AC 2008-2779: USING A WEB-BASED HOMEWORK SYSTEM TO IMPROVE ACCOUNTABILITY AND MASTERY IN CALCULUS

Jenna Carpenter, Louisiana Tech University

Dr. Jenna Carpenter is Director of Chemical and Industrial Engineering at Louisiana Tech University and Wayne and Juanita Spinks Professor of Mathematics. She is interested in the use of educational technology to enhance instruction and learning, the development of integrated STEM curricula, and issues related to improving the success of women in engineering. Dr. Carpenter received her Ph.D. in Mathematics from Louisiana State University in 1989.

Brian Camp, Louisiana Tech University

Dr. Brian Camp is a Lecturer of Mathematics and Statistics at Louisiana Tech University. His interests include numerical methods, differential equations and exploring new ways of teaching common mathematics topics. Dr. Camp is currently the WeBWorK Administrator at Louisiana Tech, a position he finds both challenging and rewarding. He received his Ph.D. in Mathematics from Virginia Tech in 2003.

USING A WEB-BASED HOMEWORK SYSTEM TO IMPROVE ACCOUNTABILITY AND MASTERY IN CALCULUS

Abstract

Homework is a standard part of most calculus courses. Designing out-of-class assignments that foster individual accountability, contribute to mastery of course content, and provide feedback to students in a timely fashion is a more challenging task. Utilizing web-based software to manage the homework experience in the calculus course provides the instructor with the ability to address each of these objectives in a fresh way. In this paper, we will examine the use of a web-based homework system, WeBWorK, in the calculus sequence at Louisiana Tech University, together with an analysis of the opportunities and challenges of using this type of system, and look at some initial assessment of student use.

Background

In the Fall of 2006, two faculty in the Mathematics and Statistics Program at Louisiana Tech University became interested in piloting a web-based homework system in an effort to provide more effective out-of-class assignments for their students. Based on previous experience, the system they were interested in using was WeBWorK. WeBWorK was developed in the mid-1990's at University of Rochester by Arnold Pizer and Michael Gage. It has historically been used by larger institutions, such as Louisiana State University and University of Michigan, which teach large lecture courses in mathematics with a number of smaller recitation sections. While Louisiana Tech University is mid-sized institution with a commitment to small (around 40) students per mathematics classes, these faculty were intrigued by the possibilities that an individualized online homework system could afford. Moreover, the Mathematics and Statistics Program at Louisiana Tech University has historically spent approximately $20,000 each year on student paper graders to grade homework assignments. The use of WeBWorK would, therefore free up most of these funds to be used in other, hopefully more effective, ways to improve student retention and success in mathematics. For the 2007-2008 academic year, for example, these funds are being used to support Supplemental Instruction for the calculus courses. Thus, the goals of this effort were to 1) increase student mastery of course content, 2) increase individual student accountability on out-of-class assignments, and 3) more effectively utilize the program budget to enhance student retention and success in mathematics.

WeBWorK[1] is a web-based (versus software-based) system that can be accessed from any computer with internet access and a web browser (such as Internet Explorer or Firefox). It is installed on a server running Linux, along with the Apache web server. Since WeBWorK is open-source software, there is no cost to use the software for either the department or the students. The only cost associated with using WeBWorK involves the cost of the server on which WeBWorK is to be installed and the cost of any support staff needed to administer the server. Many WeBWorK problems have already been written for use in a variety of mathematics classes. These problems are made available in a national problem library that can be accessed from within WeBWorK. Students generally are required to give an answer to a question and are graded as they enter answers to their homework problems. Their scores are stored on the server itself and not on their own computers. Typically problems can be attempted multiple times until the correct answer or answers are provided by the student. Only their best score is recorded by the homework system.

