

Impact of the web-based homework program WeBWorK on student performance in  
moderate enrollment college algebra courses

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**Impact of the web-based homework program WeBWork on  
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**Abstract**

The study investigated differences in mathematics achievement between college students using web-based homework (WBH) and those doing traditional homework. Twelve of 19 college algebra classes used the WBH software WeBWork and 7 used traditional paper and pencil homework (PPH). A test of algebra skills was administered pre- and post-course. Quantitative analyses revealed no significant differences in performance by ethnicity or instructor between the two homework treatments even when analysis controlled for previous mathematics achievement. However, women in WeBWork classes had statistically significantly higher score gains than women in PPH sections. Results support the conjecture that WeBWork is at least as effective as traditionally graded paper and pencil homework for students learning college algebra.

*Keywords:* evaluation of CAL systems, mathematics, pedagogical issues, post-secondary education, teaching/learning strategies.

**1. Introduction**

Opportunities to learn at a distance through on-line courses and modules have grown explosively in the last decade and internet-based enhancements to traditional courses

have proliferated in science, mathematics, engineering, and technology (SMET) disciplines (WebNet, 2001; NSF, 1998). One internet-based accessory to SMET learning gaining popularity in the U.S. is web-based homework (WBH). To date, the most growth in, and research on, WBH systems has been in large lecture-based courses (Dufresne, Mestre, Hart, & Rath, 2002; Gage, Pizer & Toth, 2001; Pascarella, 2002). In this study the focus was on moderate-sized college algebra classes of 30 to 40 students.

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). Ability, motivation towards mastery, quality of instruction, and amount of academic instructional time – including time spent on homework – are key factors in learning (Keith & Benson, 1992). However, it is clear from the research that homework may be necessary but not sufficient for achievement on exams (Peters, Kethley, & Bullington, 2002; Porter & Riley, 1996). This study compared achievement gains, measured by common exams, in college algebra skills between WBH and paper and pencil homework (PPH) groups. The WBH tool used was WeBWorK.

### *1.1 Research question*

As pointed out by Cooper (1989), a thorough investigation of the relationship between homework and achievement should control for preparedness when comparing achievement. To investigate the impact of the web-based homework interface WeBWorK on college algebra learning, the following question was addressed:

Given that the same homework problems were assigned in WBH and PPH sections, and controlling for preparedness by way of pre-test and national norm-referenced tests (SAT-Math and SAT-Verbal), did WBH and PPH students do equally well on the common post-tests and in their courses? If not, in what way(s) did their performances differ?

### *1.2 WeBWorK*

The WBH system called WeBWorK is an open-source, non-proprietary web-based interface developed at the University of Rochester (Gage, Pizer, & Toth, 2001). It uses problem libraries to create similar but individualized problems for each student, randomized by student identification number. The libraries, written in PERL, can include calls to GIF and PNG illustrations, animated GIF's, HTML hyperlinks, JavaScript code and Java applets. WeBWorK has the potential to provide individualized graphical questions and interactive mathematical experiments for students to manipulate. Course management capabilities of the program include: (a) detailed statistical information on individual student and whole-class progress, (b) adjustable due dates for individuals and 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.

WeBWorK provides immediate "correct" or "incorrect" feedback. The WeBWorK interface does not correct a student's errors or give hints. It simply lets users know whether or not they have submitted a correct answer. WeBWorK also allows the choice to try again and will provide a slightly different problem to be worked. Students are

encouraged to seek help from a fellow student, a tutor, or the instructor when stuck on a problem. They can do this in person or by email (there is a feedback button to generate email built into the WebWorK interface – see Figure 1). Certainly, it would be possible to program into WeBWorK the capacity to give hints based on the type of wrong answer. However, for the college algebra classes discussed here, the question of interest was whether or not the simple “correct”/“incorrect” feedback with retry option were sufficient to achieve the goal of reducing instructor homework grading load while still encouraging student homework efforts and maintaining course achievement.

