

STUDENT LEARNING USING ONLINE HOMEWORK IN MATHEMATICS

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INTRODUCTION

This preliminary report describes initial results studying the effectiveness of web-based homework in mathematics courses at CSU Monterey Bay (CSUMB). The system captures large amounts of data as students use the system, such as the number of attempts, time accessed, time graded, access to help tutorials and student answers to individual problems. This data is being mined in an attempt to try understand what students are actually learning using the system using techniques similar to those in [5, 6]. In particular, this paper focuses on issues of implementation and how students interact with the system. The eventual research goal of this study is to ascertain best practices for implementing mathematics online homework and to better understand how students learn mathematics using online homework.

BACKGROUND

Implementation of online homework and assessment in undergraduate mathematics courses is becoming more prevalent. For example, WebAssign claims their online homework is used at 335 universities and colleges in the United States [4]. Another example, the ALEKS web-based assessment and tutoring system has been contracted by the California State University (CSU) system to provide an online tutorial that maps to the CSU's Entry Level Math (ELM) exam [1]. The ELM is required to be taken by all incoming CSU freshman and CSU system enrolls 417,000 students [2]. Moreover, most lower-division mathematics textbook publishers offer some sort of online homework option with their texts. A natural question to ask is do such online systems actually improve student learning of mathematics and if so, how? Currently, there is limited research addressing this question and demand for such research is likely to increase as the use of online homework becomes more widespread. Several studies indicate that the use of web-based homework problems can improve performance in some lower-division mathematics courses, see [7, 9, 10], but there is little research on how students actually learn using online systems in mathematics. Bennett, Lawrence, Neumann, Verbych, and Warren [6] and Verbych [8] were able to detect conceptual learning from analysis of

online homework data. Also, Bennett et al. [6] were further able to show that transfer of learning between classes could be identified through the analysis of online homework data. Note that only measurements of overall class performance and not of individual students were obtained in [6].

THE ONLINE HOMEWORK SYSTEM

With the input of other faculty members of the Mathematics Department at CSUMB, the author developed online homework for several mathematics courses with an in-house system. The system was created using a combination of PHP and Java with a MySQL database and is based on a design by Andrew G. Bennett at Kansas State University (cf. [5]). So far, CSUMB has used this web-based homework system with a variety of instructors for the following courses: Mathematics for Elementary School Teachers I and II (since Fall 2005), Pre-Calculus (since Spring 2006), Calculus II (since Fall 2007) and Introduction to Statistics (Fall 2006).

The content of the online system is customized to coincide with the subject matter already taught in the course and is designed to handle aspects of the content that can be graded by a computer, such as procedures and calculations. The goal is to have instructors spend more time grading written work focused on conceptual understanding, such as open-ended problems, and let the online homework grade the more procedural oriented problems.

The system can handle multiple answering styles, including multiple choice, numerical, graphical, and algebraic input. The system also features a two-step grading process, immediate feedback, the opportunity to complete the homework multiple times before the assignment's deadline, and detailed solutions to problems the student did incorrectly. For each attempt, the system initially marks submitted answers correct or incorrect without the answer and the student gets one chance to fix any wrong answers. This allows students to spend time investigating how they worked missed problems and to figure out what they did wrong. Students may attempt each assignment as many times as they would like before it is due and the maximum score over all attempts is the grade the student receives for that assignment. The program generates similar, but different, problems for each attempt of an assignment and for each student. Also, students have the opportunity to view detailed solutions of the problems they missed. These tutorials directly correspond to and reinforce the methods covered by the instructor and the textbook.

There are also a few advantages the online homework has over written homework. The online homework provides instant feedback on student work whereas a student may not receive feedback on written homework for a week or more. Furthermore, the online homework allows students to redo the assignment until they get the score they want. An online homework system is also capable providing students a wide variety of different examples on the same topic.

INITIAL RESULTS

Student Reaction. Most students surveyed feel the online homework helped them learn the course material and are pleased that the course uses an online homework system. The most frequent complaints were the following: correct answers marked wrong because the answer was input incorrectly, must redo whole assignment and not just problems answered incorrectly, and they did not feel the online homework related to class material. The frequency of the last complaint has dropped considerably in recent semesters due to the fact that instructors have been spending more classroom time addressing material given in the online homework and including more online type problems in exams and quizzes. Many students initially perceive the online homework as busywork and it is important the instructor demonstrates how the online homework relates to the subject matter in the classroom.

