

USING WEBWORK EFFECTIVELY

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1. INTRODUCTION

WeBWorK is a web based program that allows instructors to assign homework, accepts student submissions, and grades their work immediately. WeBWorK is free and open source. Over 300 universities and high schools use WeBWorK all over the world [1].



Mathematicians contribute to it with the goal “of providing the mathematical community with the most robust, flexible, and mathematically capable online homework system possible” [1].

The goal of using WeBWorK, as with any form of homework, is to engage students actively and help them accurately apply course concepts to new problems. Well-chosen and well-written problems (i.e. what Merrill calls good *practice* [5]) can support a variety of learning principles that ask students to assimilate multiple concepts and apply them in new situations. By completing the assignments accurately, students should obtain basic skills and be able to approach unfamiliar, more difficult problems and applications.

WeBWorK gives immediate feedback, and when used correctly, can encourage meaningful self-evaluation and collaboration. WeBWorK saves time for instructors and money for universities and students, which might be another important reason for its spread and dominance in math education. However there are limitations to WeBWorK, but with care and attention instructors may find that it is possible to overcome these limitations and effectively engage students with the material through WeBWorK. And since WeBWorK is free, constantly improving, and widely used, it is important for instructors to understand how to use this technology to its greatest effect.

In Section 2, I discuss how students and instructors use WeBWorK and describe different functionalities. In later subsections, I will go over the advantages and disadvantages of WeBWorK. I will conclude with some ideas for supplementing WeBWorK in Section 3.

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2. WHAT IS WEBWORK AGAIN?

WeBWorK is a web based program that assigns and grades homework in a large variety of lower division mathematics classes. We will start with how instructors use WeBWorK not because that is more important,

but because in assigning the homework, the instructors initiate the interaction and set the environment in which the students will engage with the material outside of class.

2.1. How instructors use WeBWorK. Instructors must create a homework assignment and assign it to users. Instructors also choose which problems to assign to students. They may choose the number of attempts students are allowed and how many points each problem is worth. In this sense, WeBWorK is teacher-centered. Here is a list of some of the topics covered in the national problem library (NPL), the bank of problems available to anyone using WeBWorK:¹

- basic, intermediate, and linear algebra (6409 problems)
- trigonometry (661 problems)
- derivative, integral, and vector calculus (8275 problems)
- sequences and series (745 problems)
- basic ordinary differential equations (553 problems)
- complex analysis (21 problems)
- discrete mathematics (161 problems)
- financial mathematics (423 problems)
- probability and statistics (768 problems)

Lower division math courses are the target audience for WeBWorK. More advanced calculus subjects have fewer problems over a smaller range of subjects. The lower division courses have a large variety of questions that present material in multiple ways and with different applications.

In addition to the NPL, mathematicians at individual schools can add problems to the bank to fit the needs of their department or course using a programming language similar to Perl. Individual instructors can also edit problems they feel are unclear or just incorrect. These changes are saved and stored in the problem bank at the individual school. These edits are not shared with the NPL automatically, however it is possible for schools to upload to the NPL.

Instructors can also analyze where students are having difficulty with the “student progress” and “statistics” functionalities. They can view progress and statistics by student, homework set, or problem to establish which topics students find difficult by viewing the average grade on a problem or average number of attempts.

2.2. How students use WeBWorK. Although instructors set up the homework environment and pose specific questions for the students, students have a fair amount of freedom in how they work through the homework. After being assigned homework, students may answer questions in any order and at any pace they like and over multiple sessions, being restricted only by when the homework is due. This flexibility in working through homework is the learner-centered aspect of WeBWorK. Students receive immediate feedback about the correctness of their answer. I have observed that if their answers are incorrect, then students typically self-evaluate, discuss with peers, or seek help from a tutor before resubmitting a new answer. Answers can be incorrect for a variety of reasons: the student may have misunderstood the problem and worked it incorrectly or they may have made a trivial error such as a basic arithmetic error or a syntax error. WeBWorK gives no indication of the type of mathematical error the student made, but sometimes alerts the student to syntax errors. After the assignment is complete, correct answers are posted. Occasionally, an instructor might have written out a solution that is posted along with the correct answer.