To use the WBH interface, students signed on to the WeBWorK server from any internet-connected computer. Students could (if they wished) download and print out the full assignment’s problem set. Once their work was complete, students entered their solutions into WeBWorK through a text window using standard computer algebra software syntax (see Figure 1). After the due date, students could go back and review their submitted homework and view correct answers. Students could also re-work old assignments as a form of review for exams.

[Figure 1]

## **2. Methods**

Every semester the college algebra course at the site of the study, “Big Public University” (BPU), enrolls between 600 and 800 students in moderately sized class sections of fewer than 40 students each. In Fall 2002, 644 students enrolled in 19

moderately sized college algebra sections. Of these students, 532 (84%) completed the course while the other 112 (16%) dropped or withdrew. Of the 532 who finished the course, 435 (82%) passed (with A (19%), B (28%), C (24%), or D (11%)). That is, of the 644 who originally enrolled, 425 passed, a 68% pass-rate.

### *2.1 Student Participants*

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 enrollment trends at BPU). For comparison, the dark bars give U.S. national enrollment percentages (NCES, 2000). Though the student population at BPU was more diverse than the national average, the BPU distribution was representative of the projected U. S. post-secondary demographics for 2060 (Delpit, 1996).

One of BPU's primary missions is the preparation of schoolteachers. Overall, the university student body is 64% women and 36% men though the freshman class in 2002 was 70% women and 30% men. Made up mostly of first-year students, the college algebra enrollments in this study were close to this balance at 69% women and 31% men.

[Figure 2]

### *2.2 Instructor Participants*

Two years after WeBWorK was first introduced at BPU, and one year after a pilot study, 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. However, within the first two weeks of the term two instructors switched to WBH. Nonetheless, each of the three instructors who taught multiple sections of the course had at least one PPH section and one WBH section (see Table 1). In the end, 12 WBH sections were taught by 11 instructors and enrolled 408 students. Seven PPH sections were taught by seven instructors and enrolled 236 students.

Four of the 15 college algebra instructors were Graduate Teaching Assistants (GTAs) working on their master's degrees in mathematics (1 man, 3 women) and had little to no college teaching experience. Nine were instructors with master's degrees who already had some experience teaching college algebra (7 men, 2 women), and two were male Ph.D. lecturers in mathematics. Table 1 summarizes the preparation and experience of the instructors in the study (all names are pseudonyms).

[Table 1]

### *2.3 Data gathered*

The primary data forming the basis of this report were pre- and post-test scores, student preparedness information (SAT-Math and SAT-Verbal scores), demographic information, and course completion information, including homework policies and grades. All data were for Fall 2002 college algebra classes at BPU.

A 25 item multiple-choice paper and pencil test over college algebra content was administered in the first and last weeks of the term in all 19 moderate enrollment WBH

and PPH courses. The same test was used both times. Students recorded their choices on scanable answer sheets. The BPU course coordinator for college algebra and the WeBWorK implementation supervisor developed the test. A panel of five expert college mathematics instructors established its face and content validity and the test was piloted in Fall 2001 before being used for this study in Fall 2002.

University registrar's data on each PPH and WBH student was also collected, including high school grade average, entering standardized test scores, previous college mathematics course grades, end of course college algebra grades, overall grade average in college, and demographic information. For the WBH group, WeBWorK itself stored an impressive collection of data on the homework done within the program: which problems were attempted, how often, with what level of success, over what time span. Analysis of the try-retry data for web-based homework sessions is the topic of another study. PPH instructors provided copies of the homework assignments and policies for PPH students.

#### *2.4 Procedure*

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 course (Stewart, Redlin, & Watson, 2000; permission was obtained from the author and publisher). Advanced WeBWorK functionalities like animations and multiple graphs were not programmed into the BPU College Algebra Problem Library. The college algebra course coordinator determined a list of suggested homework exercises, organized by textbook section, and provided it to the PPH and WBH instructors and to the WeBWorK problem library programming team. Each WBH and PPH instructor used at

least 80% of these problems in assignments that were due weekly on a day and at a time determined individually by each instructor. Though no data was collected from PPH students on their homework practices, PPH instructors reported that students completed the majority of homework outside of class time. Students in WBH courses completed their WeBWorK outside of class on a home computer or at one over 500 computers available on-campus in labs and in the library. To analyze the numerical data of test scores, grades, demographic information, and preparedness scores, Statistical Package for Social Sciences (SPSS) software was used.

