Authentic Online Assessment with the Maple TA™ Electronic Homework System in Multiple Sections of College Algebra and Trigonometry

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In Spring 2003, select sections of the course began to use an electronic homework system called *eGrade*. It was administrated by the publisher of the textbook for the course, and students could purchase a code to get access to the system for around $15. Faculty who used it found it relatively simple to use, but the question bank was very limited. Over the years, I learned how to write questions and solutions which were algorithmic, i.e., each time the student sees the question, different values appear. While it was incredibly time consuming to supplement the question bank, there was a payoff. Students repeatedly commented how the feedback was immediate and helpful, and the faculty appreciated that they did not have to grade stacks of homework papers. By Spring 2007, almost all instructors in sections of MA 153, MA 154, and MA 159 were voluntarily requiring *eGrade*. Unfortunately, that was the last semester. The publisher eliminated *eGrade* and introduced a new, albeit inferior system called *WileyPlus*. The cost to the student quadrupled at the price of $60 per semester, the learning curve was steeper, and many features that faculty and students appreciated in *eGrade* were not available in *WileyPlus*.

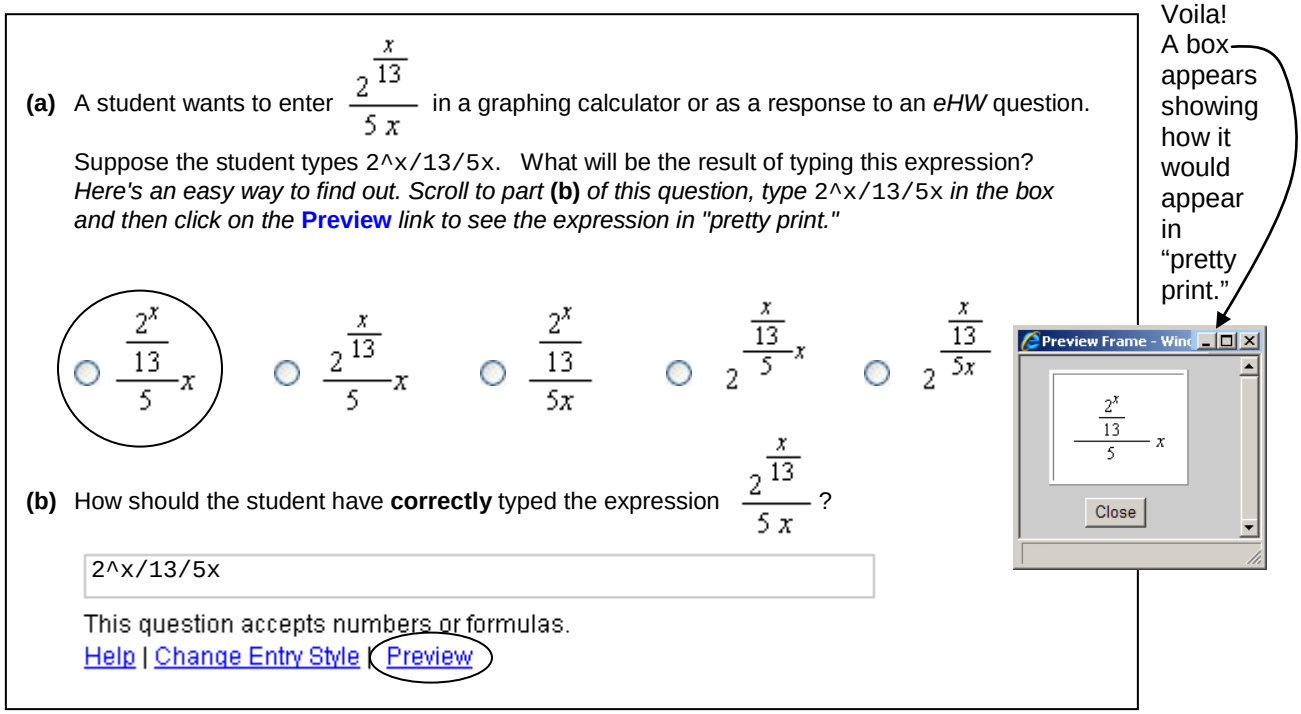
We explored a variety of replacement options[1] and found *Maple TA* (**www.maplesoft.com/**) to offer exactly what we needed. Students do not need special software or a home computer to use it. They simply get on the Internet from any Web-access point, and it is available 24-7. It is also affordable. The access code for Maple TA is only $17.75[2], which is used to recoup the cost of the site license. It also shares the same architecture as *eGrade*, so I already knew how to write the source code to author my own questions and could use some of the questions banks I had previously authored. *Maple TA* supported authentic assessment more than any other electronic homework system available at the time.