Starting in Fall 2007, the Mathematics and Statistics Program elected to discontinue the use of student paper graders in a number of classes, including the calculus and differential equations sequence, and begin use of WeBWorK to grade student homework assignments. The Program designated a faculty member as the WeBWorK Administrator. The costs associated with assigning one faculty member the responsibility of serving as the WeBWorK Administrator vary, depending on whether or not those duties are assigned to an existing faculty member as part of his/her normal load, whether or not the Administrator is provided release time from teaching to carry out these duties, etc. The Administrator handles set-up of courses, loading of students, technical trouble-shooting and overall faculty assistance. In addition, he/she provides each faculty member with an initial set of suggested problems for each section in the text, although the faculty member is free to add to, subtract from, or modify the list of problems, as he/she sees fit. Thus faculty have the discretion to incorporate WeBWorK into their course in a variety of ways. The calculus course coordinators generally advise that a student's WeBWorK grade count for no more than 10% of their overall course grade. In addition to WeBWorK, some of the calculus courses also utilize a web-based tutorial system called ALEKS, and some participate in the university's Supplemental Instruction Program.

Opportunities

Two of the primary goals of this project were: 1) to increase student mastery of course content, and 2) to increase individual student accountability on out-of-class assignments. When homework problems are assigned out of the textbook, students usually attempt each problem once or twice. They will often spend more time on those problems which have an answer printed at the back of the book in an attempt to get the right answer. It is rare, however, for students to go back to an assignment, once it has been graded and returned, and rework from scratch problems they have missed. At best they will look at the problem and attempt to determine their mistake, if sufficient information was provided as to their error. In addition, in recent years the ready availability of complete textbook solutions manuals via online retailers has further watered down the effectiveness of textbook-based homework assignments. Lastly, when student paper graders are used to grade homework assignments, only a fraction of the assigned problems get graded and/or only answers get graded, making it easier for students to cheat or gloss over difficulties with their solutions. This means students receive no feedback on their work for the vast majority of the homework problems they attempt. WeBWorK provides the ability to address each of these issues.

One of the attractive features of WeBWorK is that it allows students to attempt problems multiple times. Faculty can set the number of attempts on each problem, with the default being "unlimited" on all problems. One exception is multiple-choice problems, where it does not make sense for the number of attempts to exceed the number of different answers available. When a student works a problem in WeBWorK, they can ask WeBWorK to check their answer before they submit it. WeBWorK will generally tell a student whether or not their answer is correct, but it will not, for example on a multi-part problem, tell them which part is correct and which is incorrect. For problems with long or complicated answers, this feature also allows students to see the typeset version of their answer so that they can make sure that they have entered it correctly. Because of the immediate feedback feature, students are strongly motivated to stick with a problem until they get the correct answer. This increases the likelihood that they can correctly work each problem on the homework assignment, versus a handful of problems. Moreover, students receive feedback on every homework problem they work. Consequently, they have a much better sense of which type of problem they understand and which they do not. While most pre-written WeBWorK problems only ask for the final answer, some problems are written in such a way as to ask students to provide answers to intermediate steps in the problem. Certainly, any WeBWorK problem can be written in such a fashion.

The vast majority of WeBWorK problems are programmed so that they have one or more random parameters. Hence all students receive the same type of problem, but no two students are likely to receive problem with the same number or parameter values. Thus, given the complexity of most calculus problems and the inexperience of most students, WeBWorK really does provide individualized assignments for each student. The fact that no two students are likely to receive the exact same problem decreases the odds of cheating or copying answers from other students, both of which are widespread issues when assigning problems from the textbook. There are online homework systems, such as WebAssign, which are tailored to individual textbooks, but they typically utilize the same homework problems as in the textbook and consequently don't thwart cheating or the problems associated with easy access to complete solutions manuals.

