ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

New Orleans JAZZED about Engineering Education

Paper ID #16092

Open-source, Online Homework for Statics and Mechanics of Materials Using WeBWorK: Assessing Effects on Student Learning

Dr. Michael K. Swanbom PE, Louisiana Tech University

Dr. Swanbom is a Senior Lecturer in Mechanical Engineering. He is a major developer of innovative, hands-on, practical content for both high school and university curricula.

Dr. Daniel William Moller, Louisiana Tech University
Dr. Katie Evans, Louisiana Tech University

Dr. Katie Evans is the Walter Koss Endowed Associate Professor of Mathematics and Statistics and the Academic Director of Mathematics and Statistics and Industrial Engineering programs. She is the Director of the Integrated STEM Education Research Center (ISERC) and the Director of Louisiana Tech's Office for Women in Science and Engineering (OWISE). She earned her Ph.D. in Mathematics and M.S. in Mathematics at Virginia Tech, Blacksburg, VA. Her research interests include distributed parameter control modeling and simulation, dynamic modeling of physical systems, and STEM education. She has published 20 peer-reviewed publications in these areas, and her research has been funded by the NSF, AFRL, and LA-BOR. She also serves as an Associate Editor for the American Control Conference and the Conference on Decision and Control, two premier conferences in the controls community. She is a member of the IEEE, SIAM, and ASEE.

Dr. Timothy Reeves, Louisiana Tech University

Open-source, online homework for Statics and Mechanics of Materials using WeBWorK: assessing effects on student learning

Introduction and Goal

Many engineering programs have begun adopting interactive online homework systems, often as a way to stretch the precious resources of faculty time and energy. While an increasing number of online homework offerings are available from textbook publishers, many of these systems have proven less than ideal. Some issues the authors have experienced with these systems include errors in the embedded solutions, inflexibility to correct or expand exercise problems, and sparse or incomplete coverage of the material covered in the texts, not to mention the additional cost students incur for access to these systems.

As an alternative, the authors have developed a robust set of integrated Statics and Mechanics of Materials exercise problems for use within a free, open-source, online homework delivery tool called WeBWorK (webwork.maa.org). This tool has seen wide adoption in mathematics courses worldwide (now over 1000 institutions) and the authors' institution has considerable experience using it in that context. This work is part of a currently funded National Science Foundation (NSF) funded project aimed at expanding the use of WeBWorK into engineering courses. Problem sets for two other sophomore level courses (Circuits and Thermodynamics) have also been developed. These problems are all freely available at the National Problem Library (webwork.maa.org/wiki/Open_Problem_Library) maintained by the Mathematical Association of America (MAA), the developers of WeBWorK, and the NSF.

WeBWorK delivers unique homework problems to individual students by giving them each a different set of parameters that define the specifics of a given problem. Students are given blanks where they can enter and submit their answers, and they are given instant feedback on the correctness of their responses. Problems can be constructed such that multiple "blanks" are shown per problem. This enables instructors to give students tools to check their intermediate results on multi-step problems. It also allows problems to be configured to ask students about multiple aspects of a single root scenario.

There are several potential benefits of using WeBWorK versus traditional paper-only homework. These include more specific and more rapid feedback, customizable automated due dates/times (including a feature that allows partial credit for past-due submissions), and the ability to compel students to do their own unique work. It also has several potential benefits relative to many "for-profit" type homework systems, including lower cost to students, more flexibility and customizability for professors, and potential for collaboration across institutional lines with ideas and best practices in similar courses. At Louisiana Tech University, the students invest in PCs to complete the freshman sequence of hands-on courses (called *Living WITH the Lab* or *LWTL*), so there is not significant additional hardship when they are called upon to do homework online.

Many students use their smartphones or tablets to complete their online assignments in WeBWorK.

The goal of the study presented in this paper was to compare outcomes of students using the newly developed Statics and Mechanics of Materials WeBWorK problems online against the outcomes of students completing the same problems in a paper-only format. The view of the authors is that the WeBWorK system provides a streamlined homework delivery and feedback mechanism. As long as it can be shown to be no less effective than traditional homework assignment and grading techniques, it is the authors' view that it is worth adopting.

