

## **Student Perceptions of the Web-Based Homework Program WeBWork in Moderate Enrollment College Algebra Classes**

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Of 19 college algebra classes, 12 used WeBWork and 7 used traditional paper and pencil homework (PPH). Given the earlier quantitative result that no significant difference in performance between WeBWork and PPH classes was found, a qualitative analysis of 358 student and instructor surveys revealed 3 primary categories of student perceptions related to WeBWork: views about its usefulness, intentionality in engaging with mathematics, and challenges to student beliefs about mathematics. Student and instructor comments are reported within the context of self-regulated learning. Results support the conjecture that even a narrow use of WeBWork, as a substitute for handwritten homework, is at least as effective as traditionally graded paper and pencil homework for students learning college algebra.

## INTRODUCTION

Almost all new college students in the United States have used a personal computer by age 18 and approximately half of entering freshmen have used the Internet; the other half will be introduced to the Internet when they get to college (Pew, 2002). Opportunities to learn at a distance through online courses and modules have grown explosively in the last decade and Internet-based enhancements to traditional courses have proliferated in science, technology, engineering, and mathematics (STEM) disciplines (NSF, 1998; WebNet, 2001).

One Internet-based accessory to STEM learning gaining popularity in the U.S. is web-based homework (WBH). One of the reasons for the growth in popularity of WBH systems may be the fact that the average undergraduate teaching load for a mathematics instructor at a publicly funded U.S. college was approximately 100 students per term in 1998 (NCES, 1998). Reduced funding and concomitant assignment changes in the early years of the 21<sup>st</sup> century have increased that number by one class, or by about 35 students, to an average of 135 students per faculty member. Providing detailed, individual feedback to each student on a typical 10- to 20-problem homework assignment several times a week is problematic for college instructors within the current U.S. university culture. That culture also includes expectations that faculty do research and perform service for college and community in addition to preparing for, teaching, and evaluating their classes. Nonetheless, effective teaching practices necessitate feedback to students on their out-of-class attempts at learning.

The importance of homework, especially for the advanced cognitive development expected in high school and college mathematics, has already been established by many individual and meta-analytic studies (Cooper, 1989; Cooper, Lindsay, Nye, & Greathouse, 1998; Keith & Cool, 1992; Warton, 2001). Homework is an activity related to motivation, mastery of material, and to achievement (Keith & Benson, 1992). It is also clear from the research that homework may be necessary but not sufficient for achievement on exams (Peters, Kethley & Bullington, 2002; Porter & Riley, 1996). However, the role of homework in student achievement is only partly understood and there has been a call for both large-scale quantitative studies using multiple data collection methods as well as for smaller studies, like the present one, that investigate the self-regulatory aspects of homework (Trautwein & Köller, 2003).

Within the liberal arts tradition at U.S. colleges, the primary purpose of homework in college algebra is to foster development of a robust collection

of knowledge structures for later use in calculus. The method for achieving this goal has traditionally been through separate practice with facts and concepts. Exercise sets in most college algebra textbooks offer drill practice with facts followed by practice with application and assimilation of concepts. Many texts end an exercise set with mildly non-routine problems aimed at generating disequilibrium and encouraging deeper reflection on concepts and their relationships. For a variety of reasons, from pressure to “cover” a proscribed collection of chapters in such textbooks to the personal epistemologies of students and instructors, the practice in college algebra teaching is to assign problems mostly from the first two categories (drill and application). Though there are efforts to rewrite college algebra textbooks along the lines of the reform of calculus in the U.S. (e.g., Connally, Hughes-Hallett, Gleason, Chifetz, Flath, Lock, et al., 2004; Kime & Clark, 2001), this study was situated in a traditional setting and investigated perceptions of a technology-based perturbation to that traditional setting.

Student behaviors directed towards achievement in college algebra like effort, task persistence, and self-regulatory decision-making are shaped by two factors: their beliefs about the tasks at hand and their perceptions about their abilities to be successful in completing the tasks (Bandura, 1997; Updegraff & Eccles, 1996; Warton, 2001). In particular, the use of WBH may foster positive feelings towards it and influence motivation to use it (Liaw, 2002). This study examines student beliefs and perceptions about using WBH for learning mathematics. The WBH tool used was WeBWork.

As Warton (2001) noted, homework is a complex research topic in which the views of students and styles of teachers should not be ignored. Therefore, to investigate the impact of the web-based homework interface WeBWork on college algebra learning, at least the following must be addressed:

1. *Student Perception:* What are student perceptions of the nature, purpose, and use of WBH, particularly of their efforts and degree of success using WeBWork?
2. *Instructional Style:* What contributions to differences in students' perceptions and performance might be attributable to instructor style?

