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WeBWorK: Perceptions and Success in College Algebra

Shandy Hauk and Angelo Segalla

Introduction

The purpose of WeBWorK, an open-source web-based piece of software, is to support students' out-of-class attempts at mathematics learning. Used in many U.S. schools and colleges, the software presents mathematical tasks then students work (e.g., on paper to one side of a computer) and enter their solutions on a web-based form. Immediately WeBWorK gives feedback ("correct" or "incorrect"). The interface does not correct a student's errors or give hints. If students need help, they are encouraged to seek out a fellow student, a tutor, or the instructor. They can do this in person or by email. For more on this particular open-source program, see the information hosted by the Mathematical Association of America at webwork.maa.org.

Here, we share results from a study of college algebra classes where WebWorK was used as a substitute for paper and pencil homework. Students in 12 of 19 classes had homework problems to be completed through the web-based software, while students in the other 7 of the 19 classes had assignments of the same problems – all were from the course textbook – to be completed using the traditional pencil-and-paper approach.

First, the bottom line: Student achievement in the web-based homework group was at least as strong as that among those in the paper-and-pencil group. That is, even a narrow use of WeBWorK as a substitute for handwritten homework can be at least as effective as traditionally graded paper-and-pencil homework for college students learning the mathematics common to the high school second year of algebra. Also, from surveys of the WeBWorK students and teachers, we found out some things about their perceptions of the usefulness of WeBWorK and ways the software may productively challenge some beliefs about mathematics learning and teaching.

Our focus for this report was the first-year college algebra classes at a large state college we will call Big Public University (BPU; see Figure 1 for an overview of the student demographics compared to national averages). Our questions:

1. Student Achievement. Given that the same homework items were assigned in web-based homework (WBH) and paper-and-pencil homework (PPH) sections, and controlling for preparedness by way of pre-test and national norm-referenced tests (SAT-Math and SAT-Verbal), how did student achievement in the two situations compare?
2. Student Perception. Among the students who did web-based homework, what are perceptions of the nature, purpose, and use of web-based homework, particularly of their efforts and degree of success using WeBWorK?
3. Instructional Style. What contributions to differences in students' perceptions and performance might be attributable to instructor style?

In this study, 644 students were enrolled in the 19 class sections. Of these, 532 (84%)

completed the course while 112 (16%) dropped or withdrew. Of the 532 who finished the course, 435 (82%) passed it with a D or better: A (19%), B (28%), C (24%), or D (11%). That is, of the 644 who originally enrolled, 435 passed, 97 failed, and 112 withdrew from the course. There were no statistically significant differences in these percentages between the WBH and PPH sections. There were 408 students in the 12 WBH sections and 236 students in the 7 PPH sections. Fifteen instructors taught the 19 classes. Each of the three instructors who taught multiple sections of the course had at least one PPH and one WBH section.