Online Homework Problem Development for Statics and Mechanics of Materials Course

The opening "Statics" course at Louisiana Tech University is actually an integrated Statics and Mechanics of Materials course. It is a common course required by all engineering disciplines. Some of the pure Statics content that has traditionally been in the first Statics course at most institutions is introduced with considerable depth and rigor during the innovative freshman series at this institution (*LWTL* previously referenced). This makes it possible to introduce building blocks of Mechanics of Materials (axial, torsional, flexural stresses and deflections, etc.) alongside the more in-depth pure Statics content presented in the course. The result is that all students, regardless of engineering discipline, develop the knowledge needed to answer questions like "how thick does this member need to be to avoid excessive stress?" or "how much will this part bend under a given force?" Students in Mechanical or Civil Engineering courses of study take classes that take them much deeper, but the basic elements for understanding Mechanics of Materials are covered rigorously in this course.

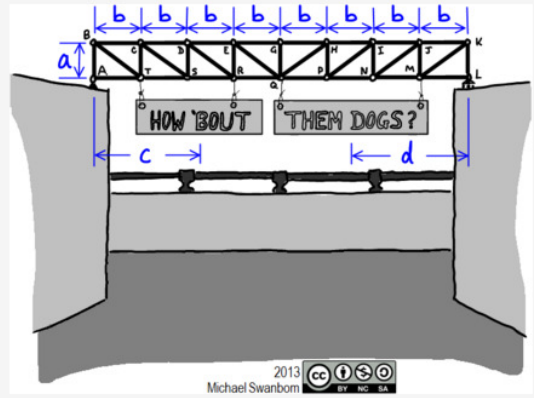
Table 1 shows a breakdown of the problems that have been created for the Statics and Mechanics of Materials problem library in a number of categories.

Statics and Mechaincs of Materials Topical Family	***Number of Problems (to date)***		
	Statics Only	*Primarily Mech. of Materials*	*Integrated Statics and M.of M.*
Concurrent Force Systems (2D and 3D)	14		3
Stress, Strain, and Deflection - Axial and Direct Shear		19	
Moments and Rigid Bodies	11		
Trusses	11		5
Frames and Machines	10		3
Shearing Force and Bending Moments in Beams	7		8
Flexural Stress and Beam Design		10	
Beam Deflection		4	
Torsional Stress and Deflection	1	4	4
Power Transmission and Gears	1	5	
Thin-Walled Pressure Vessels		4	
Stress Concentration (with charts)		1	1
General Topics	*Centroids & Centers of Mass*	*Second Moments of Area*	*Integrated into Larger Problem*
Properties of Areas and Volumes	7	5	8
Total Distinct Problems:	**127**		
the table above double-counts content in some larger problems			

Table 1: Statics and Mechanics of Materials WeBWorK Library Topical Distribution

Because of the nature of the course, several of the problems that have been developed have a Statics portion that feeds into a mechanics of materials portion. Other problems are purely Statics problems, and still others are primarily mechanics of materials problems. One community college that has adopted WeBWorK in connection with this project offers a pure Statics course, so Statics-only versions of many of the originally integrated problems were created.

Most of the problems that have been contributed to the library require multiple steps and multiple responses from the student. This allows the problem to be tailored to have the student fully explore the various aspects of a given scenario. It also allows the problem to be built with scaffolding, which helps walk the student through the problem, and gives them feedback on intermediate steps (e.g. confirm they correctly computed reactions before moving to the next step). Many of the problems contain elements that compel the student to work a sub-problem from a previously covered topic. In this way, students are made to continuously review old skills, and they see in practice how real problems tend to be integrated rather than compartmentalized. Figure 1 shows a view of a typical multi-faceted problem. Dimensions and other data are usually defined in terms of variable parameters, and students are required to submit units with their answers. WeBWorK has a built-in units parser that will give credit for equivalent answers with units other than those originally coded into the solution.



entrance sign pratt 01

A truss structure is used to hang signs at an entrance to a stadium. The locations of the centers of gravity of the signs are given by dimensions c and d. Find the forces and stresses carried in the members indicated in the table below, as well as the changes in length of those members. Dimensions, weights, and cross-sectional areas are given below. The members of the truss are composed of 2014-T4 aluminum. Neglect self-weight of the truss.

a	b	c	d	Left Sign Weight	Right Sign Weight
11 in	18 in	3.375 ft	3.75 ft	87 lb	98 lb

Reactions:

R_A	
R_L	

Members:
(Denote tension forces, tensile stresses, and elongations with positive values; compressive forces, compressive stresses and compactions with negative values.)