After a brief description of the WeBWork interface and an overview of the theoretical framing for the study, the methods used are summarized. The study was qualitative, so the results include descriptive (not inferential) statistics. The focus is on reporting and analyzing the interaction of WBH with student perceptions, intentions, and beliefs along with examination of

the possible influences of instructor style. The presentation of results is followed by a discussion of the limitations of the study and possible implications for college teaching practice.

## Overview of WeBWorK

The goal of the WBH system called WeBWorK is immediate “correct” or “incorrect” feedback. The WeBWorK interface does not correct a student’s errors or give hints. WeBWorK simply lets students know whether they have submitted a correct answer and provides the opportunity to try again. 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 (there is a “Feedback” button to generate email to the instructor built into the WeBWorK interface – see Figure 1).

◀ Previous ▶ Prob. List ▶ Next ▶



Our records show problem 9 of set 5 has not been attempted.

(1 pt) Find all real solutions of equation  $4x^2 + 3x + 7 = 0$ .

Does the equation have real solutions? Input Yes or No:

If your answer is Yes, input the solutions:

$x_1 =$   and  $x_2 =$   with  $x_1 \leq x_2$ .

*Note: You can earn partial credit on this problem.*

Show Correct Answers

*Note: it is after the due date. Answers available.*

Display Mode:  formatted-text  typeset

Problem Set Version Number: 91521

Page produced by script: /var/www/webwork/system/cgi/cgi-scripts/processProblem8.pl

**Figure 1.** Screen shot of a WeBWorK problem on quadratic equations requiring mathematical notation in the answer

WeBWorK is an open-source, non-proprietary web-based interface developed at the University of Rochester (Gage, Pizer & Roth, 2001). It uses problem libraries to create similar but personalized problems for each student. WeBWorK has the potential to provide individualized graphical questions and interactive mathematical experiments for students to manipulate. Course management capabilities of the program for use by instructors include: (a) statistical information on individual student and whole-class progress, (b) adjustable due dates for individuals or groups, (c) group email lists for a class, and (d) exporting of grade data to spreadsheet programs. In the semester of this study, Fall 2002, instructors incorporating WeBWorK into their courses rarely used capabilities (a)-(c) but did make use of grade exporting.

To use WBH, students signed on to the WeBWorK server. From there they could (and were encouraged to) download and print a hard copy of their assignment. Once their work was complete, students entered solutions into WeBWorK through a text window using standard computer algebra software syntax (see Figure 1). After the WeBWorK due date, they could go back and review their submitted homework and view correct answers. Students might also re-work old assignments to review for exams.

## THEORETICAL FRAMEWORK

The educational philosophy underpinning both the development of WeBWorK and this study is constructivist: understandings are conceptual structures built mentally by a learner. Such construction is generated by personal and social interaction with information, ideas, and processes. The "constructing" in constructivism involves acquiring tacit and implicit knowledge of conventions (facts) in addition to the goal-based, cumulative, reflective, and self-regulated process of building operational awareness and structuring of conceptual understanding (von Glasersfeld, 2001). WeBWorK may facilitate both factual and conceptual knowledge building for individual learners. However, we explicitly acknowledge that WBH is only a support tool for an individual's efforts to structure knowledge, and is by no means a replacement for dialogic interactions between teacher and student or the social generation of collective understanding of peer and near-peer group work. What WeBWorK does do is replace the unevenly implemented pedagogical interaction of homework grading with a uniform method of feedback.

Because of a radical constructivist core philosophy, and in response to the call to action in research involving homework by Trautwein and Köller

(2003), the comparative analysis of student and instructor responses to WBH reported here was grounded in social cognitive theory, in particular in the foundational ideas of self-regulation and self-efficacy (Bandura, 1997). Self-regulation is the reflective generation of thoughts, feelings, and actions aimed at achieving a particular goal (Schunk & Zimmerman, 1994). Self-efficacy, which interacts with self-regulation, is a constellation of one's perceptions about "what one can do under different sets of conditions with whatever skills one possesses" (Bandura, 1997). Self-efficacy is not a measure of subject-specific skill. Nonetheless, a plethora of research has indicated that mathematical performance and achievement require available working memory and pertinent mathematics skills, *along with* robust efficacy beliefs and self-regulatory ability to use knowledge flexibly (Goldin, 1999; Higgins & King, 1981; Pajares & Schunk, 2002).