Authentic assessment should prevent situations where test takers who don't understand the material still do well on tests. One way to control this is by writing questions which are not only multiple-choice, but constructed response and algorithmic (where a portion of the numbers in the question and in the answer change each time). Yet even here, a savvy student can sometimes crack the code and predict what the answer should be after repeated trials. A better way is to use a group of problems that are consistent in content and difficulty and have the software choose randomly one question from the group for each assignment. *Maple TA* makes it easy for an assignment to use these "template questions", which are necessary to make online homework as useful as possible to students so they learn the material.

Authentic assessment should measure what it intends to measure. Students who know how to do the questions should get a good score. While the syntax for entering equations is the same as on a graphing calculator (which is required and integrated into the curriculum), students do become legitimately frustrated when their mathematics is correct, but they miss the problem because they enter the answer in the computer incorrectly. *Maple TA* has a Preview Feature which can minimize this, but many students are not aware of it. Missing questions because of small mistakes also frustrates students, but this can foster the habit of checking one's work. To reduce this frustration, students receive a handout on the first day of class which shows them how to use the Preview feature. They then must complete eHW #0 which assesses if they understand Maple TA and teaches them how to use it if they don't. On the next page is part of the handout given to students which shows a question from eHW #0.

Using the Preview Option in Responses

Use the **Preview** option to view your response as a typeset mathematics expression. **Preview** demonstrates how the system interprets your entry (inspecting it for misplaced parentheses and other unintended keystrokes). For example, in the following question, if a student types `2^x/13/5x` in the box and clicks, on **Preview,** then,



The student can determine that the first response is the answer to part **(a)**. To answer part **(b)**, the student can delete `2^x/13/5x` and use **Preview** to check that `2^(x/13)/(5x)` correctly gives the desired expression.

A symbol palette is also available if you click on **Change Entry Style** and select **Symbol Mode**, but this slows the system down considerably, especially if you are using a dial-up connection.

In this course, understanding the correct use of parentheses and order of operations is vitally important. The **Preview** tool in *eHW* can help you hone this skill by giving you immediate feedback.

Whenever appropriate, the questions that I wrote contained suggestions for checking one's work using the graphing calculator. This can also help lower frustration, since there is no partial credit in grading.

In addition to writing material for students, I wrote brief user guides for faculty so that even the most "technophobic" instructor can easily use Maple T.A. Once a set of assignments is created, the instructor can inherit them and use them as is. They need only learn a small number of technological tasks: how to copy an inherited assignment and change the settings (due date, whether it is visible/invisible to students, if it is for homework or for practice), how to download the assignment scores, and, optionally, how to change a grade in case the computer marks an answer incorrect when a human grader would not. In the latter case, most faculty kept a grade book external to Maple TA and manually changed it there. This was handled at a special session at the annual Fall Orientation, or, handled one by one if needed. In addition, I was given a course release to provide personal technical support to any faculty in need.

Study Design

I was primarily interested in the answers to these two questions:

- Do graded eHW assignments help students learn the material as effectively as graded paper and pencil assignments?
- Which kind of assignments do students like better, eHW or graded paper and pencil assignments? Why?

Although graded electronic homework was used in all face-to-face sections of MA 153 in Fall 2008, I narrowed my data collection to two sections of MA 153 and two sections of MA 154 where both electronic homework and graded paper and pencil would be used. The two sections of MA 153 were taught by the same instructor who had taught the course before but never using *Maple TA*. He was skeptical about the efficacy of electronic instructional interfaces due to past experiences as a student where its benefit did not outweigh the level of frustration. I taught the two sections of MA 154.

I was interested in how each kind of homework method, eHW and WR, would help students meet a set of student learning objectives. These learning objectives were chosen in consultation with Doug Townsend, associate chair. Our hope was to not only include objectives that I was interested in, but those of other faculty for whom this course is important.

MA 153: *College Algebra and Trigonometry I*

1. Students will choose the appropriate procedure and create a formula which models given **exponential** data.
   Level 1: Data is consecutive (each input is 1 unit apart) contains a *y*-intercept.
   Level 2: Data is not consecutive and contains a *y*-intercept.
   Level 3: Data is consecutive and does not contains a *y*-intercept.
   Level 4: Data is not consecutive and does not contains a *y*-intercept.
   Level 5: Applied problems which require this objective.