Surveys done on students who have used the system indicate they felt they benefited from using the online homework. Since Fall 2005, 72% of students believed they learned the material covered in the online homework more thoroughly because they could keep doing the assignments until they mastered the material. Also, 83% of those surveyed believed that they were able to learn how to do problems they missed by looking at the detailed solutions provided by the system and two-thirds of students agreed that their course should continue to have online homework. The most desirable aspects cited by students are the two-step grading system, multiple attempts, availability, detailed help on missed problems and immediate feedback.

How Students Use the system. The system collects a great deal of data as students complete their online homework. The data the system collects includes the number of attempts submitted for each assignment, time accessed, time graded, access to detailed solutions for missed problems and answers to individual problems.

Preliminary analysis of the data indicates that the average score over all assignments is over 80% or 90% depending on the course. Students tend to work to attain a desired score, then quit. However, students

who consistently make greater than 4 or 5 attempts per assignments do not do well in the course. About half of the students start their first attempt on the due date; assignments are usually due at 11:59pm on the due date. Students who consistently start assignments earlier, tend to earn higher course grades.

Assignment	# of Students	Avg. Attempts	Avg. Score	Perfect Score
1	117	1.8889	9.14	53
2	121	1.6529	9.56	97
3	106	1.9623	8.60	43
4	103	2.4563	8.39	46
5	115	1.7652	9.27	86
6	101	1.9802	9.04	66

TABLE 1. Pre-calculus online homework from Spring 2008 semester accessed March 8, 2008 at 9:47 pm

A particularly noteworthy issue is students inputting formulas for answers. For example, a problem in a pre-calculus online assignment requires a student to find the formula for an exponential function f given that $f(0) = -4$ and $f(-1) = -4/3$. The answer in standard mathematical type would be $-4(3)^x$, but the student would enter the answer in computer readable form as $-4(3)^x$. Notice in Table 1 that highest number of average attempts occurs in assignment 4, which happens to be the only online assignment listed in the table requiring this type of input. In Calculus II, the issue is more problematic because there are much more complicated answers to enter, hence, the number of attempts for these types of assignments averages around 4.0. If answers are too difficult to input, students will give up and settle for a lower score. Another issue that occurs is rounding errors. Sometimes a problem will require a decimal approximation within a stated tolerance, say $\delta = 0.01$. Many students complete their calculations rounding to 0.01 in each step of their solution and their final answer ends up outside the tolerance.

CONCLUSIONS

Initial results indicate several implications for implementation. Online homework should be tightly integrated into the course. Students tend to initially perceive online homework as busywork. It is important for students to view online homework as tool to help them learn the subject matter. If a student views the online homework as a task to done only to receive a better grade, they will not take the time to try to understand the material when their answers are marked wrong. The instructor needs to explicitly communicate how the online homework supports course learning outcomes and should be very deliberate

about what material goes into the online homework. Furthermore, any content in the online homework should be included in any summative assessment, such as exams and quizzes, just as written homework is.

Ideas and procedures specific to the online homework need to be addressed in the classroom. For example, in CSUMB's Calculus II course, the first lab is devoted to learning how to enter formulas in the system and how the computer parses student answers. This has led to a significant reduction in the number of student complaints regarding correct answers getting marked incorrect due to input error. Also, there needs to be a system in place for students and instructors to receive technical support. It's important to not let technical issues prevent student or instructor access to the system. There also needs to be a clearly communicated policy in place for student redress when assignments are not completed in time because of technical issues. It is also important for students to assess the system. Numerous improvements to the system at CSUMB have been made due to student feedback of the system.

A last note on implementation. The online homework is not designed to replace all homework or reduce workload for instructor. Students submit only their answers into the online homework, which means that the instructor cannot view the work the student did to arrive at the answer. If online homework were to replace all homework, there would be little opportunity for an instructor to assess gaps or misconceptions in understanding. Although computer grading does reduce instructor workload, the time saved gets taken up in implementation issues described above. However, online homework does give the opportunity to do more with less, such as letting students submit multiple attempts for grading.

In terms of the larger research question, how do students learn using an online homework system?, further work needs to be done. Currently there is work finding patterns in the data that will distinguish students who pass the course versus those that fail. The idea is to establish an early warning system for students who might be failing and have the course instructor attempt to get them back on track to success. There is also work on understanding the types of learners for which the online homework is most effective and how the system can be designed to suit more types of learners. Additionally, student answers are being analyzed to see if they can provide clues to identifying misconceptions about the material. Also, the problems in the online homework are being restructured and classified by their cognitive complexity, which refers to the cognitive demand associated with a problem [3]. The hope is to better parse student understanding using demands on their thinking as a measure.

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