Several studies have indicated that the regulatory and socio-mathematical norms established in a college classroom are a consequence of a complex array of factors, including individual and community perceptions of what constitutes learning, understanding, communication, and progress (Davis & Simmt, 2003; Yackel, Rasmussen, & King, 2000). Included in these interactions is the monitoring for correctness offered by the grading of homework. As is discussed further below, the nature of the feedback provided by instructors to students on a traditional paper and pencil homework (PPH) assignment in college algebra may differ very little from the dichotomous feedback offered by WeBWorK.

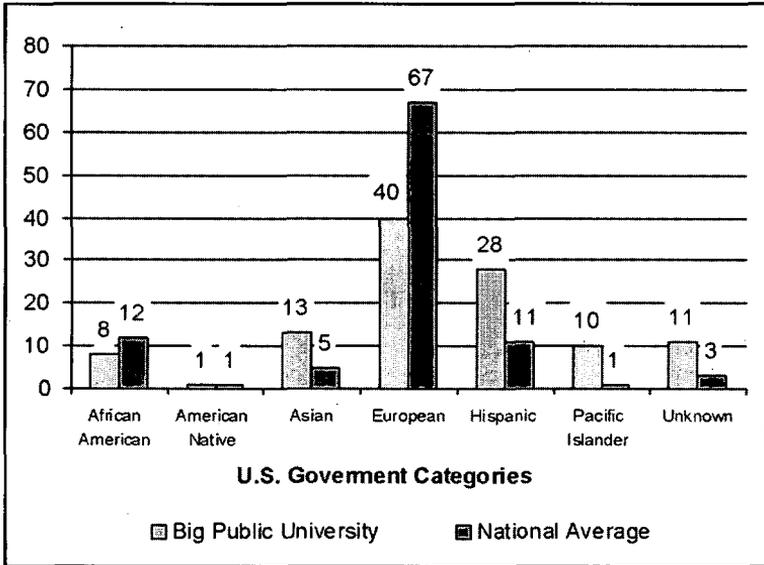
## METHODS

### Student Participants

This study of WeBWorK took place at a large publicly funded university in the western United States, pseudonymously: Big Public University (BPU). Every semester the college algebra course at BPU enrolls between 600 and 800 students in class sections of fewer than 40 students each. An additional 200 to 400 students enroll in large lectures (100 students or more, not the focus of this report). In Fall 2002, 644 students were enrolled in 19 moderately sized college algebra 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 an 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.

The population of students at U.S. public universities is diverse. The light bars in Figure 2 show the distribution of students in this study at BPU by U.S. government ethnic identification (these percentages are also representative of university-wide trends at BPU). For comparison, the dark bars give U.S. national enrollment percentages (NCES, 2000). Though the student population in the study was more diverse than the national average, the BPU distribution was representative of the projected U.S. post-secondary demographics for 2060 (Delpit, 1996).

BPU plays an important role in the state’s K-14 teacher preparation program. The university enrolls approximately 64% women and 36% men with the freshman class typically 70% female, 30% male. Mostly first-year students take college algebra, consequently the enrollments in this study were 69% women and 31% men.



**Figure 2.** Percentage of enrollments, by U.S. government assigned demographic groups

### Participants – Instructors

Two years after WebWork was first introduced at BPU, and one year after piloting the survey instrument, the current study began. Assignments

among the 19 moderate-sized sections of college algebra (taught by 15 different instructors) were initially random with 10 WBH and 9 PPH classes, but within the first two weeks of the term two instructors who had used WeBWorK the previous term asked to be switched to WBH.

Each of the 3 instructors who taught multiple sections of the course had at least 1 PPH section and 1 WBH section. The 12 WBH sections were taught by 11 instructors and enrolled a total of 408 students. The 7 PPH sections were taught by 7 instructors and enrolled 236 students.

Among the college algebra instructors were four Graduate Teaching Assistants (GTAs) working on their master's degrees in mathematics (1 man, 3 women) who had little to no college teaching experience. Nine instructors had master's degrees and already had some experience teaching college algebra (7 men, 2 women). Two instructors were male Ph.D. lecturers in mathematics. The names used for instructors throughout this report are pseudonyms (see Table 1 for information on the instructors and their full-time equivalent (FTE) teaching experience).