### **3. Results**

Due to late additions, absences, and drops, out of the 532 students completing the course there were 464 (87%) pre- and post-test pairs composed of 291 (86%) of the WBH and 173 (89%) of the PPH students' work. Though the drop-rate in the WBH courses (13%) was slightly lower than in the PPH courses (18%), the difference was not statistically significant.

#### *3.1 Differences in student test performance by WBH or PPH group*

The main statistical result in comparing achievement by paired pre- and post-test scores 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 ( $p < 0.05$ )*. Approximately one-eighth of PPH and WBH students had a negative gain (i.e. they scored worse than they had on the same questions 12 weeks earlier). About one-third of each class had no

significant change in test score ( $0 \pm 4$  points) while about half of PPH and WBH students scored at least 5 points higher (out of the 25 possible) on the post-test than on the pre-test. The WBH group did a bit better, with a slightly tighter distribution, than the PPH group (see Figure 3). The difference, though, was not statistically significant.

[Figure 3]

The two groups began in essentially the same place with no significant differences in scores between PPH and WBH students on the pre-test, and ended, as groups, about the same. The results of paired *t*-test analysis are shown in Table 2. As would be expected, regardless of the method of homework, students scored significantly higher on post-test than on pre-test.

[Table 2]

Can one then say that WBH instead of PPH did no harm to the students' performance? Backing for an assertion of "Yes" requires more than just statistical investigation of overall mean improvement (i.e., Table 2). Comparisons of the two groups that control for a variety of factors, such as previous achievement, ethnicity, and gender are also necessary to triangulate support for the assertion. That is, did approximately the same proportion of students do better, the same, and worse from pre- to post-test and was the distribution of these groups of students correlated to previous achievement, ethnicity, gender, instructor?

When previous achievement as measured by SAT-Math and pre-test scores was taken

into account, no significant difference between WBH and PPH groups was found. Similarly, no statistically significant differences attributable to instructor were found. However, some interesting things arose when investigating ethnicity and gender.

### *3.2 Differences in test performance by ethnicity*

One concern was that students from family cultures or socio-economic status where computers were less common might be at a disadvantage. Table 3 presents the results of the Analysis of Covariance (ANCOVA) of post-test scores statistically controlling for pre-test scores by three factors: group (WBH or PPH), ethnicity, and gender.

[Table 3]

There was a significant main effect of ethnicity on the post-test scores after controlling for pre-test scores ( $p = 0.016$ ). It is important to point out that no significant interaction of ethnicity by group was found, indicating that any ethnicity-correlated differences in performance were independent of the student's being in WBH or PPH groups.

The significant main effect of ethnicity on post-test scores after controlling for pre-test scores was investigated further using a Bonferroni pair wise comparison of adjusted post-test means. Table 4 presents the means for pre-, post- and adjusted post-tests that resulted from this post-hoc analysis. Based on the adjusted post-test means, students who had identified themselves upon university entrance as being Asian or Asian-American scored significantly higher than those identifying themselves as Hispanic. No other

significant differences depending on ethnic group were found.

[Table 4]

### *3.3 Differences in test performance by group and gender*

The other significant difference that arose in the ANCOVA analysis (Table 3) was a group by gender interaction ( $p = 0.005$ ). Univariate post-hoc analysis was performed to determine the significance of the differences by gender. Table 5 gives the mean pre-, post-, and adjusted post-test means by gender and group. There was a significant difference between PPH and WBH scores for women with WBH students scoring higher,  $F(1, 329) = 4.07, p = 0.045$ . For men, however, although the PPH adjusted mean was higher than that for WBH, the difference was not significant,  $F(1, 129) = 2.12, p = 0.148$ . Fewer male participants (there were 332 women and 132 men among the paired pre- and post-test results) may have contributed to this finding.