2.3. Advantages to WeBWorK. One obvious advantage to WeBWorK is that it is free and open source and does not significantly contribute to the cost of education. At schools with large classes and not enough resources to pay homework graders, WeBWorK might be the only feasible way to provide homework for the students.

Mayer, Almeroth, Bimber, Chun, Knight, and Campbell wrote, “Active learning occurs when students pay attention to relevant material, mentally organize the material into a coherent cognitive representation, and mentally integrate the new material with existing knowledge” [4]. Active engagement is essential for students to learn mathematics, and WeBWorK makes this possible in a way that is different from pencil and paper homework. WeBWorK can draw attention to important concepts even if the question format is not optimal. Well-chosen (or well-written) problems or problem sequences can require students to “integrate

¹The number of problems is approximate since some of them are cross referenced and applicable problems are sometimes difficult to locate.

the new material with existing knowledge” and help students mentally organize how concepts fit together so that they might apply their knowledge to new situations.

One important advantage of WeBWorK over pencil and paper problems is that students receive multiple attempts and immediate feedback. So if a student answers a problem incorrectly, they know to and can reattempt the problem while the set up and reasoning are “still fresh in mind” [6]. Since the attempts are generally unlimited, students can try one method and test their answer, think about it and try another, or come back to it later. The student can self-evaluate and correct mistakes until the answer is correct, which is not possible with hand-graded homework. First of all, allowing unlimited attempts when the homework is hand-graded is not feasible. Second, it might take a week to get a hand-graded assignment back, at which point the course has moved on, there is a new homework assignment, and the student might have trouble getting back into the question. The study by Roth, Ivanchenko, and Record also showed a strong correlation between the grades of students and the amount of WeBWorK problems they completed [6].

Taking the homework online creates an environment where students know in advance of the assignment’s due date that their answer is incorrect and that they can correct it. This is a classic behaviorist practice although ‘music isn’t played’ and there is no “entertaining animation” when a student finally gets the correct answer [2]. The positive feedback would be in terms of a higher homework grade. Students know they will get negative feedback in the form of a grade if they leave an answer incorrect or skipped, and moreover, they have the power to change that. This is specifically unlike on an exam or written homework where the number of attempts is limited to one. This aspect of WeBWorK empowers students in that it gives them control over a portion of their grade (maybe 20%), which Gee noted would be a positive principle to adapt from video games to education [3].

As noted, students have a lot of flexibility in the pace and order they complete homework. There isn’t a lot of pressure to get a problem right the first time, and this encourages students to start trying, reconsidering, and find their own “favorite way” to solve a problem. This idea was touched on by Gee when he outlined how we could adapt the principle of ‘customizing’ from video games to education [3]. By only checking the answer, students are allowed to work a problem any (correct) way they would like.² WeBWorK is very good at telling when someone submits different but equivalent solutions, so that although learning the syntax might be frustrating, they do not have to guess at how simplified their answer needs to be or worry that they used the “right method” that gives the correct form for the answer.

Some instructors might limit the number of attempts for various reasons. For instance, true/false and multiple choice questions would be trivial if there were more than one attempt allowed. Some instructors believe that limiting the number of attempts on free response problems encourages more thoughtful self-evaluation.

The process of self-evaluation and correction is not exclusively between the student and the computer. It can involve going to office hours or consulting with a friend. The “Email Instructor” functionality in WeBWorK allows students to begin a dialogue with the instructor by sending questions that include a link to the page the student sees, complete with previous answers. It is often possible to guess what the student is doing incorrectly by viewing their final submissions. Not only does WeBWorK encourage self-evaluation but also peer evaluation. All students receive the same homework set but with different numbers so that students can work together yet still have to work through their personal problem in order to get credit for it on WeBWorK.