**Table 1**

Summary Profile of WBH and PPH Class Instructors

WBH only	Degree in Fall 2002	Years of College Teaching	Years of 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
<b>PPH only</b>			
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
<b>WBH &amp; PPH (#sections)</b>			
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

### **WeBWorK for the Study**

The college algebra problem library programmed into WeBWorK for the study was made up of exercises selected from the textbook used by all sections of the college algebra course at BPU (Stewart, Redlin, & Watson, 2000)<sup>1</sup>. Advanced WeBWorK functionalities (e.g., animations, multiple graphs) were not programmed into the problem library. Instead, problems taken directly from the textbook were the basis of WeBWorK assignments. There were three reasons for this narrow use of WeBWorK: (1) An initial survey of instructors indicated no interest or intention to use the advanced capabilities of the program; (2) The introduction of WeBWorK at BPU was constrained by the available funding for programming of the database and training of instructors in using the software; (3) Most significantly, the research question of interest was about the impact of a minimal intervention: web-based feedback as a direct substitute for teacher-generated feedback on homework.

The BPU college algebra course coordinator determined the list of suggested homework exercises, organized the list by textbook section, and provided it to all 19 instructors. The list of problems was also given to the WeBWorK problem library programming team. As directed by the course coordinator, each PPH instructor used at least 80% of these problems in paper and pencil assignments; WBH instructors also assigned at least 80% of the problems. WBH and PPH assignments were due weekly on a day and at a time determined individually by each instructor.

Before the term began, WBH instructors attended a two-hour session on the nature, scope, and use of WeBWorK. One additional meeting for WBH instructors of approximately one hour occurred in the first month of the term. During this meeting instructors gave feedback to the WeBWorK development team at BPU about how the use of WeBWorK was going, reporting glitches in access and getting clarification on how homework deadlines worked in WeBWorK. Throughout the term both on-line and in-person consulting about WeBWorK were available to WBH instructors. Most consulting was procedural (e.g., how to import the scores for students into a grade spreadsheet).

### **Data Gathering and Analysis**

The primary data reported on here were student and instructor surveys for the 19 moderate-sized college algebra classes at BPU in Fall 2002. Ad-

ditionally, a 25 item multiple-choice paper and pencil test on college algebra concepts and skills was administered in the first and last weeks of the term in all moderate enrollment WBH and PPH courses. The quantitative analysis of test results will be reported elsewhere, but the key finding was that there was no statistically significant difference in achievement as measured by performance gains from pre- to post-test, even when controlling for a variety of factors including ethnicity and previous mathematics achievement.

At the end of their courses, WBH students completed a short survey designed to measure their comfort with computers and their perceptions of 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 (see Table 2). A similar survey of instructors was administered.

**Table 2**  
WeBWorK Student Survey Items<sup>a</sup>

- |  |
|--|
| <p>1. In general I found the WeBWorK program:</p> <p>(a) Very user-friendly (b) User-friendly (c) OK (d) Non-user-friendly (e) Very non-user-friendly</p> <p>2. I found entering my answers in WeBWorK to be:</p> <p>(a) Very easy (b) Easy (c) Just right (d) Hard (e) Very hard</p> <p>3. Overall, I found that using WeBWorK I studied _____ than doing homework in a traditional way.</p> <p>(a) A lot more (b) Somewhat more (c) About the same (d) Somewhat less (e) A lot less</p> <p>4. WeBWorK's ability to give me an immediate response to my input versus the traditional way of waiting for the instructor to hand back the homework was:</p> <p>(a) Very helpful (b) Helpful (c) OK (d) Unhelpful (e) Very unhelpful</p> <p>5. I found that getting to a computer to access the Internet so I could do my homework was:</p> <p>(a) Very Easy (b) Easy (c) OK (d) Hard (e) Very Hard</p> <p>6. Before taking this course how comfortable were you using a computer?</p> <p>(a) Very comfortable (b) Comfortable (c) OK (d) Uncomfortable (e) Very uncomfortable</p> <p>7. Please add one or two - or more- comments about WeBWorK:</p> <p>a. Numerical coding: a=1, b=2, c=3, d=4, and e=5.</p> |
|--|

Exit interviews with PPH instructors indicated students' typically completed paper and pencil homework assignments outside of class, with about 65% turning in homework. Students in WBH courses completed their WeBWorK outside of class on a home computer or at one of over 500 computers available in on-campus labs. The WeBWorK server kept track of the efforts of the 78% of WBH students who did their WeBWorK.

Qualitative methods were used to examine student and instructor written responses to open-ended survey prompts and instructor interviews. Data were analyzed using the qualitative constant-comparative coding methods commonly employed in naturalistic inquiry and theory building (Strauss & Corbin, 1998).