Member	Cross-Sectional Area (in^2)	Force	Stress	Change in Length
EG	0.75			
EQ	0.125			
QR	0.125			
GQ	0.75			
GH	0.75			
HQ	0.125			
PQ	0.125			

be sure to include units with your answers

Figure 1: Multi-Faceted Problem

The problems in the Statics and Mechanics of Materials library generally have a figure that defines and describes the relevant problem geometry or other graphical information needed in the problem. These figures are stored as .png image files, and are freely available at the same repository where the problems may be retrieved. This repository is GitHub (github.com), with which many individuals in the open-source community are familiar. (A search for "open problem library" at GitHub will direct the interested user to the necessary repository. Look for a folder named "*OPES*.") The behavior of each problem is defined in a text file with a .pg extension. This file contains the code with the problem solution, as well as the code that creates the desired look for the problem. The primary language of this code is Perl, and it has many formatting and typesetting options available via LaTeX. Editing the code is as simple as editing a text file stored on a WeBWorK server.

If an institution has the requisite servers and technical support, then the creation of a locally-hosted WeBWorK system is simple and free. Institutions lacking such resources or those that wish to adopt WeBWorK on a trial basis can opt to utilize off-site hosting provided by the MAA. All information about courses and applying to have courses hosted can be found here: http://webwork.maa.org/. The libraries of problems created as part of this project can be used freely whether WeBWorK is hosted on-site or remotely.

Prior Studies

Many benefits associated with the use of WeBWorK versus traditional homework have been previously documented, both for improving student learning and efficiently using faculty resources. Research has shown that immediate feedback helps students learn, and WeBWorK is a platform that gives such feedback regarding the correctness of answers [1]. Customizable homework set parameters such as automated opening and closing dates and times, partial credit for past-due attempts, and number of allowed attempts, help the instructor design a beneficial learning experience that meets the needs of their students. One WeBWorK study showed that students tended to complete a problem 94.4% of the time once it was begun. [2]. Students tend to achieve better learning outcomes when they have the opportunity and motivation to "continue working on a task until it is completed and accurate" [3].

The correlation between online/offline tutorial services and student success has been suggested by several studies. Louisiana Tech conducted one study which indicated that students utilized online tutoring significantly more than traditional tutoring programs, suggesting that many students may prefer quality technologically powered learning tools to more traditional learning aids [4]. The Department of Education conducted a meta-analysis that found "on average, students in online learning conditions performed modestly better than those receiving face-to-face instruction" [5]. A study of college algebra students at a community college produced similar findings, showing that online homework was "just as effective as textbook homework in helping students learn college algebra and in improving students' self-efficacy" [6]. It was also observed that "online homework may be even more effective for helping the large population of college algebra students who enroll in the course with inadequate prerequisite math skills." Some universities have found that the use of WeBWorK correlated with small, yet statistically significant improvement in performance on exams relative to classes that did not use it [7, 2].

Diverse groups of students seem to react positively to using WeBWorK as a learning tool, with one study showing that the benefits crossed lines of academic rank, gender, and preferred learning styles [8]. In another study, it was observed that "females expressed stronger opinions on the fact that instant scores and feedback helped them overcome difficulties in mathematics problem solving" [9]. WeBWorK was recently expanded for use in computer science as part of an NSF-funded global experiment spanning students and faculty from three continents. Feedback from this experiment regarding WeBWorK as a learning tool has been consistently positive, with one author noting that "Systems such as WeBWorK offer the potential to transfer knowledge and teaching practices from one country to another" [10].

A preliminary study of the use of WeBWorK in a first Circuits course completed as part of this project suggests that there is no disadvantage of using WeBWorK versus traditional homework delivery methods as measured by targeted quizzes [11]. That study has since been expanded and refined, and results will be published concurrently with those presented in this paper.