[Table 5]

Based on the quantitative analyses – particularly the fact that no overall significant difference in performance between WBH and PPH groups was found – the conjecture is offered that WBH saves instructor time while supporting student achievement at least as well as PPH.

#### **4. Discussion**

Though there was a main effect for ethnicity, no interaction with group (WBH or PPH) was found. It seems that whatever may be culturally biased in the structure and processes of college algebra, the use of WBH does not appear to significantly exacerbate or diminish it. The only significant result between groups was that women did better in WBH sections than in PPH sections. One possible explanation for this difference could be the nature of WeBWorK: the software did not know whether or not the student was female. Research has indicated that college instructors give differential feedback to students that may undermine the progress of women (Maher & Tetreault, 1994; Sadker & Sadker, 1995). Perhaps there was sufficient absence of such sexism in the WeBWorK interface that improvement in female students' performance was fostered.

Unlike internet auto-tutorials, discovery learning modules, or electronic communication by instructors about individually graded homework (Hall, Butler, McGuire, McGlynn, Lyon, Reese, et al., 2001; Monson & Judd, 2001; Yazon, Mayer-Smith, & Redfield, 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 is both good and bad.

##### *4.1 Benefits and limits of WeBWorK*

The simplicity of WeBWorK is good in that the likelihood of its adoption by traditional college instructors is increased since it is a tool to eliminate the grading of large numbers of undergraduate mathematics homework papers. Instructional use of WeBWorK may be bad, however, in that it does nothing explicitly to challenge the notion

widely held by many undergraduates and 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 (Laurillard, 1995; Kirschner, 2002).

It is clear from work to date on human-computer interactions that computers have a mediating effect on learning, particularly in mathematics, which differs from the effects of other learning environments (Karasavvidis, Pieters, & Plomp, 2003; Liaw, 2002).

What is also clear from the results presented here is that substituting WeBWorK for paper and pencil homework in college algebra does not appear to harm student performance.

While it would be beneficial if it actually improved performance, an interface as straightforward as WeBWorK is unlikely to lead to such a result. Nonetheless,

WeBWorK might be used by college instructors to make teaching loads more manageable and it appears to be at least as effective as PPH homework for most students.

One shortcoming of WBH is that though student and teacher can know quantitatively how the student is doing from their WeBWorK score, there is no qualitative information for the teacher to use in helping a student construct conceptual understanding. WeBWorK does not have a qualitative feedback mechanism (it just is not designed that way) that gets at what other evaluation methods can.

#### *4.2 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; [author]). The benefit of delegating the masses of skill practice for which PPH is viewed useful to a web-based interface is that it allows instructors the flexibility to spend what would have been homework grading time on alternative forms of feedback that may be more beneficial to students.

An instructor can choose additional formative and summative assessments to support the growth of students' intellectual 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 help students build rich conceptual scaffolding to give context to their skills. Among the possible alternative methods for instructional interaction with students are projects (Gold, 2004), concept-based quizzes (Romagnano, 2001), or a variety of writing exercises (Bolte, 1999; Sterrett, 1992; [author]).

#### *4.3 Future work*

Several areas of research around WBH implementation hold great promise. First and foremost, replication of the results reported here is necessary. Additionally, qualitative exploration of student and instructor views in the context of WBH is needed. As with any curricular innovation, it is important to discover how the intended curriculum is implemented, received, and activated for students. How is student engagement affected? Is student learning, performance, or persistence in mathematics modified? How? What interactions with ethnicity, culture, gender, are at work? How? Investigation of these questions at other levels (e.g., secondary school) would also be valuable since web-based technology will eventually become ubiquitous in the schools.