## RESULTS

Based on earlier quantitative results – particularly the fact that no significant difference in performance between WBH and PPH groups was found – it is conjectured that WBH supports student achievement at least as well as PPH while saving instructors homework grading time (Hauk et al., 2004). Support for this conjecture is provided here through careful descriptive analysis of the information from WeBWorK students and instructors.

The perceived usefulness of a Web-based tool is an outcome expectation, a facet of self-efficacy influencing self-regulation. In particular, students' *perceptions* about the usefulness of a Web-based tool, their *intentions* to use it, and their *beliefs* about a subject are key determinants of motivation to persist in efforts, in this case to do mathematics, in a Web-based environment (Liaw, 2002). Moreover, *instructional style* can influence perceptions, intentions, and beliefs (Spangler, 1992). If perceptions of WBH's usefulness or related intentionality are weak, then WBH may, at best, be of limited use in student learning of mathematics.

### Student Perceptions

Work to date on human-computer interactions indicates that computers have a mediating effect on learning, particularly in mathematics, that differs from the effects of other learning environments (Karasavvidis, Pieters & Plomp, 2003). For this reason, students were surveyed about their existing level of comfort working with a computer, the accessibility of the Internet for them, and about the WeBWorK interface in particular (see Table 2 for

survey items). Though not the focus of this investigation, the scaled survey results gave some context for interpreting the replies to the free-response prompt.

*Ranked survey responses.* Averaging across all 12 class sections, the 358 students in WBH classes who completed the survey responded with a mean of 3.1 or "OK," for the four questions about the use of the WebWorK interface and reported studying "about the same" amount with WBH as they had in previous PPH courses. The mean of responses about ease of Internet access was 2.5, or that it was fairly easy. On average, comfort with computer use was 1.7, or that students were already pretty comfortable using computers when starting their courses. Standard deviations for each measurement were between 0.9 and 1.2 both within sections and across sections.

*Open-ended survey responses.* Additional written comments by 149 WBH students in response to Prompt 7 were coded into three basic categories related to the ideas of self-regulation and self-efficacy: 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 responded to Prompt 7). Consequently, the 149 written responses are representative of the WBH students in some ways. Of the 149 students, 75 wrote comments relating their perceptions about WebWorK and its interaction with personal study habits. In particular, 40% of student comments attributed difficulties in using WebWorK to problems in communicating effectively with the software: "Sometimes my correct answers would come up 'incorrect' because I did not type my answers the way the computer could understand." Or, as another student put it, "I found it difficult to input my answers in webwork. It took longer to input [an] answer than the time it took to actually solve the problem." Ten percent of students also mentioned an urge to "put off homework because it's so frustrating" to use WebWorK.

The frequency with which students remarked on the difficulties of inputting their solutions in the notational language common to graphing calculators and computer algebra systems was a concern. WebWorK version 2, release 3, attempts to address this concern with drop down function menus containing commonly used macros like `sqrt[]` to indicate square root and `abs[]` for absolute value.

### Student Intentions

As a facilitator for engaging in mathematical self-regulation WeBWorK is involved only as a monitor for correctness. Good monitoring is a key facet of learning to be an intentional and 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 heuristics, and the impact of mathematical beliefs rests on the student. For most of the students who wrote comments, control and problem-solving heuristic responses to WeBWorK did not appear to be viewed as especially different from what they did with paper and pencil homework. That is, the 35% of students responding to Prompt 7 who evidenced expert-like views of mathematics learning as a complex and personal process of building conceptual understanding appeared to view WeBWorK as a tool that helped or hindered that process whereas the other 65% of students, whose reports indicated a novice-like view of mathematics learning as a disconnected collection of formulae and “plug-and-chug” strategies, appeared to view WeBWorK as either helping or hindering their procedural approach. This collection of intentionality views aligns with those reported by Pascarella (2002) in her work with WBH in large physics courses. On the other hand, student beliefs about mathematics appeared to be challenged frequently by their WeBWorK experiences.

### Student Beliefs

Spangler (1992) summarized four main beliefs about mathematics widely held by college students: (1) mathematics is *computation* that 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 intentionality on the part of the student is necessary). These four beliefs can inhibit activation of the goal-setting, reflection, intention, action, and evaluation components that make effective self-regulation possible (Schunk & Zimmerman, 1994).

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.