Current Study in Statics and Mechanics of Materials Course

The purpose of this study is to search for statistically significant differences between students' performance on targeted quizzes when given access to WeBWorK for the completion of their homework versus completing the same problems with pencil-and-paper only. The study was performed in two academic terms. In the fall quarter of 2014, four course sections were studied and in the winter quarter of 2014-2015, three course sections were studied. These seven course sections represented all of the offerings of this course at Louisiana Tech University. In the fall term, two of the sections were instructed by the same professor (I1), and two other professors instructed the remaining two sections (I2 nd I3). In the winter term, two of the course sections were instructed by I1 and the remaining section was instructed by I2.

Four topics were chosen as the subjects of the targeted quizzes. For each of these topics, two cohorts were defined, one required to submit the associated homework sets with pencil-and-paper only, and one that submitted their answers into WeBWorK. Students submitting their answers into WeBWorK were also asked to turn in their properly-formatted work for a formatting and appearance grade only (not correctness). The paper-only cohorts were given the same problems as the cohorts with WeBWorK access, but the entire paper-only cohort used the same problem-defining parameters, whereas each student in the WeBWorK cohort was assigned unique parameters by the WeBWorK system. The paper-only cohort was not given the correct answers to their problems until after the assignment was due. In an attempt to minimize variability due to potential instructor differences, student cohorts were selected such that for each homework set studied, a cohort of each type (i.e. WeBWorK vs. paper-only) were in sections taught by I1. In an attempt to minimize variability due to the overall aptitude of one section versus another, the cohorts alternated between having access to WeBWorK and completing paper-only homework for the homework sets studied. Table 2 shows how the cohorts were divided and the topics covered in each quiz and associated homework set.

	Term:	Fall 2014				Winter 2014-2015		
	Course Section:	001	002	003	004	001	002	003
	Meeting Time:	8:00 AM	12:30 PM	2:30 PM	10:00 AM	8:00 AM	12:30 PM	2:30 PM
Topic	Instructor:	I1	I2	I3	I1	I2	I1	I1
1: 2D Equilibrium		WeBWorK	WeBWorK	Paper Only	Paper Only	WeBWorK	WeBWorK	Paper Only
2: Trusses, Method of Sections		Paper Only	Paper Only	WeBWorK	WeBWorK	Paper Only	Paper Only	WeBWorK
3: Centroids		WeBWorK	WeBWorK	Paper Only	Paper Only	Paper Only	WeBWorK	Paper Only
4: Second Moments of Area		Paper Only	Paper Only	WeBWorK	WeBWorK	WeBWorK	Paper Only	WeBWorK

Table 2: Definition of Cohorts

The targeted quizzes used to assess students' performance in the chosen topical areas were administered at the beginning of the meeting where the associated homework sets were due. Some of the quizzes required that the students work out a problem that was then blindly graded by a third party (not the instructors themselves) according to rubrics supplied by the instructors. Other quizzes were given in a multiple choice format, with multiple questions and no partial credit awarded. Thus in both quiz formats used, potential biases of the instructors toward individual students or toward particular groups were eliminated.

Not all students in each section took all the quizzes. To eliminate skewing in the results due to differing populations taking the quizzes, the only quiz scores that were added to the dataset were from students that took all of the quizzes administered to their course section.

The quizzes were created from scratch for the purpose of this study, thus eliminating the possibility that any student had already had the chance to try the problems. Since each problem was new, the instructors did not have a standard by which the difficulty of one quiz could be established relative to another. Because the authors wanted to compare differences in performance due to WeBWorK access, fair comparisons had to be made across multiple quizzes. Toward this end, the raw scores for each quiz were converted to z-scores using the mean and standard deviation from the dataset population for that quiz. Averages of the z-scores earned by students with WeBWorK access could then be compared to averages of z-scores earned by students without access. T tests were also evaluated to determine the probability that the averages found were really "the same." If the standard 5% significance level is the target, it means that only t test probabilities less than 5% will indicate a statistically significant difference in the means.