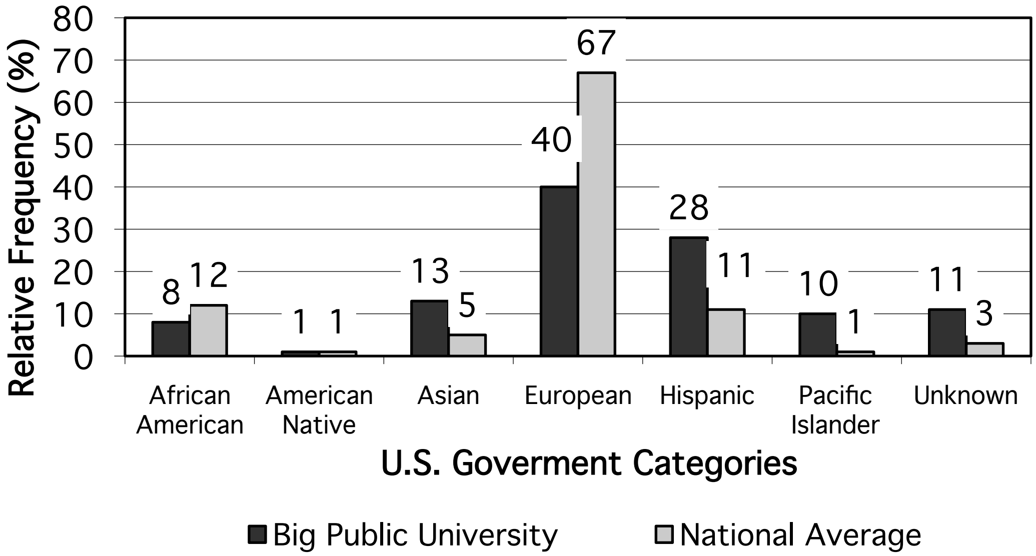


Figure 1. Student demographics at BPU compared to U.S. national averages.

Methods

Achievement. We collected algebra pre- and post-test scores, student preparedness information (SAT-Math and SAT-Verbal scores), demographic information, and course completion information. All students in the 19 classes took a 25-item multiple-choice paper-and-pencil test over college algebra content in the first and last weeks of the term. The same test was used both times. Developed and reviewed by the instructor who coordinated the course and five expert college mathematics instructors, the exam was pilot tested in the year before being used for this study.

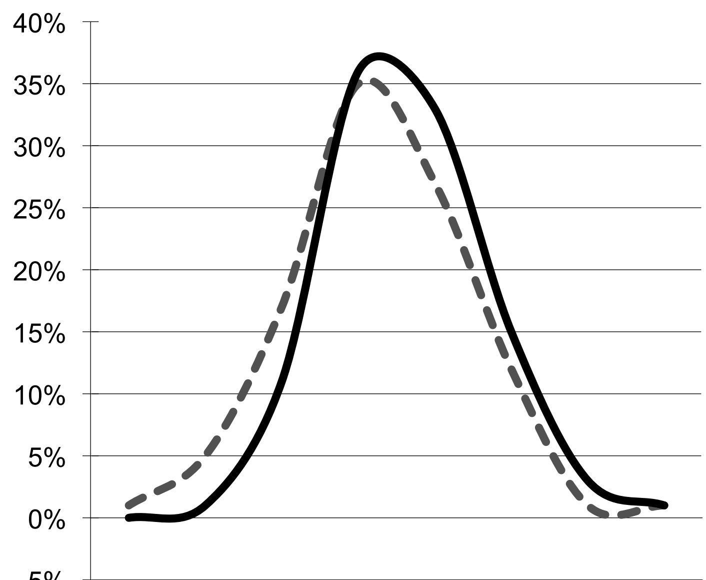
Assignments. The college algebra problem library programmed into WeBWorK for the study was made up of exercises selected from the textbook used by all the classes (Stewart, Redlin, & Watson, 2000; permission was obtained from the author and publisher). The college algebra course coordinator determined a list of suggested homework exercises, organized by textbook section, and provided it to all instructors and to the WeBWorK problem library programming team. Each WBH and PPH instructor used at least 80% of these problems in weekly assignments. Students completed the majority of homework outside of class time. Students in WBH courses did their WeBWorK on a home computer or at a computer in an on-campus lab.

Perceptions. At the end of the semester, WBH students completed a short survey designed to measure their comfort with computers and their perceptions of learning mathematics using the WeBWorK system. The survey included six statements, each with a five-point response scale, the seventh item was a prompt for written comments about WeBWorK. A similar survey of instructors was administered.

Results

Achievement

First, we give some context. In the PPH classes, instructors reported that about 65% of students turned in homework regularly. The WeBWorK server records indicated that 78% of WBH students regularly attempted their web-based homework. The main statistical result was that no significant differences in performance were found between WBH and PPH students on the post-test nor were there any statistically significant differences in score gain between the groups from pre- to post-test (see Figure 2). It seems WBH supports student achievement at least as well as PPH while saving instructors homework grading time. We note here that, though disheartening, trends similar to those found in student achievement in high school algebra were present at BPU (e.g., with some students' score *gain* being negative or zero)



	-15	-10	-5	0	5	10	15	20
Paper&Pencil	1%	5%	17%	35%	27%	12%	1%	1%
WebWorK	0%	1%	11%	36%	33%	15%	3%	1%

Figure 2. Student score *gains* from pre- to post-test (25 points possible).