For example, in WeBWorK, computation can be done by the program; so, given the problem:

$$\text{Solve for } x: 3x + 1 = 7,$$

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 for which their first response netted "That answer is INCORRECT." Because of the immediacy of the interface, approximately 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. As mentioned above, 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 11% of the student comments. Secondly, and perhaps more significantly, were the reports by about 8% of student respondents who appeared to view "the answer" to a WBH problem as "That answer is CORRECT." This group appeared to have both the naïve 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. Prompted by these comments, a quick review of the WeBWorK audit trail indicated that some college algebra students submitted as many as 35 guesses before moving on to the next problem. This small subset of students apparently did not see their role as learners to include self-regulatory meta-cognitive efforts like monitoring and control, so the monitoring offered by WeBWorK was of little use.

On the other side of this coin were students who disliked the fact that all they saw was "That answer is INCORRECT," 13% wanted "hints about what is wrong" and the teacher is active, Belief #4, came into play. The WeBWorK interface 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 once an answer was determined to be incorrect. Such prompting might be experienced by a student working on a problem in class, where the teacher would be in close proximity (just as a computer is during WeBWork).

### **Instructional Styles and Assessment Practices**

All 15 instructors (WBH and PPH) in this study relied on lecture as the primary instructional technique. Some instructors occasionally had students work problems in class individually, with partners, or in groups. No instructor reported spending more than 10% of class time on such activities.

Assessment of the course learning goals of understanding of variable, slope, functions, and their representations came in three forms: homework, quizzes, and exams. Written feedback to students by all 15 instructors fell into four categories: credit for effort, dichotomous (right/wrong) grading, partial credit grading (zero, half, full credit), and commentary. WBH and PPH instructors were asked about their pre-study homework grading practices. The most common forms of homework grading reported were the credit for effort and dichotomous grading. Instructors who gave “credit for effort” on homework put a check mark or number of points on each student’s paper for simply turning in homework, none of the actual work of the student was reviewed by the instructor. Dichotomous grading was used on all assigned problems, or for 2 instructors, on a subset of the assigned problems. No writing other than the scoring was put on student’s homework. Clearly, for students of these 10 instructors, the immediate dichotomous grading offered by WeBWork would be no less detailed than what the instructor would provide.

Four instructors reported giving partial credit and, in general, marking a student’s work to indicate the point (usually by circling or crossing out the error) at which the solution attempt appeared to “get derailed.” This was the *only* kind of feedback, other than half-credit being indicated for “starting out okay,” offered by these instructors. One PPH instructor reported that he wrote detailed comments on students’ homework about what they had done wrong and what they should do, frequently writing out the correct process on a student’s paper. However, this instructor also reported that he only occasionally finished grading homework this way and frequently returned papers to students with a check mark to acknowledge that “they have tried.” In other words, students might get 3 or 4 heavily commented on homework

assignments returned to them, but the rest (12 assignments or more) were given “credit for effort” grades.

For the most part, the instructors asserted that the only way they felt they could know what students understood was by students’ performance on quizzes and exams. The assessments written by these instructors included short-answer and mildly non-routine questions. Through student responses to test and quiz items instructors felt they got the most information about student progress. And, it was in grading these items that instructors reported investing the most time and effort.

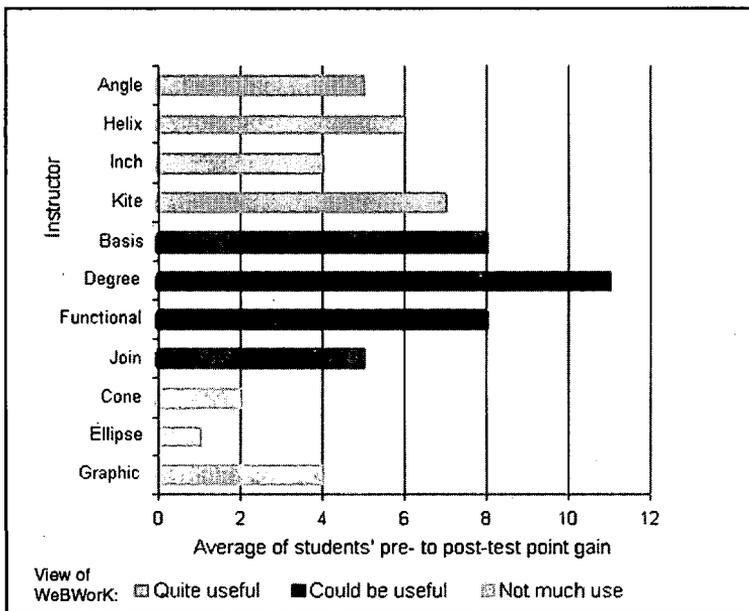
As has been noted in the literature, instructor attitude and comments about curricular revisions and innovations can impact their effectiveness (Dufresne, Mestre, Hart, & Rath, 2002; Schoenfeld, 1992). WBH instructors had a variety of views about the usefulness of WeBWorK and what instructors said about 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. As was mentioned earlier, this meant two instructors switched from PPH to WBH; however, no WBH course instructor requested to be in the PPH group.