2. Given data which can be modeled by a **power function**, students will choose the appropriate procedure (requiring the use of logarithms) and create a possible formula.
   Level 1: One of the inputs is the value 1 and the power can be found by inspection or trial.
   Level 2: One of the inputs is the value 1 and logarithms must be used to find the power.
   Level 3: None of the inputs is the value 1 and the power can be found by inspection or trial.
   Level 4: None of the inputs is the value 1 and logarithms must be used to find the power.
   Level 5: Applied problems which require this objective.

These earning objectives reflect higher order thinking skills (involving choosing and creating) which are at the top of Bloom's Taxonomy, yet cannot be achieved without mastery of lower order skills (including taking *n*th roots of both sides of an equation, eliminating a variable through substitution, applying elementary laws of exponents, and using properties of logarithms to solve an exponential equation). Logarithms are notorious in *College Algebra* and have been since the beginning of time. Both objectives require choosing from four different procedures, i.e determining what to do at the appropriate level (1-4). Both objectives also lend themselves to rich applications.

MA 154: *College Algebra and Trigonometry II*

1. Students will, over a given interval, solve a **simple trigonometric equation** of the form $\sin\theta = k$ or $\cos\theta = k$, reporting the exact value(s) of the angle θ in radians.
   Level 1: Any solutions to the equation correspond to points on the unit circle which fall on the *x*-or *y*-axis, i.e. solve $\cos\theta = 0$. The sketch of a right triangle is not required.
   Level 2: The solution to the equation leads to the sketch of a right triangle, i.e., $\sin\theta = \frac{1}{2}$.

2. Students will choose the appropriate procedure to create a formula of the graph of a **sinusoidal function.**
   Level 1: The graph of the function can be written as a phase shift of a multiple of $\frac{\pi}{2}$,
   i.e, the formula is of the form $y = A\sin Bx + k$ or $y = A\cos Bx + k$ for parameters *A*, *B*, and *k*.
   Level 2: The graph of the function can be written as a phase shift which is not a multiple of $\frac{\pi}{2}$.
   i.e, the formula can be written in the form $y = A\sin(B(x-h)) + k$ or $A\cos(B(x-h)) + k$.

3. Students will choose the correct trigonometric identity to **simplify a trigonometric expression** which may lead to compound fractions. For example, simplify $\tan x / \sec x$.

4. Students will choose an appropriate trigonometric identity to **solve a trigonometric equation** over a given interval and report the exact value(s) of the angle θ in radians.
   Level 1: The equation can be solved by removing a greatest common factor.
   Level 2: The equation requires solving a trinomial quadratic equation which must be factored.

These objectives are listed in order of difficulty. The first learning objective is required in order to achieve the last objective, which requires factoring a trinomial, a skill almost as notorious as logarithms. The second learning objective requires students to choose whether to model the function with an inverted or non-inverted cosine or sine function and find parameters so that the formula has the same amplitude, vertical and horizontal shift and period as the given graph. If the phase shift of the graph is not a multiple of $\frac{\pi}{2}$, the task is much more difficult. The third learning objective involves the equally challenging manipulation of compound fractions.

To form a basis for comparison, students in one section of the course were assigned eHW to help them learn half of the learning objectives, while students in the other section were assigned graded paper and pencil written (WR) homework. For the other half of the objectives, the roles were switched, so that students in both sections experienced some use of eHW and WR homework. Students in the paired sections were similar in mathematical background, as measured by a quiz on prerequisite skills given the first week of class. Paired sections received the same notes, in-class activities, quizzes, tests, final exam, and the same eHW and WR homework assignments whenever additional course objectives not measured by this study were addressed. Student performance on embedded questions on the tests and the final exam were evaluated to assess how well students learned the targeted objectives. If a student did not complete any eHW or WR assignment on that objective, their performance was not included when calculating the percent successful. All exam questions used in the study were graded by third party who had no idea which students were in which group.

After each chapter exam, students in the four sections were given a minute paper[3] to elicit unprompted feedback, asking them to share what has helped them most and what has helped them least. Once that was collected, they were asked to rate each kind of homework method using a five-point scale, making it possible to calculate a total numerical value from all of the responses. At the end of the semester, students were given a lengthier questionnaire asking them to report

how much time was spent on each kind of homework, whether they were happy with their performance, the effectiveness of the various components of the course, and more in-depth questions. To encourage honest feedback, these questionnaires were anonymous.