Student Perceptions

Student answers to the items on the end-of-term survey indicated that WeBWorK was seen as accessible and that they studied "about the same" amount with WBH as they had in previous PPH courses. Most students reported that they were already comfortable using computers when starting college algebra.

On the open-ended survey question, 149 students (of the 348 who completed the survey) offered written comments. We grouped them into three categories: perceptions, intentions, and belief-conflicts. The ethnic, gender, and course instructor distributions for the 149 responders were approximately those of the entire WBH population, though the distribution of grades was not the same as the whole population (students who ended the course with a grade of F were underrepresented in the 149 who made comments). Among the 149 responders, 40% perceived WeBWorK as "difficult to communicate with," noting: "Sometimes my correct answers would come up 'incorrect' because I did not type my answers the way the computer could understand." A small group of students (10%) also mentioned an urge to "put off homework because it's so frustrating" to use WeBWorK.

Student Intentions

As a support for engaging in mathematical thinking, WeBWorK is involved only as a monitor for correctness. Good monitoring is key in learning to be an effective problem solver. In the language of Schoenfeld (1992), the web tool does some monitoring but responsibility for meta-cognitive control (response to the monitoring), problem-solving, and the impact of mathematical beliefs rests on the student. For the 35% of students responding whose comments indicated a view of mathematics learning as a complex and personal process of building conceptual understanding, WeBWorK was a tool that helped or hindered concept learning. The other 65% of students, whose reports indicated a procedural view of mathematics learning as a disconnected collection of formulae and "plug-and-chug" strategies, appeared to view WeBWorK as either helping or hindering a procedural approach.

Student Beliefs and Belief Conflicts

Student beliefs about mathematics appeared to be challenged frequently by their WeBWorK experiences. Spangler (1992) summarized four main beliefs about mathematics widely held by high school and college students:

(1) mathematics is computation; it does not involve reflection during task engagement;
(2) mathematics must be done quickly, or, spending little time is a more important task goal than sense-making;
(3) mathematics problems have one right answer and no further action or evaluation is required once an answer is found; and
(4) the teacher is the agent of mathematical learning, not the student (i.e., only intentional acts on the part of the teacher lead to learning, no intention on the part of the student is necessary).

Many of the concerns voiced in student comments about WeBWorK can be traced back to a violation of, or challenge to, one of these four beliefs. As an illustration, in WeBWorK, some computation can be done by the program. For example, given the problem:

Solve for x: $3x + 1 = 7$,

a student who submitted, through the WeBWorK interface, (7-1)/3 would get back the response: "That answer is CORRECT." Some students reported feeling that they "weren't really doing math" because the program, not the student, would do such computation, a challenge to Belief #1.

Challenges to Belief #2 were evidenced in student comments about the role of time in using WeBWorK. Students could (and often did) retry problems. About 10% of students perceived a "re-try-ability" of problems that they said led them to further effort. Another 10% commented with a tone more of complaint than self-reflection that they spent more time on their efforts in WBH than in previous PPH coursework and that "math homework shouldn't take so long."

Belief #3, that mathematics problems have only one correct answer, appeared to conflict with the use of WeBWorK in two ways. First, WeBWorK would do computation for students so that (7-1)/3, 6/3, and 2 were all correct answers to the problem "Solve for x: $3x + 1 = 7$." The possibility of multiple correct versions of an answer was a concern in about 10% of the student comments. Secondly, and perhaps more significantly, were the reports by about 10% of student respondents that the goal was seeing "That answer is CORRECT." This group appeared to have both the view that mathematics was a collection of algorithms and the intention to aim for "that feeling of satisfaction" resulting from "That answer is CORRECT." Within this group there were four students who remarked on guessing many times when the first answer was not correct. We reviewed the WeBWorK audit trail and found that a very few students submitted as many as 35 guesses before moving on to the next problem. This small subset of students may not see their role as learners to include monitoring and control, so the monitoring offered by WeBWorK was of little use.