Ms. Cone, Mr. Ellipse, and Mr. Graphic, for example, reported seeing little positive value in the use of WBH. The majority of their students who made written comments reported that WeBWorK was “useless” and “hated it” as “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. Their reservations centered on a perception that a personal type of interaction was missing: they saw no way for themselves as instructors 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 by writing: “it was helpful, but...” and included comments like “I prefer getting feedback from the professor because he could help me understand what I did wrong much better.” It should be noted, however, that these comments come from first-year college students whose expectations for grading of their work may have been more indicative of their secondary school experiences than college practice.

Mr. Angle, Mr. Helix, Mr. Inch, and Ms. Kite all felt 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. These students accepted WeBWorK as valuable and wanted to improve their efficacy in using it, a sign of a strong intention to engage with mathematics in the way supported by WeBWorK.

The number of WBH instructors was too small ( $n=11$ ) to look for statistically significant differences between the performances of their classes based on a grouping by the instructor’s perceptions about the usefulness of WeBWorK. However, the pattern apparent in Figure 3 is provocative. Certainly, the instructor-view artifact that others have reported appears: when an instructor did not view a curricular change as valuable, student learning was prone to suffer by comparison (e.g., the bottom three bars for the “not useful” group in Figure 3).



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

However, the instructors who expressed hesitancy about the use of WeBWorK actually 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 about the growth of mathematical understanding. 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.

Regardless of their opinion of WeBWorK, all WBH instructors perceived it as a “major timesaver” for them. Also, for the 10 WBH instructors who implemented and counted WeBWorK as a component in course grading, student performance from pre- to post-test improved at least as much as it did in PPH classes. Ms. Kite, a GTA for whom Fall 2002 was her first time ever teaching a college mathematics class, did not count WeBWorK as a part of the course grade. Nonetheless, her clear messages in-class in support of it as a valuable tool appeared to have led her students to do their WeBWorK anyway.

Mr. Angle, Mr. Basis, and Ms. Cone, the three instructors who had both PPH and WBH sections, regularly collected homework from their PPH students but did not grade each problem for correctness. Three of the four PPH-only instructors assigned but did not collect or grade homework since “the odd answers were already in the back of the book” for students to use to check their work. However, Mr. Saddle, Ms. Torus, and Mr. Undo (the non-collectors) regularly gave and graded in-class quizzes on the assigned homework “to motivate students to do it.” One PPH-only instructor, Dr. Radian, regularly collected his students’ homework, though it was not always graded, and 15% of the course grade depended on homework performance. Interestingly, the average pre- to post-test gain for the four PPH instructors who collected homework was slightly lower than that for the three non-collectors who gave quizzes (4-point vs. 6.5-point gain).

Recall that WeBWorK appeared to disrupt beliefs that inhibit self-regulation. Though WeBWorK may not promote self-regulation, it is possible that it does perturb students’ relationships with mathematics in ways that admit the development of self-regulation. Focused student-teacher interactions (like Ms. Degree’s special problems, or short in-class problems or quizzes used by some instructors) together with WeBWorK may do more than the same interactions combined with ungraded or credit-for-effort PPH to advance the development of sense-making goals, reflection on tasks, evaluation of progress, and other self-regulatory efforts. Instructors noted that they did not grade PPH mathematics problems with the same attention to student efforts given to a quiz, exam, or specially assigned problem. Since many

instructors reported simply putting check marks “for the effort” on PPH assignments while others “graded a few key problems,” college algebra students in the PPH courses did not usually get much detailed feedback from their instructors on their homework. Keep in mind that WBH students asserted that feedback from the instructor was important, *in addition to* the validation of work available through WeBWork.

## DISCUSSION

### Benefits and Limits of WebWork

Unlike Internet auto-tutorials, discovery learning modules, or electronic communication by instructors about individually graded homework (Hall, Butler, et al., 2001; Monson & Judd, 2001; Pascarella, 2002; Yazon, Mayer-Smith, et al., 2002), 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 traditional college instructors is increased because WeBWork can be seen as a tool to obviate the need to grade piles of undergraduate mathematics homework papers. It may be bad, however, in that WeBWork does nothing explicitly to challenge the notion widely held by many undergraduates (and some instructors) that learning, particularly in college algebra, is a matter of habituation in skill practice rather than construction of personal knowledge structures rich in conceptual connections to previous learning (Kirschner, 2002).