One aspect of teaching that WeBWorK can change radically is the meaning of "office hours". WeBWorK allows students to e-mail their instructor and/or other designated person(s) from inside a particular problem in their WeBWorK assignment. The instructor (and/or other designee) receives not only the message from the student, detailing their question(s), but also a direct link to the student's problem inside WeBWorK. The instructor can see the most recent answer the student has submitted (if any), the number of times the student has attempted the problem, the correct answer for the problem, as well as a link to the computer code for the problem. This generally provides the instructor with sufficient information, when paired with the student e-mail message, to provide meaningful feedback (versus just telling them the answer). That is, it is fairly easy to distinguish between conceptual errors, syntax errors, potential programming errors in the problem, etc. Using standard e-mail alone to provide virtual assistance to students affords none of these niceties and is generally unsatisfactory when used for this purpose.

It has been our experience that the ease of e-mailing the instructor encourages students to contact their instructor significantly more often than they would if they had to come to office hours the next day. Consequently, there are a few caveats to making this arrangement manageable and effective. First, it is important for students to understand that the instructor cannot handle 20 questions per student per day. Students should exhaust other sources of assistance first. This includes attempting the problem multiple times (trying every strategy they know), checking their notes/the textbook, looking for calculation and syntax errors, etc. They should also try to seek help from a fellow student, if that is feasible. Only after exhausting these options is it acceptable to contact the instructor. This not only prevents the instructor from being overloaded with e-mails and trivial questions, but also makes sure that the student has first exerted sufficient effort on his/her own and really has a substantial question. It has been our experience that students will respect these guidelines. Secondly, to be truly effective the instructor feedback needs to be near real-time. Students usually work on their homework in the evenings, while office hours are usually between 8 a.m. and 5 p.m. If students know their instructor is online in the evenings, the e-mail option can be very effective in helping students successfully work through conceptual or other issues that often get ignored with standard out-of-the-book homework assignments. It is usually sufficient for the instructor to check e-mail two to three times during the evening. And even when students do come by during office hours, they often bring their laptop and walk in the door with the WeBWorK problem in question already pulled up on their computer screen. Lastly, the email from students serves as an excellent measure of where students are currently experiencing difficulty in the course. As a result, the time used in the classroom to discuss homework problems may be easily tailored to cover the topics with which students have already indicated they are having problems.

Another nice feature of WeBWorK is that it automatically produces a variety of spreadsheet-like summaries of data (by student, by assignment, etc.) which the instructor can access at any time during the term. This makes it easy for the instructor to spot, for example, problems that students haven't answered, problems that students have attempted a large number of times, etc. Moreover, WeBWorK can save these statistical summaries as a .csv file which can easily be imported into the instructor's spreadsheet program, such as Excel, at the end of the term.

Faculty have successfully used WeBWorK in a variety of ways in their classes. Some use WeBWorK exclusively to assign and grade out-of-class homework assignments. Others continue to assign (but not collect or grade) homework assignments from the textbook, while assigning a small sample of problems to be completed (and graded) on WeBWorK. There are faculty who assign and grade homework using WeBWorK on a daily basis, much as they would if they were assigning problems from the textbook, while others make weekly assignments and still others only require that all assigned WeBWorK problems be completed by the end of the term. One attractive feature of WeBWorK is that it allows individual faculty the flexibility to incorporate the system in a variety of ways.

Challenges

Utilizing WeBWorK for out-of-class homework assignments is not without its challenges. First, there is a learning curve for both faculty and students. In order to acclimate students to the peculiarities of WeBWorK with regard to format, preferences, etc., our program utilizes an initial Orientation Assignment developed at Union College in New York. This seems to provide students with a fairly smooth introduction to WeBWorK. The astute faculty member can further alleviate such issues by providing clear instructions in problem statements that require a special format for the answer and by alerting students to potential pitfalls ahead of time in class.