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## **References**

- Bolte, L. A., (1999). Using concept maps and interpretive essays for assessment in mathematics. *School Science and Mathematics*, 99(1), 19-30.
- Cooper, H. (1989). *Homework*. White Plains, NY: Longman.
- Cooper, H., Lindsay, J. J., Nye, B., & Greathouse, S. (1998). Relationships among attitudes about homework, amount of homework assigned and completed, and student achievement. *Journal of Educational Psychology* 90(1), 70-83.
- Delpit, L. (1996). *Other people's children: Cultural conflict in the classroom*. New York: New Press.
- Dufresne, R. J., Mestre, J., Hart, D. M., & Rath, K. A. (2002). The effect of web-based homework on test performance in large enrollment introductory physics courses. *Journal of Computers in Mathematics and Science Teaching*, 21(3), 229-251.
- Gage, M., Pizer, A. & Toth, V. (2001). WeBWorK: An internet-based system for generating and delivering homework problems. Presentation and Minicourse at the *Joint Meeting of the American Mathematical Society and the Mathematical Association of America* (New Orleans, LA, January 2001). Slides available at: [http://webwork.math.rochester.edu/apizer/Minicourse\\_Talk/contents.html](http://webwork.math.rochester.edu/apizer/Minicourse_Talk/contents.html)

- Gold, B. (Ed.). (2004). *Innovative Teaching Exchange*. Published online by the Mathematical Association of America. Retrieved 12 February 2004 from [http://www.maa.org/t\\_and\\_l/exchange/exchange.html](http://www.maa.org/t_and_l/exchange/exchange.html)
- Hall, R. W., Butler, L. G., McGuire, S. Y., McGlynn, S. P., Lyon, G. L., Reese, R. L. & Limback, P. A. (2001). Automated, web-based, second-chance homework. *Journal of Chemical Education*, 78(12), 1704-1708.
- Karasavvidis, I., Pieters, J. M., & Plomp, T. (2003). Exploring the mechanisms through which computers contribute to learning. *Journal of Computer Assisted Learning* 19, 115-128.
- Keith, T. Z. & Benson, (1992). Effects of manipulable influences on high school grades across five ethnic groups. *Journal of Educational Research*, 86(2), 85-93.
- Keith, T. Z & Cool, V. A. (1992). Teaching models of school learning: Effects of quality of instruction, motivation, academic coursework, and homework on academic achievement. *School Psychology Quarterly*, 7, 209-226.
- Kirshner, D. (2002). Untangling teachers' diverse aspirations for student learning: A crossdisciplinary strategy for relating psychological theory to pedagogical practice. *Journal for Research in Mathematics Education*, 33, 46-58.
- Laurillard, D. (1995). Multimedia and the changing experience of the learner, *British Journal of Educational Technology*, 26(3), 179-189.
- Liaw, S.-S. (2002). Understanding user perceptions of world-wide web environments. *Journal of Computer Assisted Learning* 18, 137-148.
- Maher, F. A. & Tetreault, M. K. (1994), *The feminist classroom: An inside look at how professors and students are transforming higher education for a diverse society*. New

York: Basic Books.

Monson, R. & Judd, K. (2001). CalMaeth: An interactive learning system focusing on the diagnosis of mathematical misconceptions. *Journal of Computers in Mathematics and Science Teaching*, 20, 19-43.

NCES – National Center for Education Statistics (2000). Profile of undergraduates in U.S. postsecondary institutions: 1999-2000. Statistical analysis report from the *National Postsecondary Student Aid Study*. Published by the U.S. Department of Education; publication number NCES2002-168

NSF – National Science Foundation (1998). *Information technology: Its impact on undergraduate science, mathematics, engineering, and technology*. NSF Report Number NSF98-82.

Pascarella, A. (2002). CAPA (Computer-Assisted Personalized Assignments) in a large university setting (Doctoral dissertation, University of Colorado, Boulder). *Dissertation Abstracts International*, 63, 2872.

Peters, M., Kethley, B. & Bullington, K. (2002). The relationship between homework and performance in an introductory operations management course. *Journal of Education for Business* 77(6), 340-344.

Porter, T. S. and Riley, T. M. (1996). The effectiveness of computer exercises in introductory statistics. *The Journal of Economic Education*. 27 (4), 291-299.

Romagnano, L. (2001). Implementing the assessment standards: The myth of objectivity in mathematics assessment, *Mathematics Teacher*, 94, 31-38.

Sadker, M. & Sadker, D. (1995). *Failing at fairness: How America's schools cheat girls*. New York: Scribner.

