particularly with the instant feedback that they wouldn't get from ordinary paper homework assignments. After only one pilot semester of College Algebra, it is too soon

to tell whether there is any improvement in understanding of material. However, we anticipate the results of a study on student performance in College Algebra as well as performance in subsequent quantitative courses for students who participate in WeBWorK courses.