Belief #4, came into play for the small group of students who wanted WeBWorK to "be the teacher." About 15% of students said they disliked the fact that all they saw was "That answer is INCORRECT," and wanted "hints about what is wrong." WeBWorK may have been seen as a surrogate teacher failing to be active because the interface did not suggest solution paths or give hints for how to proceed.

Instructor Perceptions

The 15 instructors had a variety of mathematics and teaching backgrounds. See Table 1 for information on the instructors and their full-time equivalent (FTE) teaching experience (all names are pseudonyms). WBH instructors also held differing view about the usefulness of WeBWorK. As has been noted in the literature, what and how teachers communicate with students about innovation can impact its effects. Indeed, what instructors said about it was reflected in their student's survey comments and pre- to post-test gains. Figure 3 shows the average gain score for each instructor's students, with instructors grouped according to the opinion they expressed about the usefulness of WeBWorK. It should be noted here that though the initial assignment to WBH or PPH for each section was random, instructors had the choice to withdraw from either group. Two instructors switched from PPH to WBH; however, no WBH course instructor requested to be in the PPH group.

Table 1. Summary Profile of WBH and PPH Class Instructors.

WBH only	Degree at time of study	Years of teaching	Years teaching College Algebra
Ms. Degree	M.S.	>10	>5
Mr. Ellipse	M.S.	>10	>5
Dr. Functional	Ph.D.	>10	3-5
Mr. Graphic	M.S.	>5	3-5
Mr. Helix	M.S.	3-5	3-5
Mr. Inch	GTA	3-5	3-5
Ms. Join	GTA	<1	<1
Ms. Kite	GTA	<1	<1
PPH only			
Dr. Radian	PhD	>10	>5
Mr. Saddle	M.S.	>10	>5
Ms. Torus	M.S.	>10	>5
Mr. Undo	M.S.	1-3	1-3
WBH & PPH			
Mr. Angle (1W, 1P)	M.S.	3-5	3-5
Mr. Basis (2W, 1P)	M.S.	3-5	1-3
Ms. Cone (1W, 1P)	GTA	<1	<1

Ms. Cone, Mr. Ellipse, and Mr. Graphic, each said in one way or another that they saw web-based homework as "not much use." This was reflected in their students' comments, including those who said it was "a colossal waste of time."

On the other hand, Mr. Basis, Ms. Degree, Dr. Functional, and Ms. Join all said they thought WeBWorK was a good idea and "could be useful," but weren't sure it could replace regular homework. They each felt a personal type of interaction was missing: they saw no way for themselves as teachers to guide students when the students made mistakes (connected, perhaps, to their awareness of students' tendency towards Spangler's Belief #4). Students of these four instructors reflected their teachers' hesitant views of the usefulness of WeBWorK and included comments like "I prefer getting feedback from the professor because he could help me understand what I did wrong much better."

Mr. Angle, Mr. Helix, Mr. Inch, and Ms. Kite all asserted that WeBWorK was a valuable tool and this was reflected in student comments about how "helpful" it was. Moreover their students, like those of the instructors in the "could be useful" group, also made suggestions for how the interface might be improved.