In both terms, there were two course sections taught by the same professor (I1). The average z-scores with and without WeBWorK access were compared using the data subset of this professor's sections only. The comparisons were also performed where data from all sections were used. Further, averages with and without WeBWorK were found for all four quizzes in each term, and then all eight quizzes from both terms. Table 3 summarizes the findings of this analysis. The “n” values listed in the table are total numbers of quiz scores included in the data from a given quiz or group of quizzes. In all cases, these “n” values were split fairly evenly between quiz scores of those using WeBWorK and those completing paper-only homework.

Assessment or *Group of Assessments*		Common Instructor (I1)				All Instructors			
		n	Average Score with WW Access	Average Score without WW Access	t test probability	n	Average Score with WW Access	Average Score without WW Access	t test probability
Fall 2014	Quiz 1	59	0.0068	0.0474	0.873	110	-0.0997	0.1287	0.230
	Quiz 2	59	-0.1153	0.1383	0.324	110	-0.0332	0.0257	0.763
	Quiz 3	59	0.1615	0.0728	0.714	110	-0.1600	0.2067	0.051
	Quiz 4	59	0.0684	-0.2238	0.302	110	0.0884	-0.0684	0.407
	Fall Quizzes	236	0.0294	0.0096	0.877	440	-0.0612	0.0612	0.198
Winter 2014-15	Quiz 1	63	0.1833	-0.0143	0.386	93	0.0062	-0.0143	0.921
	Quiz 2	63	0.0254	-0.1689	0.471	93	0.0254	-0.0109	0.881
	Quiz 3	63	0.1232	-0.1513	0.275	93	0.1232	-0.0744	0.341
	Quiz 4	63	0.0868	0.0181	0.796	93	-0.0109	0.0181	0.893
	Winter Quizzes	252	0.1101	-0.0787	0.128	372	0.0258	-0.0258	0.618
All Quizzes		488	0.0711	-0.0360	0.229	812	-0.0213	0.0213	0.542

Table 3: Z-Score Average and t Test Probability Results from Targeted Quizzes

A few observations arise from these data. The biggest takeaway is that **no statistically significant difference can be detected between the populations that used WeBWorK to complete their homework assignments and those that completed their assignments on paper only**. When only the performance of sections taught by I1 are considered, all but two of the quizzes showed slight advantages for students using WeBWorK, although none of them are statistically significant at the 5% level. Considering all quizzes given in the winter term to students in the I1 dataset, there seems to be a benefit to using WeBWorK that begins to get near to statistical significance (0.128) but still not actually significant. The lowest t test probability detected for any of the comparisons was for Quiz 3 in the fall term, considering course sections taught by all instructors (0.051). What is particularly striking about this quiz is that students in the I1 dataset seemed to marginally benefit from using WeBWorK, while WeBWorK seemed to play a negative role (nearly significantly) for those in the larger dataset. No other factors have yet been identified to account for this poor performance on quiz three among all course sections.

Student Survey Results

One interesting outcome of this study was hearing some of the inevitable informal verbal feedback. After having used WeBWorK for all their homework assignments, when students got to one of the sets we were studying and WeBWorK wasn’t available, they generally weren’t happy about it. After submitting one such assignment, a student volunteered the statement: “Well, it did take a lot less time, but I have no idea if I’m doing it correctly. Can we please NOT do that again?” It is common to hear complaints about WeBWorK, but when students are pressed on what alternative they would prefer, they generally admit WeBWorK is among the best options for homework tools. Some of the specific features students tend to mention as positives are the immediate feedback, the ability to make multiple attempts, and the convenient button that allows them to email their instructors easily.

As a part of this project, the authors have collected student opinions more formally by administering pre- and post- surveys in ENGR220 (Statics and Mechanics of Materials) and ENGR221 (Circuits). There were 211 respondents at the beginning of the fall quarter, 2014, and 99 respondents at the end of that term. In the winter quarter, 2014-2015, there were 185 respondents at the beginning of the term and 50 respondents at the end. Table 4 shows the percentage of students that agreed with the given statements regarding identity and self-efficacy at the indicated points in time.