The cross-over design had several advantages. No section had any perceived advantage over the other. Students in each section took turns being the experimental group and the control group, yet they had no idea which role they were at any time; hence, there was no possibility of bias when they were asked to later rate the effectiveness of the kinds of assignments. If a set of students using one homework method outperformed those using the other, one could assume that they were simply better students. However, if on a similarly challenging task, this same set of students were then outperformed by the other set when the homework methods were switched, one can be more confident that it was not due to intellectual superiority but the homework method itself.

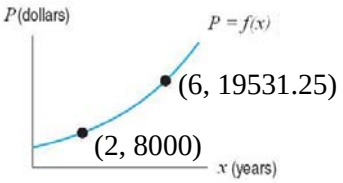
Results and Findings

MA 153 Learning Objective 1: "Students will choose the appropriate procedure and create a formula which models given exponential data."

For this learning objective, students were given a question almost identical to that shown below, only in multiple choice format. The format of the question appeared on a review for the exam. This is the most challenging kind of data set possible for this objective (Level 4), since students must first find the value of the parameter b in the formula $y = ab^x$, and then use that value to find the value of the parameter a.

The function $P = f(x)$ gives the balance, in dollars, of an investment in year x. In other words, $f(2) = \$8000$ and $f(6) = \$19{,}531.25$.
Find a formula for the function, assuming exponential growth.

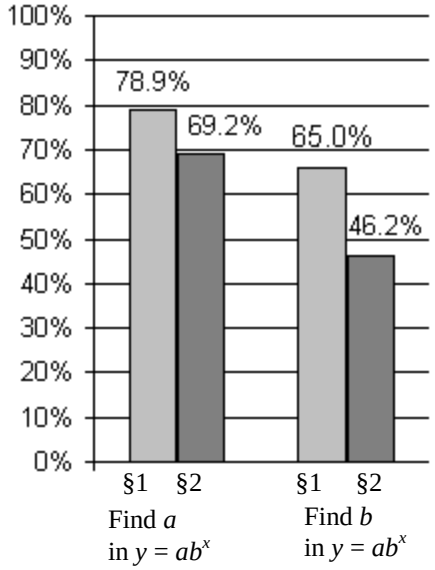
1. What is the initial balance?
2. What annual interest rate does the account pay?



The data below compares the performance on the final exam between the two student groups, which we will designate as Section 1 and Section 2. All 20 students in Section 1 completed eHW on this objective. As many as 78.9% correctly found the parameter a, while 65.0% correctly found the parameter b. Of the 14 students in Section 2, 13 completed WR assignments on this objective. While 69.2% of the 13 were successful in finding a, only 46.2% found b.

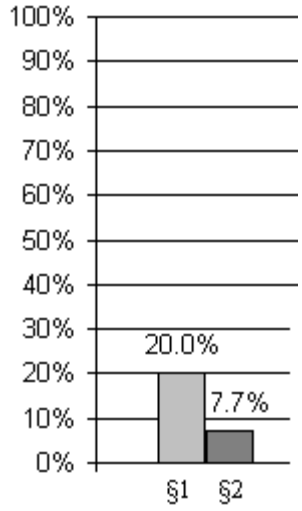
MA 153 Learning Objective 1 (Level 4):
Find the formula of an exponential function $y = ab^x$
(Data with nonconsecutive inputs and no y-intercept.)

MA 153 Objective 1	Find *a*	Find *b*
Section 1 (§1): eHW (*n*=20)	15/20=75.0%	13/20=65.0%
Section 2 (§2): WR (*n*=13)	9/13 = 69.2%	6/13 = 46.2%



How do students perform when asked to apply what they have learned, and use the skills in this objective to solve a problem that they have never seen before? On the same exam, students were asked to solve such an applied problem which involved creating an exponential model. The inputs were nonconsecutive, but the *y*-intercept was given. This question typically separates the A students from everyone else. Most students cower and leave it blank. It is open-ended, and graded by someone other than the instructor. As shown in the figure and table to the right, 20% of the students in Section 1 who used eHW that addressed exponential functions answered the question correctly, compared to only 7.7% of those in the WR group. We can conclude that the eHW students gained more confidence on their fundamental skills to attack the problem. This same exam tested the next learning objective concerning power functions.