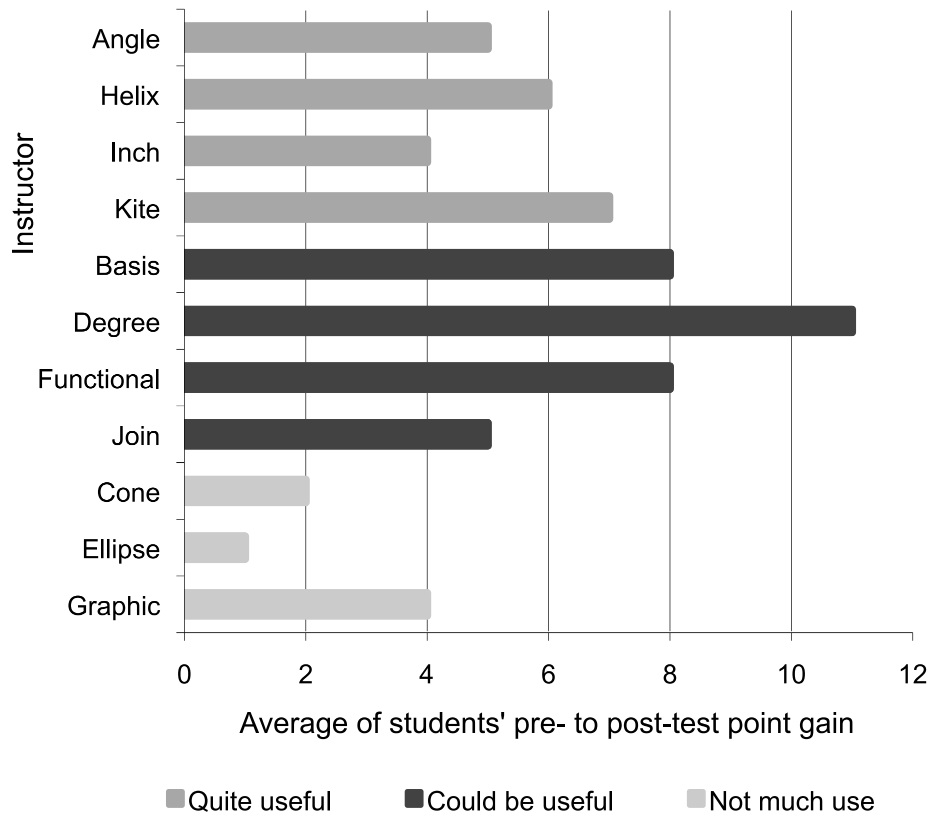


Figure 3. Instructors' views of the usefulness of WeBWorK and their students' pre- to post-test gains (out of 25 points possible).

Though the number of WBH instructors was too small to look for statistically significant differences among the performances of their classes based on a grouping by the instructor's perceptions about the usefulness of WeBWorK, the pattern apparent in Figure 3 is provocative. Certainly, when a teacher did not view the use of WeBWorK as valuable, student learning was prone to suffer by comparison (e.g., the bottom three bars for the "not useful" group in Figure 3).

Notably, the instructors who expressed *cautious interest* about the use of WeBWorK had higher average gains in their classes than those instructors who asserted they found WeBWorK quite useful. The "could be useful" group of instructors reported carefully reflecting on what might be missed through the use of WeBWorK – qualitative feedback to their students – and said they implemented alternative methods for interacting with students. In fact, Ms. Degree (the instructor with the most experience, 21 years) assigned both WeBWorK and a few additional paper and pencil homework problems in her section. She carefully commented on these extra, mildly non-routine problems, before returning papers to students. Her WBH class also had the highest average gain from pre- to post-test.

Benefits and Limits of WebWorK

Unlike internet auto-tutorials or discovery learning, the web-based homework of WeBWorK investigated here does not openly conflict with traditional direct instruction or lecture methods of classroom teaching nor does it take a large amount of instructor time. This may be both good and bad.

It is good in that the likelihood of WBH adoption by experienced teachers is increased because WeBWorK can be seen as a tool to reduce the need to grade piles of mathematics homework papers. It may be bad, however, in that WeBWorK does nothing explicitly to challenge the notion widely held by many students (and some teachers) that learning, particularly in algebra, is a matter of skill practice rather than construction of personal knowledge structures rich in conceptual connections to previous learning.

While it would be wonderful if WBH actually improved student performance, we think that an interface as straightforward as WeBWorK is unlikely to lead to such a result without additional teaching efforts (such as used by Ms. Degree). Nonetheless, WeBWorK can be used by teachers to make a teaching load more manageable while being at least as effective as PPH homework for most students.

A benefit of delegating the masses of skill practice for which PPH is viewed useful to a web-based interface is that it frees up instructor time and allows instructor choice in the nature of written interaction with students. That is, WeBWorK creates flexibility to spend what would have been homework grading time on alternative forms of feedback that may be more beneficial to both instructor and students (Cooper, Lindsay, Nye, & Greathouse, 1998).

Note

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