For faculty, the learning curve is understandably steeper. Fortunately, faculty do not have to write problems themselves. At our institution, the WeBWorK Administrator pre-loads suggested problems for each section in the textbook. Moreover, should a faculty member wish to augment the list of suggested problems, there are several problem libraries which contain problems submitted by participating institutions. Single institution problem libraries may be organized by assignment, section in the book, or topic. Some of these are of limited use to faculty outside the institution, although the libraries at University of Rochester and Union College are helpful. There is also the nation-wide Problem Library, organized by course, such as calculus, and by topic, such as differentiation, from which the faculty member can select problems. Many topics contain a number of problems from which to choose, although the number, quality and precision of problems vary, depending on the topic and source of the problems. In addition, the same problem may appear a number of times in the list if it has been used by different institutions who contribute to the same problem library. Also, some commands used in older WebWorK problems are no longer supported by newer versions of the software and will consequently produce errors when students attempt to work these problems. Problems from any of the problem libraries can easily be imported by the faculty member into a particular assignment by a couple of clicks of a mouse.

Certainly faculty new to WeBWorK would be well-advised not to invest a great deal of time writing their own problems from scratch. It is almost impossible, however, for a faculty member to completely avoid the programming issue altogether. More than likely, there will be problems here and there which the faculty member wishes to tweak and, from time to time, there will be problems which contain programming errors that have to be repaired. Our institution has appointed course coordinators to assist faculty with these issues. The WeBWorK Administrator can also be called in to assist in these situations. It is also a good idea (and more efficient) for the faculty member to learn something about how to deal with these issues him or herself. WeBWorK problems are written in Perl and utilize a number of pre-written macros and LaTeX commands. Consequently, some familiarity with these is very valuable. One effective way to "write" new problems, for example, is to edit a problem in a problem library that is structured similar to the desired problem. It is important, however, to carefully think about any edits. Common mistakes include using a range for parameters that produces an error, such as division by zero or an even root of a negative number, and programming the format of the answers incorrectly. As with most new technologies, an energetic faculty member can teach him- or herself quite a bit. Useful strategies at our institution have included utilizing local expertise, attending the on-campus faculty orientation session each term, and exploring helpful online resources, including the MAA WeBWorK Documentation and Discussion Website at http://www.maa.org/webwork, the WeBWorK Wiki at http://www.webwork.maa.org/moodle, the University of Rochester WeBWorK site at http://webwork.rochester.edu/docs/, and the NASA site on Help with LaTeX Commands at http://www.giss.nasa.gov/tools/latex/ltx-2.html.

There are some miscellaneous minor issues related to using WeBWorK. These include the fact that some problem types are challenging to program using WeBWorK, so on occasion the instructor may still wish to assign problems out of the textbook. Also, with unlimited attempts on each problem, students sometimes become frustrated with a problem that they cannot successfully work and, after a certain number of attempts, may start guessing answers. If answers are whole numbers, for example, this technique is more likely to be successful. Based on anecdotal feedback from students, however, this strategy can be successful, though not often, on a variety of problems. Lastly, WeBWorK only tells students if their answer is correct or incorrect. It doesn't provide any information as to where their error may be, it doesn't include example problems or show any fully worked problems, and it doesn't grade student work (only answers). It is possible, however, to code full solutions or even hints in WeBWorK, although most problems in the WeBWorK problem libraries are not written with these features. Thoughtful problem design can also address the issue of requesting only the answer by asking several intermediate questions which require the complete solution.

A Comparison of Homework, Test and Course Grades with and without WeBWorK

One goal of this study is to increase student mastery of course content. To determine if use of WeBWorK does in fact affect student mastery in calculus, two groups of Calculus I students and their performance were analyzed. Their homework, test, and course grades were examined in both a Calculus I course taught by Instructor A that exclusively utilized WeBWorK for homework assignments and in a Calculus I course (also taught by Instructor A) that exclusively utilized textbook homework assignments with a grader (with all other course aspects being identical). In addition, the second group of Calculus I students were followed in Calculus II (still utilizing textbook homework assignments and taught by Instructor A) and in Calculus III (utilizing WeBWorK assigned on a weekly basis for homework and taught by Instructor B).

