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# WeBWork: An Open-Source Online Homework System

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William K. Ziemer, California State University, Long Beach, Long Beach, CA

WeBWork is a free online system for administering and automatically grading student homework. The system, developed by mathematicians Michael Gage and Arnold Pizer at the University of Rochester (<http://webwork.math.rochester.edu>), has been carefully assessed at numerous sites and has repeatedly been shown to improve student learning. Over the past few years, the number of institutions using WeBWork has grown to over 50 schools.

## WeBWork Features and Benefits

### Automatic grading

Homework problems are organized into sets containing as many problems as the instructor cares to assign. Students call up problems one at a time, work them out, enter their answer in the indicated location, and then submit their answer for scoring. The answer is immediately evaluated, and the system tells the student if it is correct or incorrect. WeBWork keeps a running score for each problem and the entire set after each answer submission, so that students can complete assignments in multiple sessions.

The immediate feedback on every problem is a vast improvement over typical homework submission, where usually only a sampling of problems is graded, and there is often a significant delay between submission and getting a graded assignment back.

### Randomized problems

WeBWork allows random values to be used in each student's set of problems. This means that students in a class are doing essentially the same problem set, but the numbers are dif-

ferent from one student to the next. Thus, it is not possible for one student to work a problem and another (or 10 others!) to simply copy the answer and submit it. Problem sets that are similar yet varied are ideally suited to support cooperative learning, something that has been well documented to improve student learning. Instructors can have students work together to help each other figure out how to do a particular type of problem, but each student has to work out the details for their individual version of a problem.

### Multiple submissions

Because a computer is doing the grading, there is no instructor effort required to let students attempt problems more than once. Each problem in a set can be configured to allow students a fixed number of submissions or an unlimited number.

It has been repeatedly documented that completing homework is a primary factor in learning mathematics. Most implementers of WeBWork give students unlimited attempts at problems. By doing this, students are encouraged to try again if they do not get a problem right the first time, instead of just moving on. WeBWork sites consistently report that students are remarkably persistent when working on WeBWork problems, with several noting that 75% or more of students get every problem correct over the course of a term.

### Flexibility

WeBWork can be configured to suit the needs of virtually any user. In particular:

- The answer parser can handle mathematical expressions in a variety of forms, including functions, answers with

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units, keywords, and even situations where there is a family of correct answers (e.g., answers to indefinite integral problems).

- Problems can be programmed to give different feedback for different answers, thus allowing the possibility of custom hints. Problems can also be written to provide a worked solution (as opposed to just the final answer) once the submission deadline has passed.
- The system can be configured to let students use it in "practice mode" where scores are not recorded and the answer is always available. Thus, it's possible to post a large collection of problems (more than would ordinarily be assigned) for students to work on their own.
- It's suitable for a wide range of courses and has been used in intermediate algebra, college algebra, finite mathematics, precalculus, calculus, multivariable calculus, differential equations, linear algebra, financial mathematics, discrete mathematics, and more. And unlike commercial homework systems, WeBWorK is not tied to any text, so that a department can have all courses that use web-based homework on the same system.
- The system is usually installed locally by the institution rather than running on a remote server. It's also "open source," with a community of developers contributing code that has been integrated into the core of the system.

Many of the sites that have implemented WeBWorK have studied its effectiveness, and the results have been consistently positive. For example, the University of Virginia found students in WeBWorK calculus courses performed better on exams than students in control sections. Rutgers University documented that students who persist and complete their homework using WeBWorK perform better in their math classes. California State University, Long Beach (CSULB), has verified that for a variety of measures, WeBWorK boosts the performance of students in undergraduate mathematics courses.

Once WeBWorK is up and running and the problems are ready, it's easier for instructors to use than collecting, grading, and returning written homework. If the system is free, student performance improves, and it's easier for instructors. Why isn't everyone using WeBWorK?

The system runs on a Linux server, and some administrative tasks, such as constructing homework sets, require

direct interaction with the server. Thus, instructors need to have at least a passing knowledge of the Linux operating system.

Writing problems are time-consuming and require knowledge of the PG (problem generating) language, a hybrid of LaTeX and Perl. An option is to use existing WeBWorK problems, of which an estimated 15,000 exist at various schools. Unfortunately, most of the problems are not centrally available, and sifting through those that are is slow and unwieldy. The documentation is piecemeal, making it difficult to find information.

Although none of these issues are insurmountable, they are significant, particularly for mathematics instructors with high teaching loads (and thus minimal discretionary time) and limited access to technical support. For instance, in discussions with faculty using WeBWorK at CSULB who primarily teach at community colleges, the consensus was that no matter how well the system performs, it will not be used if the instructor has to learn a new coding language or operating system. We encountered the same reaction from 2-year college faculty we spoke with at the national American Mathematical Association of Two-Year Colleges (AMATYC) meeting in 2002 and have heard similar sentiments from a wide range of faculty at other types of institutions.

At schools that have thus far adopted WeBWorK, there's almost always a technically capable faculty member who is able to put time into installing and supporting the system. In several cases, further impetus has been provided by an NSF CCLI A&I grant for implementation.

WeBWorK version 2 addresses these issues. The system is being made "point and click" with a 100% browser-based administrative interface, and users have convenient searchable access to a large library of existing problems.

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