Statement	Fall 2014 % Agree or Strongly Agree		Winter 2014-15 %Agree or Strongly Agree	
	Pre (n=211)	Post (n=99)	Pre (n=185)	Post (n=50)
I have friends in engineering.	95%	93%	94%	96%
I belong in engineering.	95%	88%	94%	94%
I am good at solving engineering problems.	88%	83%	88%	98%
I excel in my engineering studies compared to my peers in engineering.	55%	60%	56%	62%
I will be an excellent engineer.	86%	76%	85%	92%
I can have a fulfilling career in engineering.	90%	77%	90%	96%
I am comfortable working in an online environment.	83%	83%	91%	94%
I am comfortable using a computer to solve engineering problems.	90%	87%	92%	98%
Homework problems are a critical part of the learning process in engineering classes.	96%	90%	96%	96%
The amount of effort I put into solving the homework problems will affect how much I gain from the course.	92%	84%	89%	92%
The amount of effort I put into solving the homework problems will affect my grade in this course.	95%	85%	94%	96%
My grade in this course will be affected by the amount of effort I put into this course.	81%	87%	81%	84%
I will not gain the same amount of knowledge from this course regardless of the amount of effort I put into this course.	81%	85%	79%	84%

Table 4: Pre- and Post- Identity and Self-Efficacy Survey Results

These data indicate that these students generally feel comfortable with their choice of engineering as a major, their identity as an engineer, and their prospects for a successful career in engineering. The students appear to have these feelings to about the same degree both before and after taking the course. The students also seem to understand the importance of homework toward their success in grasping relevant engineering concepts and skills, and toward earning good course grades. Not as many students assessed themselves as excelling relative to their peers in engineering. Most students indicated comfort with working in an online environment and using computers to solve engineering problems.

On the surveys administered at the end of each term, students were asked to rate their level of agreement with 18 additional statements. Some of the interesting results of this survey, particularly with respect to the perceived value of WeBWorK relative to other homework systems, are shown in Table 5.

Statement	Fall 2014 % Agree or Strongly Agree	Winter 2014-15 %Agree or Strongly Agree
Make better grades	56%	63%
Prefer WeBWorK (WW) to other methods	58%	71%
Prefer WW to pencil-and-paper	62%	69%
Better prepared for exams	62%	78%
Know immediately if answer correct	96%	100%
Feedback more useful than traditional	52%	66%
Get more out of class	54%	70%
Prefer because confident work has been graded	58%	72%
Previous experience with WW has been positive	68%	80%

Table 5: Survey Results Regarding Perceived Effectiveness of WeBWorK

Based on these results, it appears that the aspect of WeBWorK that the largest number of students found valuable was the instant feedback on the correctness of their answers. A fairly strong majority also felt that WeBWorK better prepared them for exams than other forms of homework. A majority of respondents preferred WeBWorK over other homework formats, and one reason for this was an improved feeling of confidence that their homework had been graded.

It is also helpful to know if students are feeling negatively toward various aspects of the use of WeBWorK. Table 6 gives survey results regarding several areas of complaints that the authors tend to hear with respect to the use of WeBWorK.

Statement	Fall 2014 % Agree or Strongly Agree	Winter 2014-15 %Agree or Strongly Agree
Difficult to use	20%	10%
Counts correct answers incorrect	56%	36%
WeBWorK problems more difficult	56%	68%
Give up on problems because of difficulty	58%	48%
Too difficult to submit answers	17%	14%

Table 6: Survey Results Regarding Negative Feelings toward WeBWorK

In most areas, there were fewer negative feelings toward WeBWorK in the winter term than the fall term. This may be due to the more positive previous experience with WeBWorK among the students taking the course in the winter. A feeling that the problems are too difficult was noted from these data. Upon reflection, the authors concluded that many of the newly-crafted problems were more on the difficult end of the scale, and more were needed at the easier end of the scale to assist students in building their skills and confidence gradually. Additions to the problem library addressing this concern have since been added, but these additions were not in place at the time of any of the surveys reported here. One significant item to note is the sharp reduction from fall to winter in feelings that WeBWorK was improperly marking answers wrong. The authors believe this has two major causes. First, a few of the problems used in the fall really did have bugs that were located and resolved after the problems were deployed. Once students see this even a few times, they quickly lose confidence in the system, even when the vast majority of problems work properly. Second, the makeup of the class in the fall was much more heavily weighted toward first-time takers (86.4%) of the course than the winter (64.3%). The higher rate of re-takers in the winter led to a bigger percentage of the class that had already seen and used the problems, and had built confidence and experience with them. This effect also likely influenced the decline in 'giving up because of difficulty' reported in the winter versus the fall.