MA 153 Learning Objective 1 (Levels 2 and Level 5):
Solve an applied problem which requires creation of an exponential model $y = ab^x$

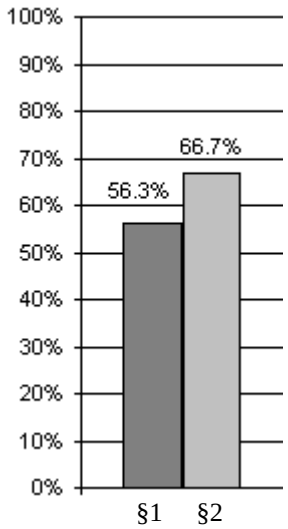


MA 153 Objective 1	Levels 2 and 5
Section 1 (§1): eHW (*n*=20)	4/20=20.0%
Section 2 (§2): WR (*n*=13)	1/13=7.7%

MA 153 Learning Objective 2: "Given data which can be modeled by a power function, students will choose the appropriate procedure (requiring the use of logarithms) and create a possible formula."

For this objective, the roles of the groups were switched. Section 1, which had used eHW on the previous objective over exponential functions and outperformed Section 2, had used WR assignments to learn power functions, while Section 2 was given eHW over power functions. This question was multiple choice. After determining the formula of the power function, students had to use the formula to find a value of *y* given a specific value of *x*.

MA 153 Learning Objective 2 (Level 2):
Find the formula of a power function $y = kx^p$ where $x = 1$ is present in the table and *p* must be found with logs.



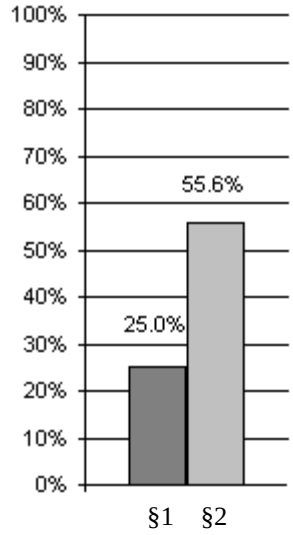
MA 153 Objective 2	**Level 2**
Section 1 (§1): WR (*n*=16)	9/16 =56.3%
Section 2 (§2): eHW (*n*=9)	6/9 =66.7%

Only 9 of the 14 students in Section 2 used eHW for this objective, while 16 of the 20 students in Section 1 completed WR assignments related to this task. These 9 who were outperformed by the other section now turned the tables: two thirds of them were successful, compared to little more than half of the 16 students.

How did these 9 eHW students fair on an applied power function problem of similar difficulty to the applied exponential problem, compared to these 16 WR students? The percent successful for the eHW group was more than twice the percent successful for the WR group. See the next page for the data. Again, this applied power function problem is highly missed, often left blank, and neither group has seen a similar problem prior to the test. The only instructional variable between the two groups is the kind of homework they received.

MA 153 Learning Objective 2
(Levels 4 and 5):
Solve an applied problem which requires creation of a power function model $y = kx^p$ where $x = 1$ is **not** present in the table and p must be found with logs.

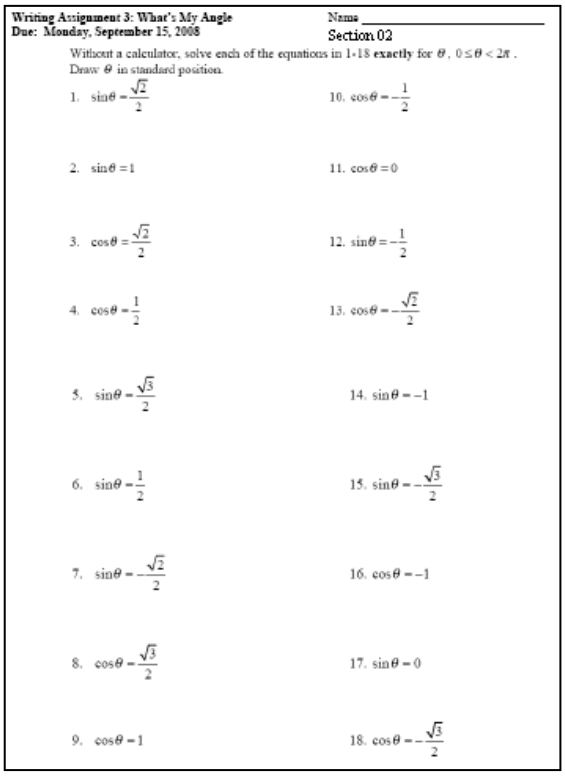
MA 153 Objective 2	Levels 4 and 5
Section 1: WR (n=16)	4/16 = 25.0%
Section 2: eHW (n=9)	5/9 = 55.6%



MA 154 Learning Objective 1: "Students will solve, over a given interval, a simple trigonometric equation of the form $\sin\theta = k$ or $\cos\theta = k$, reporting the exact value(s) of the angle θ in radians."