2.4. Drawbacks to WeBWorK. We have already hinted at some of the drawbacks to WeBWorK. The reader can tell from looking at the list of problem types that there are deficiencies. For instance there are only twenty-one complex analysis problems compared with 8275 calculus problems, which is over 1000 problems per calculus course at UCSB.

However, within one course, there might be several topics missing. For instance, there are very few (or no) problems asking students to optimize multivariable functions or calculate certain types of multivariable integrals. Asking students to optimize a function requires that they apply concepts learned in an earlier course on derivatives to functions of multiple variables, and so it is disappointing that there would be a deficiency in this area. At UCSB, graduate students have been employed to fill the gaps in WeBWorK

²For instance, some students would prefer expanding $f(x) = (2x + 1)^2$ before taking the derivative rather than applying the chain rule or the product rule. There are many examples in calculus where simplifying algebraically can lead to problems that students consider to be easier.

problems in multivariable calculus. However, since local editors do not “talk” directly to the NPL, these improvements are local and do not improve WeBWorK on a national level.

These gaps in WeBWorK cause problems for instructors when they want to ask a variety of questions to support different learning methods. The previous example would make it more difficult (or impossible for an instructor who cannot code WeBWorK problems) to help students learn by activating previous knowledge of derivatives and optimization in the new setting of multivariable calculus. Additional application problem to a larger variety of subjects would help students integrate the concepts into their field of study and future career path. Each of these first principles from Merrill can be achieved by an instructor assigning well-chosen problems and filling in the gaps with additional problems he or she codes into WeBWorK or through hand-written assignments [5].

WeBWorK is rigid in the form of answers it will accept. Although it is certainly less rigid than most programming languages. WeBWorK will understand $\sin x$ as $\sin(x)$, for instance. This allows students to input $\sin(x)$ as they would write it on their paper. However WeBWorK is picky about parentheses in general. This reinforces solid knowledge of order of operations, but sometimes causes students to get answers incorrect when they would not have gotten them wrong on a written assignment. Having worked out $\int \frac{dx}{(6x+4)^2}$ on a piece of paper, a student would likely come up with the following (correct) answer:

$$\frac{-1}{6x+4} \text{ which a student would likely try to enter as } -1/6x+4.$$

However, WeBWorK would return that the student’s answer was incorrect, because it should have been entered as $-1/(6x+4)$.

There are also conceptual problems. Despite having over 17,000 problems, WeBWorK is not well-equipped to ask certain questions. This problem is highlighted by questions that normally require a free response but must be asked as a multiple choice question such as graphing questions that come up in all levels of calculus more advanced concepts where the reasoning and work shown is far more important and nuanced than students understand when they only select yes or no, true or false, or A, B, C, or D. On these types of problems, it is entirely possible for students to get the “correct” final answer with incorrect work and walk away believing they understood the concept.

Another concern with WeBWorK is that students guess the answers. A study by Roth, Ivanchenko, and Record showed that despite the perceived concern that students try guessing answers at a very low rate [6]. They note that guessing is likely more prevalent on multiple choice questions, but is generally ineffective on the free response questions with answers that are formulas or numbers. Guessing on multiple choice problems is frequently discouraged by giving students a limited number of tries on these problems.

That WeBWorK reinforces the idea that only the final answer matters is an important drawback to this technology, when in fact it is more valuable for students to learn quantitative reasoning skills. Students can certainly gain the desired skills by using WeBWorK, but that requires discipline on the part of the student and careful attention to student perceptions on the part of the instructor. When resources are unavailable for instructors to hand grade homework assignments on certain topics, they should take steps to alert students to the specific skills they should acquire after a homework set.