Louisiana Tech University is on a quarter calendar with semester hours. Terms are 10-weeks long and the maximum full-time student course load is 12 semester credit hours. The calculus sequence consists of five three-semester hour courses. Calculus I consists of algebra and trigonometry topics (approximately 2/3 of the course) and calculus topics (limits and conceptual development of derivative as a limit, up to but not including, the derivative rules). Calculus II consists of differential calculus, starting with derivative rules, applications of differentiation and antiderivatives leading up to, but not including, integration. Calculus III covers integral calculus, including limits of Riemann sums, integration techniques, and applications of integration, with a short module on solution of separable and linear first-order homogeneous and inhomogeneous differential equations.

Calculus I and II utilize a web-based tutorial program called ALEKS, developed at University of California-Irvine and marketed by McGraw-Hill[2]. Students log-on to ALEKS and take an initial assessment (covering pre-requisite algebra and trig content needs for Calculus I). Students then spend time working on only those topics which they have not mastered. Students are prompted to take periodic assessments to assist ALEKS in accurately assessing their content mastery. In Calculus I and II, Instructor A requires students to take the initial ALEKS assessment during the first week of the term. Students must then spend at least 3 hours and make at least 6% progress each week of the term in order to receive credit for ALEKS usage. ALEKS usage counts for 4% of the overall course grade in Instructor A's Calculus I and II courses.

In previous studies of students at Louisiana Tech University, a strong relationship has been established between a students' initial ALEKS assessment score and their preparedness for Calculus I[3]. Other studies, however, have suggested that incorporating the initial ALEKS assessment score into the Math Placement procedure (currently based on Math ACT score) at Louisiana Tech University would not serve to substantially improve success in Calculus I[4]. Initial ALEKS assessment scores were used for this study, along with Math ACT scores, GPA and homework averages, to account for variability in student preparedness and performance.

Data Analysis

Data from 37 Calculus I students from Fall 2006 and 35 Calculus I students from Fall 2007 were examined. Both classes were designated for honors engineering freshman students. Note that while WeBWorK is being used in all calculus classes, as well as in a number of courses below the calculus level, the authors' experience with WeBWorK has been in the honors courses, which they teach. Both classes were taught by Instructor A, with all aspects of the Fall 2007 Calculus I course identical to the Fall 2006 Calculus I course, with the exception of daily WeBWorK homework assignments in Fall 2007 lieu of daily textbook homework assignments graded by a paper grader in Fall 2006. For each student, the following data was collected: highest Math ACT score, initial ALEKS assessment score, GPA at the end of the Fall 2007 term, and numerical final grade for exams, homework and the course. The following table summarizes the class averages for each of these items (the range for ACT scores is 0 to 36; the range for GPA is 0 to 4.0; the range for initial ALEKS Assessment Scores and Course Grades is 0 to 100):

	Class Average on Math ACT	Class Average on Initial ALEKS Assessment Score	Class Average GPA	Class Average Course Grade
Calculus I Fall 2006	29.972	22.270	3.3096	86.006
Calculus I Fall 2007	31.294	41.800	3.4592	82.179

Course load (number of semester credit hours carried each term) was also initially considered, but since these students enroll as cohorts in the same mathematics, engineering and science (chemistry or physics) sections, there was almost no variability in their course load. Consequently, course load was not included in the analysis. Note that the average Initial ALEKS Assessment Score, which indicates proficiency with prerequisite algebra and trigonometry topics, for the Fall 2007 Class was nearly double that of the Fall 2006 Class and the average Math ACT for the Fall 2007 class was slightly more than 1 point higher than that of the Fall 2006 class. However, the class average for Calculus I was approximately four points lower for the Fall 2007 class than for the Fall 2006 class.