Verifying that a student possesses mental access to a collection of facts does not measure *understanding* or flexibility in using that factual knowledge. Nonetheless, having immediate mental access to factual knowledge is a fertile state of mind for the growth of conceptual understanding (von Glasersfeld, 2001). As was mentioned earlier, the implementation of homework in college algebra in the U.S. has traditionally focused on exercises that build factual and assimilative knowledge with only a few non-routine or novel problems that challenge students to grapple with difficult concepts on their own outside of class. Part of the reason for this focus in assignments may be explained by college algebra instructors' views of homework and the nature of their marking of it. Certainly, the relationship among textbook, instructor views, and student views is more complex than the small slice examined here in the context of WeBWork.

While it would be wonderful if WBH actually improved student performance, we posit that an interface as straightforward as WeBWorK is unlikely to lead to such a result without additional teaching efforts (either computer-based or pencil-and-paper based). Nonetheless, WeBWorK can be used by college instructors to make their teaching load more manageable while being at least as effective as PPH homework for most students (Hauk et al., 2004).

Along this line, it is worth noting again that Ms. Degree's students, and the students of the instructors who had regular, short, in-class quizzes did slightly better on average. Could the same (or greater) gains be obtained by a hybrid format where WeBWorK was the homework and in-class quizzes of one or two questions per week gave opportunity for detailed instructor-student interaction? As was mentioned by several instructors, one perceived shortcoming of WBH was that though student and teacher might know quantitatively how the student was doing from their WeBWorK score, there was no qualitative information for the teacher to use in helping the student construct conceptual understanding. However, given the reported homework grading practices of college algebra instructors, it appears it may not be the grading of homework so much as it is the *scanning of it* that is useful to instructors. WeBWorK does not allow instructors to scan student writing for conceptual engagement (it just isn't designed that way). On the other hand, WeBWorK can provide timely feedback to students in ways that short-answer quiz and exam problems (and PPH when it is carefully graded) cannot.

The 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.

### **Learner-Centered Use of Instructor Grading Time**

While it is true that computer-based learning environments can act as catalysts for change in the perceptions students have of themselves as learners, such change is by no means automatic or persistent after a single semester course (Pascarella, 2002; Yazon, et al., 2002). Nonetheless, with the use of WBH time is freed for formative and summative assessments that can be chosen by instructors to augment their own understanding of their students' progress and to support the growth of students' self-regulation and intel-

lectual autonomy in learning mathematics. If understanding is constructed by learners, then such construction can be facilitated through *both* the skill-practice available through an interface like WeBWorK and through assignments that challenge students to reflect critically on their knowledge and understanding, helping students build rich conceptual scaffolding to give context to their skills. Three possible alternative uses of instructor grading time are highlighted below as alternate methods of assessment: concept-based quizzes (Romagnano, 2001), writing exercises (Sterrett, 1992), and projects (Gold, 2004).

A concept-based quiz consists of a single question that requires the articulation of a concept in response to a prompt like: "Carefully explain why a quadratic equation with no real roots has a graph that does not cross the  $x$ -axis." Grading student responses to such a quiz can be time consuming, even if the quiz is given cooperatively (where two students work together and turn in one paper for a shared grade). With no PPH to grade, an instructor has the option of spending time on careful feedback to students.

Transactional writing communicates one's understanding of concepts (as compared to expressive writing about one's perceptions). Following a carefully detailed rubric for solving, reflecting on, and extending their work on half a dozen routine to mildly non-routine problems over the course of a school term has been indicated as an effective way to enrich conceptual understanding and foster autonomy among college algebra students (Hauk & Isom, 2005). Designed to strengthen self-regulation in problem situations and help students develop a flexible understanding of mathematics, the Problem-Solution-Objectives-Linking-Vocabulary-Extend (PSOLVE) rubric provides an opportunity for instructor and student to communicate on paper in a cycle of refinement of ideas. In a PSOLVE assignment, students examine a single homework problem in great detail. Students type up their PSOLVE responses and the instructor responds. In addition to providing students the opportunity to become operationally aware of their understandings, students' PSOLVE efforts offer an instructor the opportunity to read sufficient detail about what students *think* they know to form insight into the level and robustness of that understanding (what Ms. Degree felt was missing from WeBWorK).

Finally, the wide array of mathematics projects that college algebra students can do outside of class may require instructor time (particularly in office hours) for direction. That time may be more readily available if no PPH grading is necessary.

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