Conclusions and Future Studies

A significant number of parameterized Statics and Mechanics of Materials problems have been created for use within an open-source, interactive online homework system called WeBWorK as part of an NSF-funded project. The project is aimed at expanding the use of WeBWorK from its genesis in mathematics into sophomore-level engineering courses. These problem libraries are free; the problems are easy to correct or customize, and have been in use for two years at Louisiana Tech University. Student feedback regarding this homework system is positive relative to other homework methods, largely because students tend to appreciate the instant feedback it provides regarding the correctness of their answers. The authors have found the system to be quite beneficial because of the feedback it automatically provides students, and because it streamlines the management of the homework aspect of their courses. To evaluate if use of the WeBWorK system provides measurably different learning outcomes relative to traditional paper-only homework, students were separated into groups that did use the system for particular assignments and those that did not. Quizzes were used to assess the relative performance of students using the system against those that did not use the system. No statistically significant difference could be detected between students that used WeBWorK and those that did not.

Work is currently underway to integrate the study of the effectiveness of WeBWorK into the normal activities of the course. The type of examination being given in the Statics and Mechanics of Materials course lends itself particularly well to mapping homework sets to examination questions. Groups of students can be restricted from using a WeBWorK set (and given paper assignments instead), then their performance on the corresponding examination question can be compared to those using WeBWorK. The authors find this to be a less intrusive technique of performing a study like this, and plan to publish the findings using this technique in the near future.

References

[1] R. L. Bangert-Drowns, C.-L. C. Kulik, J. A. Kulik and M. Morgan, "The instructional effect of feedback in test-like events," Review of Educational Research, vol. 61, pp. 213-238, 1991.

[2] L. Hirsch and C. Weibel, "Statistical Evidence that Web-Based Homework Helps," MAA Focus, p. 14, February 2003.

[3] R. J. Marzano, D. J. Pickering and J. E. Pollock, Classroom instruction that works: Research-based strategies for increasing student achievement, Alexandria, VA: Association for Supervision and Curriculum Development, 2001.

[4] J. P. Carpenter and B. D. Camp, "Using a Web-Based Homework System to Improve Accountability and Mastery in Calculus," in 2008 ASEE Annual Conference & Exposition, Pittsburgh, 2008.

[5] B. Means, Y. Toyama, R. Murphy, M. Bakia, K. Jones and Center for Technology in Learning, "Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies," U.S. Department of Education, 2010.

[6] D. S. Brewer, The Effects of Online Homework on Achievement and Self-efficacy of College Algebra Students, Utah State University, 2009.

[7] W. Ziemer, "WeBWorK: An Open-Source Online Homework System," in Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education, NSF DUE in collaboration with EHR and AAAS, 2004, pp. 169-171.

[8] D. Doorn, S. Janssen and M. O'Brien, "Student attitudes and approaches to online homework," International Journal for the Scholarship of Teaching and Learning, vol. 4, no. 1, January 2010.

[9] D. M. Nguyen, Y.-C. J. Hsieh and G. D. Allen, "The impact of web-based assessment and practice on students' mathematics learning attitudes," Journal of Computers in Mathematics and Science Teaching, vol. 25, no. 3, pp. 251-279, 2006.

[10] O. Gotel, C. Scharff, A. Wildenberg, M. Bousso, C. Bunthoeurn, P. Des, V. Kulkarni, S. Palakvangsa Na Ayudhya, C. Sarr and T. Sunetnanta, "Global Perceptions on the Use of WeBWorK as an Online Tutor for Computer Science," in 38th ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, New York, 2008.

[11] K. Evans, P. Hummel, M. Gates, "Assessing the Effect of Online Homework on Student Learning in a First Circuits Course" 2015 ASEE Annual Conference and Exposition, Seattle, Washington.

Acknowledgements

This material is supported by NSF DUE Grant #1244833. Any opinions, findings, and conclusions or recommendations expressed are those of the authors and do not necessarily reflect the views of the National Science Foundation.