The data for the Fall 2006 and Fall 2007 Calculus I classes was analyzed using a covariance analysis, comparing course grades in Calculus I after adjusting for the effects of the initial ALEKS assessment score, Math ACT score and GPA. The goal was to determine if there was a statistically significant difference in course grades between the two classes (Fall 2006 using textbook homework assignments and Fall 2007 using WeBWorK homework assignments), after controlling for the variables of class (Fall 2006 versus Fall 2007), Math ACT, GPA and Initial ALEKS Assessment Score. Math ACT scores were not significant, so they were dropped and the analysis was re-run without considering the effect of Math ACT. The analysis revealed that the Fall 2007 Calculus I class had statistically significantly higher Initial ALEKS Assessment Scores and GPAs, but the Fall 2006 class had statistically significantly higher course grades. Thus this data does not suggest that use of web-based homework improved students mastery of course content.

A regression analysis was also performed, comparing the Fall 2006 and Fall 2007 Calculus I classes. This analysis showed a statistically significant difference in the variables of Initial

ALEKS Assessment Scores, GPAs and class (Fall 2006 versus Fall 2007), with p-values of 0.0239, 0.0001 and 0.0020 respectively. Again, the Math ACT was dropped after an initial run revealed that it was not significant. Together, the class (Fall 2006 versus Fall 2007), Initial ALEKS Assessment Score and GPA account for approximately 45% of the variability in course grades. This means approximately half of the variability in course grade is attributable to other factors, such as individual effort. As before, the correlation between class (Fall 2006 and Fall 2007) and course grade is negative. That is, the Fall 2006 class had higher grades in Calculus I than did the Fall 2007 class, even though the Fall 2007 class had higher Initial ALEKS Assessment scores and higher GPA. Again, this data does not suggest that use of web-based homework improved students mastery of course content.

The Initial ALEKS Assessment and Math ACT score both measure incoming preparation of students. Neither measures level of effort exerted by students in the Calculus I course. While effort is a difficult quantity to measure, successful completion of homework assignments does represent some measure of effort on the part of the student. Consequently, the statistical tests were re-run, including the homework averages, to determine if they might be a contributing factor. These tests, however, showed that the homework averages were not a significant variable. Consequently, we are only able to account for approximately 45% of the variability in course grade in Calculus I with Initial ALEKS Assessment scores, GPA and class (Fall 2006 versus Fall 2007).

Given that the Fall 2007 Calculus I class appears to have been better prepared (higher Initial ALEKS Assessment scores and higher Math ACT scores) than the Fall 2006 Calculus I class, it is interesting that their performance in Calculus I was worse. One possibility is that the web-based homework system was not as effective as assignments out of the textbook in helping the students master the calculus concepts. Students can often enter their answers in an unsimplified form in WeBWorK, which requires less work and does not require them to use all of their algebra and trigonometry skills. With unlimited opportunities to answer each question before the due date, students may be guessing answers correctly more often than instructors realize. Students could also be receiving more help from other students than is anticipated by instructors.

Another theory relates to performance on the Initial ALEKS Assessment. Most students in Calculus I have already seen the majority of the content in Calculus I in high school, although studies, such as the TIMSS studies[5], indicate that content in high school textbooks is mostly low level. Consequently, students often feel that they already know the course material and don't need to study, even though the Calculus I material is at a more elevated level. Anectdotal observations by instructors suggest that, when students perform poorly on the Initial ALEKS Assessment in the first week of the term, they quickly become convinced that they need to attend class, take good notes and pay more attention to their homework. Thus, the Initial ALEKS Assessment may be serving as an early and effective wake-up call for students in the first week of the term, when they can easily get caught up. It is theorized that this may be one reason that ALEKS usage in Calculus I correlates strongly with successful performance in the entire two-year calculus and differential equations sequence[6]. Students in the Fall 2007 Calculus I class scored much higher on their Initial ALEKS Assessment than did their counterparts in Fall 2006. Consequently, the Initial ALEKS Assessment may not have communicated to them a need to adjust their study habits, as it may have done for their Fall 2006 counterparts. Test grades for the two classes show that the class average on Test I in Calculus I for the Fall 2006 class was 87%, versus 79% for the Fall 2007 class. Since Test 1 comes at the end of the first third of the term, students who do not realize how much they need to study until after the first test may not be as successful in catching up as students who find this out within the first week of class An analysis of variance run on the scores for Test 1 for the Fall 2006 class and the Fall 2007 class revealed that the difference between the scores of the two classes on Test 1 was, in fact, highly significant, with a p-value of 0.0069 for the F-test. Other test averages for the two classes show much less variation:

Fall 2006:	Test 2 – 81	Test 3 – 86	Test 4 – 82	Comprehensive Final Exam - 85
Fall 2007:	Test 2 – 83	Test 3 – 83	Test 4 – 80	Comprehensive Final Exam - 84

Hence, the data may be suggesting an inverse relationship between preparation for Calculus I and overall course performance in Calculus I.

In addition to comparing Fall 2006 and Fall 2007 Calculus I classes, Calculus I students from Fall 2006 were followed throughout the freshman year in Calculus I and II (both taught by Instructor A and both utilizing textbook homework assignments graded by a student paper grader) and Calculus III (taught by Instructor B and utilizing weekly WeBWorK assignments for homework).

Paired sample t-tests were run on the data to determine if there was a significant difference in performance in the course (course grade). Performance in Calculus I (Instructor A and textbook-based homework assignments graded by a paper grader) was compared to performance in Calculus III (Instructor B and WeBWorK homework assignments). While the Calculus I grades were slightly higher than those in Calculus III, the difference was not significant. For these same students, performance in Calculus II (Instructor A and textbook-based homework assignments) was compared to performance in Calculus III (Instructor B and WeBWorK homework assignments). This time, the grades were higher in Calculus III than in Calculus II, but again the difference was not significant. Consequently, these analyses offer no insight into the effect of textbook versus online homework.

Conclusion

This paper looks at the challenges and opportunities of using online homework in the calculus sequence, along with the potential effect on student performance. The goals of this project are to 1) increase student mastery of course content, 2) increase individual student accountability on out-of-class assignments, and 3) more effectively utilize the program budget to enhance student retention and success in mathematics. Statistical analysis of the data did not suggest that use of online homework assists in student mastery of course content. Statistically significant differences in the preparation of the two Calculus I classes compared in this study, and other variables (such as level of effort), may be contributing to differences in performances and/or masking the effect of the different homework systems. The use of individually parametrized assignments in online homework does have the potential to increase individual student accountability by decreasing the likelihood and ease of copying another student's homework.

The online homework also provides the opportunity to use the program budget to support other student support services, such as Supplemental Instruction.

To shed further light on this subject, it would be helpful to gather additional data, perhaps using non-honors sections of Calculus I, focusing on higher level calculus courses, or comparing Calculus I classes with more similar backgrounds. It might also be helpful to examine other ways to measure student effort, such as student logs of time spent studying, to better understand its role in mastery of course content.

Bibliography

1. WeBWorK: Online homework for math and science, http://webwork.maa.org/moodle/

2. ALEKS, Math for Colleges and Universities, General Information, http://www.highedmath.aleks.com/about/Welcome-ENGLISH.html.

3. J.P. Carpenter, R.E. Hanna, "Predicting Student Preparedness in Calculus," Proceedings of the 2006 American Society for Engineering Education Annual Conference, June 2006.

4. J.P. Carpenter, R.E. Hanna, "Predicting Student Success in Calculus," Proceedings of the 2007 American Society for Engineering Education Conference, June 2007.

5. Trends in International Mathematics and Science Study (TIMSS), http://nces.ed.gov/timss/

6. J.P. Carpenter, R.E. Hanna, "Using Web-Based Tutorial Software to Increase Retention and Success in Mathematics," Proceedings of the 2004 American Society for Engineering Education Annual Conference, June 2004.