The two sections of MA 154 had enrollments of 35 (Section 1) and 30 (Section 2). Of the 35 students in Section 1, there were only 2 who did not complete the eHW related to this learning objective. (One of these students did no eHW at all throughout the course, and the other added the course after the eHW was due.) Of the 30 students in Section 2, there was 1 who did not complete the WR.

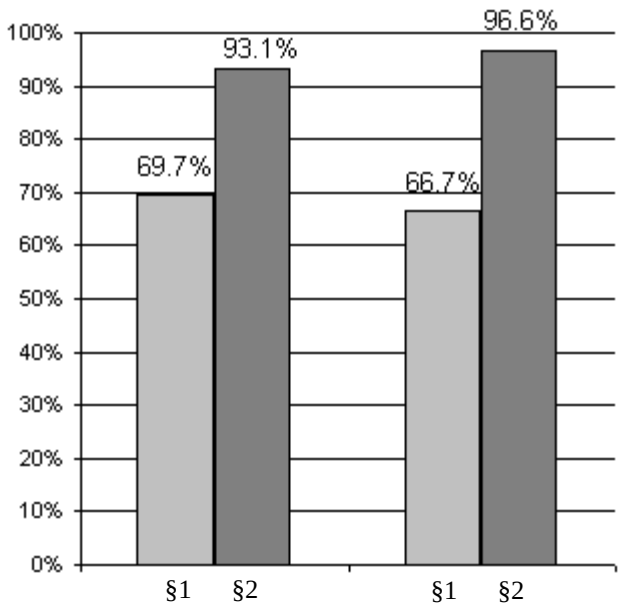
Although this is the easiest of the learning objectives in this study, it is not easily mastered by students. The solution requires conceptual understanding of the definition of the trigonometric functions and, if more than one solution exists, a visual sketch to find both. To the right is a reduced copy of the written homework assignment, and they encounter every exact value involving the sine or cosine. Eleven of the 18 questions require the construction of a triangle (Level 2), while the remaining 7 do not (Level 1). The eHW for this objective asks these same questions shown to the right, but students will not encounter all 18. It will pick from these 18 and show them 2 at a time. In addition, the eHW addresses other learning objectives in the course as well. Therefore, most students will not see all 18 possibilities unless they intentionally redo the assignment. I was not aware of this design flaw until after I collected the performance assessment data which follows. This is another testament to the value of a good assessment study!


Writing Assignment 3: What's My Angle Name _____
Due: Monday, September 15, 2008 Section 02

Without a calculator, solve each of the equations in 1-18 **exactly** for θ, $0 \le \theta < 2\pi$. Draw θ in standard position.

1. $\sin\theta = \frac{\sqrt{2}}{2}$
2. $\sin\theta = 1$
3. $\cos\theta = \frac{\sqrt{2}}{2}$
4. $\cos\theta = \frac{1}{2}$
5. $\sin\theta = \frac{\sqrt{3}}{2}$
6. $\sin\theta = \frac{1}{2}$
7. $\sin\theta = -\frac{\sqrt{2}}{2}$
8. $\cos\theta = \frac{\sqrt{3}}{2}$
9. $\cos\theta = 1$
10. $\cos\theta = -\frac{1}{2}$
11. $\cos\theta = 0$
12. $\sin\theta = -\frac{1}{2}$
13. $\cos\theta = -\frac{\sqrt{2}}{2}$
14. $\sin\theta = -1$
15. $\sin\theta = -\frac{\sqrt{3}}{2}$
16. $\cos\theta = -1$
17. $\sin\theta = 0$
18. $\cos\theta = -\frac{\sqrt{3}}{2}$

MA 154 Learning Objective 1
(Levels 1 and 2):
Solve a simple trigonometric equation over a given interval.