- Sterrett, A. (Ed.). (1992). *Using writing to teach mathematics*. MAA Notes Number 16.  
Washington DC: Mathematical Association of America.
- Stewart, J., Redlin, L., & Watson, S. (2000). *College Algebra, 3<sup>rd</sup> edition*. Pacific Grove, CA: Brooks-Cole.
- Warton, P. M. (2001). The forgotten voices in homework: Views of students.  
*Educational Psychologist, 36*(3), 155-165.
- WebNet (2001). *Proceedings of WebNet 2001: World Conference on the WWW and Internet* (Orlando, FL, October 23-27, 2001), Fowler, W., & Hasebrook, J., (Eds).  
Norfolk, VA: Association for the Advancement of Computing in Education (ERIC #ED466945).
- Yazon, J. M. O., Mayer-Smith, J. A. & Redfield, R. J. (2002). Does the medium change the message? The impact of a web-based genetics course on university students' perspectives on learning and teaching. *Computers & Education, 38*, 267-285.

## Figure Captions

*Figure 1.* Screen shot of a homework problem on solving a quadratic equation requiring mathematical notation in the second part of the answer.

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

*Figure 3.* Relative frequency distribution for score gains from pre- to post-test grouped by standard deviation from the overall mean (grouped at interval mid-point values).

**Table 1.**

Profile of WBH and PPH Class Instructors.

	Degree in Fall 2002	Years Teaching College	Years Teaching Algebra
<b>WBH only</b>			
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>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
<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

**Table 2.**

Paired *t*-test Results for Performance Differences by Group.

Group	<i>N</i>	Pre-test		Post-test		<i>t</i>
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
WBH	291	9.20	3.89	15.11	4.28	20.68*
PPH	173	8.45	4.12	14.57	4.34	15.24*
Combined	464	8.92	3.99	14.91	4.31	25.67*

\*  $p < .0005$

**Table 3.**

Three-way Analysis of Covariance by Group, Ethnicity, and Gender –  
Statistically Controlling for Pre-test Scores.

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Pretest	515.04	1	515.04	30.74	.000
Group	9.87	1	9.87	0.59	.443
Ethnicity	235.80	5	47.16	2.82	.016*
Gender	7.27	1	7.27	0.43	.510
Group□Ethnicity	102.26	5	20.45	1.22	.298
Group□Gender	136.55	1	136.55	8.15	.005*
Ethnicity□Gender	125.69	5	25.14	1.50	.188
Group□Ethnicity□Gender	73.49	5	14.70	0.88	.496
Error	7321.99	437	16.76		

**Table 4.**

Mean Pre-test, Post-test, and Adjusted Post-test Score by Ethnicity

Ethnicity	<i>N</i>	Pre-test		Post-test		Adjusted Post-test
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i> <sup>a</sup>
African American	34	7.77	4.49	14.27	3.89	15.92ab
Hispanic	112	8.76	3.54	13.63	4.29	13.35a
Pacific Islander	50	9.48	4.62	15.12	4.53	14.94ab
Asian	60	10.40	4.36	16.12	4.57	15.27b
White	144	8.87	3.79	15.40	4.29	15.30ab
Unknown	62	8.21	3.59	15.08	3.74	15.55ab

<sup>a</sup> Covariates are evaluated at: Pre-test = 8.94.

Note: Adjusted means with the same letter are not significantly different based on a Bonferroni pair-wise comparison.

**Table 5.**

Mean Performance Scores of Group by Gender.

Gender	Group	N	Pre-test		Post-test		Adjusted
			M	SD	M	SD	Post-test M <sup>a</sup>
Female	PPH	125	8.20	3.83	14.22	4.14	14.34*
	WBH	207	9.29	3.85	15.45	4.15	15.42*
Male	PPH	48	9.08	4.78	15.48	4.76	16.16
	WBH	84	8.99	4.00	14.27	4.52	14.28

<sup>a</sup> Covariates are evaluated at: Pre-test = 8.94

\* Univariate analysis of group by gender was significant ( $p < .05$ )

◀ 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