3. CONCLUSION AND IDEAS FOR ENCOURAGING MEANINGFUL ENGAGEMENT WITH WEBWORK

WeBWorK use is popular because it is free, saves time, and provides a service instructors cannot: immediate feedback on homework. Having recognized some of the disadvantages that do affect students’ learning, I now make suggestions on how to blend WeBWorK use with other methods and technologies to overcome disadvantages and make WeBWorK even more effective.

3.1. Combine WeBWorK with Written Work. This might seem like a step “backwards” with respect to using technology in the classroom, but it is important to use technology when it helps and not use it when it does not. As discussed above, WeBWorK is ineffective at asking certain questions and relaying to students the skills that they should take away in these situations.

In large classes at UCSB, teaching assistants frequently grade one quiz problem per week. It is not unreasonable for teaching assistants to grade two to three homework problems every couple of weeks. In a differential equations class, the teacher can select four to five topics that are not well tested by WeBWorK and have students submit a written assignment on these topics. Combining this with a hand written solution

of one homework problem each week can give students a better idea of what they are expected to be able to do and how they should express themselves after learning a concept.

Below are two questions that are not well asked in WeBWorK:

- (1) Write a paragraph explaining the relationship between secant lines, tangent line to a curve, and the derivative of a function, $f(x)$. Use complete sentences and draw pictures to demonstrate the relationships.
- (2) Many WeBWorK problems on series ask students to determine the convergence of a series using a specific method. However the concept that is interesting for them to learn is how to judge which method will be the most effective and to recognize when a method is not working and move on to another attempt.

Written assignments can also support a constructivist use of WeBWorK by providing some of the basic experience needed to draw conclusions about mathematical methods. After a WeBWorK assignment on series tests, students could write a description about what qualities of series would motivate them to try one test first. There isn't one right answer to this question, so an individual student's guidelines might differ based on the strengths in their personal skills set. Again students need to have worked with examples themselves to build this kind of intuition, and WeBWorK is effective at providing this. Students can draw deeper conclusions on applying mathematical concepts to new situations for which the 'best method' is not given to them or otherwise immediately clear, and these individually defined guidelines are based on prior knowledge and experience and "embedded in the setting in which it is used" [2]. Instructors hope that by defining their own strategies for applying methods based on understanding how these methods work that students have also created for themselves "interrelated, symbolic mental construct[s] that form the basis of knowledge and skills" [2].

3.2. Forums for Peer Review. An advantage to forums is that the instructor can ask any question he or she believes to be insightful and useful in aiding the students learning. Some forums, like GauchoSpace, have the option for students to write math symbols. Students upload their responses and receive feedback from their peers, who also learn in return by evaluating the original work. The hope is that students will self correct and learn by reading each other's work, however motivation to participate constructively in forums may be low if the forums are not graded. Should an instructor choose to grade the forum participation, then the amount of work increases exponentially with the number of responses each student is expected to make. This is a way of bringing the peer evaluation that the instructor hopes is occurring outside of class to a more formal setting that the instructor can supervise and step in when necessary.

The second question in the preceding section can be addressed especially effectively in forum format because there are many ways to decide the convergence of a sequence or series. Students can post solutions and discuss convergence tests that did and didn't work and discuss why some tests are more effective than others. This can be effective with any problems that have multiple solutions or questions where incorrect solutions can inadvertently lead to the correct answer.

These ideas for enhancing WeBWorK can be applied to any online homework tool. It is the responsibility of the instructor to identify which learning outcomes are not being effectively addressed by WeBWorK and fill that gap. The other suggested forms of engagement enable students also learn different skills. WeBWorK requires self-evaluation but without the requirement that the evaluation be articulated. Written homework requires that students explain their answers fully and write clear explanations. Forums require that students evaluate other students' work and comments on their own work and respond in a way that is constructive and clear for their peers. While WeBWorK has shortcomings, these issues can be addressed by the instructor and student in other ways that do more than simply fill the gaps but encourage different types of engagement and analysis of the material.

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