Level 1
Solve $\cos\theta = 0$
(No triangle needed)

Level 2
Solve $\sin\theta = 0.5$
(Right triangle needed)

MA 154 Learning Objective 1	Level 1	Level 2
Section 1: eHW (n=33)	23/33 =69.7%	22/33 =66.7%
Section 2: WR (n = 29)	27/29 =93.1%	28/29 =96.6%

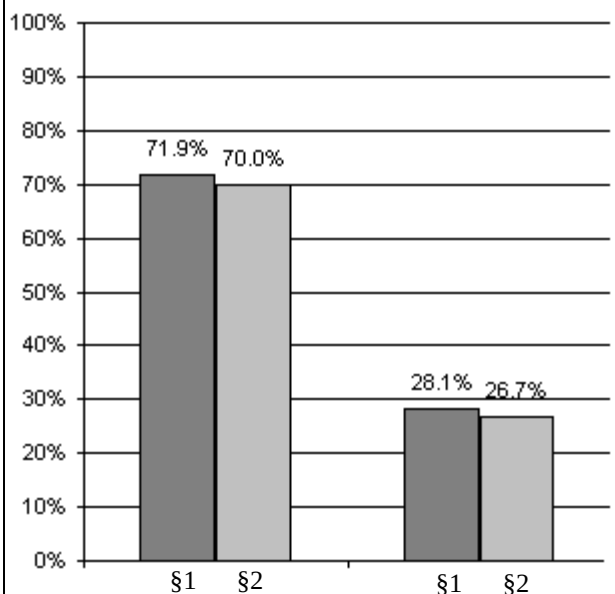
Section 2, using the written homework, outperformed Section 1. It is worth noting which section did better, since this topic returns in the fourth learning objective in this study. It is understandable that those using eHW did not perform as well, once I looked at how the assignment was designed. Essentially both groups performed about the same for each level.

MA 154 Learning Objective 2: "Students will choose the appropriate procedure to create a formula of the graph of a sinusoidal function**.**"

Of the 35 students in Section 1, there were 3 who did not complete the writing assignment on this objective. Of the 30 students in Section 2, all completed the related eHW. If they can't do Level 1, it is impossible to do Level 2. Here eHW and WR students faired just about the same.

MA 154 Learning Objective 2	Level 1	Level 2
Section 1: WR (n = 32)	23/32 =71.9%	9/32 = 28.1%
Section 2: eHW (n = 30)	21/30 = 70.0%	8/30 = 26.7%

MA 154 Learning Objective 2
(Levels 1 and 2):
Create a formula of the graph of a sinusoidal function.



Level 1
No phase shift required

Level 2
Phase shift required

This is actually encouraging. If eHW helps students just as much as WR, then this frees the instructor from all of that grading.

MA 154 Learning Objective 3: "Students will choose the correct trigonometric identity to **simplify a trigonometric expression** which may lead to compound fractions. "

Writing Assignment 4: Trig Identities Name _____
Due: Friday, October 10, 2008 (40 pts) Section 01

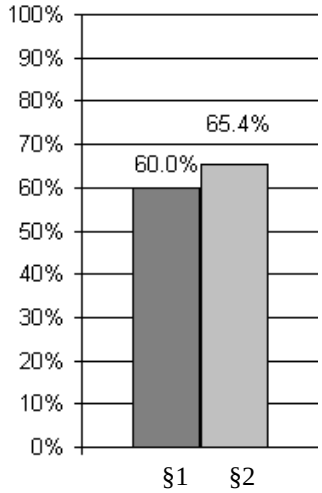
Reduce to a single term. Select from this list. Verify your claim. Attach work.

(4) 1. $\frac{\cos^2\theta}{\sin\theta}+\frac{1}{\csc\theta}$
(4) 2. $\frac{\sin^3\theta}{\cos\theta}+\sin\theta\cos\theta$
(4) 3. $\frac{1}{1-\cos\theta}+\frac{1}{1+\cos\theta}$
(4) 4. $\sin\theta\sec\theta$
(4) 5. $\tan\theta\cos\theta$
(4) 6. $\csc(-\theta)\tan(-\theta)$
(4) 7. $\tan\theta\sin\theta+\cos\theta$
(4) 8. $\frac{\sin\theta}{1-\cos\theta}-\frac{\sin\theta}{1+\cos\theta}$
(4) 9. $\frac{1-\cos\theta}{\sec\theta-1}$
(4) 10. $\sin\theta+\frac{\cot^2\theta}{\csc\theta}$

A. $\sin\theta$
B. $\cos\theta$
C. $\tan\theta$
D. $\csc\theta$
E. $\sec\theta$
F. $\cot\theta$
G. $2\cot\theta$
H. $2\cot^2\theta$
I. $2\csc\theta$
J. $2\csc^2\theta$
K. None of these

At this point in the semester, Section 1 now had 33 students, 3 of whom chose not to do the writing assignment, shown to the right. In this learning objective, manipulation with fractions rears its ugly head, and typically students learn how to do these by practicing as many as possible. Of the 29 students that were now enrolled in Section 2, only 3 did not do eHW. The eHW assignment was designed similar to that for the first learning objective, only the question bank was much broader. For this learning objective, students would get 1 of 38 different kinds of problems similar to those shown at the right. Because the problems were more difficult, students retook the assignment more frequently. They worked many more of these kinds of problems on this eHW than what students received on the eHW assignment for the first learning objective, which was also much easier (so less repeats). That may attribute to the slightly higher percent successful, as shown below, although we should conclude that the both kinds of homework performed fairly evenly. Although students find it frustrating that they must work the entire assignment instead of just redoing the one question that they missed, it is more beneficial to them. The assignments are kept short enough so that re-doing them is not a matter of busy work or an onerous task, if they understand the material. While the written assignment is only done once, there is the expectation that full work must be shown; eHW accepts only the final answer.

MA 154 Learning Objective 3
Simplify a trigonometric expression which may lead to compound fractions.



MA 154 Learning Objective 3	
Section 1: WR (n = 30)	18/30 =60%
Section 2: eHW (n = 26)	17/26 = 65.4%

MA 154 Learning Objective 4: "Students will choose an appropriate trigonometric identity to solve a trigonometric equation over a given interval and report the exact value(s) of the angle θ in radians."

In the first learning objective, students needed to solve a trigonometric equation. Recall that Section 1, which used eHW, did not perform as well as Section 2, which had a writing assignment that provided more practice. For this assignment, there were 33 students in Section 1, but 30 did the eHW assignment. Of the 29 students in Section 2, there were as many as 10 students who did not hand in the written assignment that is shown to the right. This was a very challenging WR assignment, so some students gave up before even starting.

Writing Assignment 4: Trig Equations
Due: Friday, October 24, 2008 (40 pts)

Name _____
Section 02

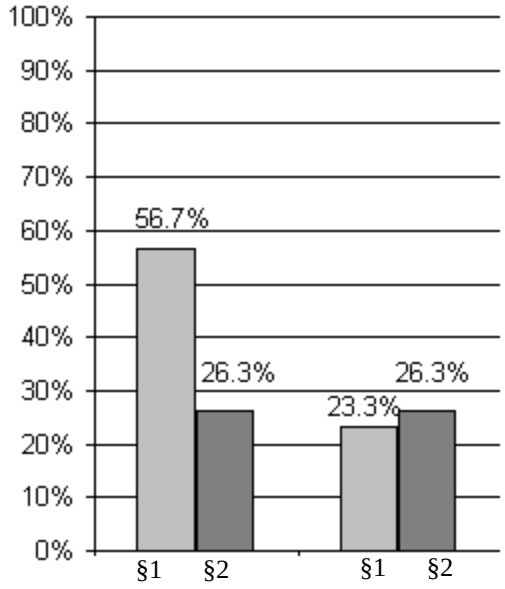
(4) 1. Find the angle θ, in degrees, in the **third** quadrant whose cosine is -0.849. Your angle should be in the interval $0° \le \theta < 360°$. Round to 1 decimal place.

(6 each) 2. Solve the equations on the interval $0 \le x < 2\pi$ algebraically, reporting **exact** values. Attach work.

a. $2\cos^2 x - \cos x - 1 = 0$
b. $\cos 2x - 1 = \sin x$
c. $\cos^2 x - 3\sin x = 3$
d. $2\cos x + 4 = 4\sin^2 x$
e. $\sin 2x \sin x = \cos x$
f. $\cos 2x + 1 = \cos x$

Again, for this objective the eHW question bank was broad, containing roughly 50 kinds of trigonometric equations. Each time the student took the assignment they were required to do three different kinds (some at level 1, some at level 2). At this point in the semester, students knew to use eHW to continue to redo the assignment until they understood the concept. Section 1 surpasses Section 2 for this objective. These are not the students who had earlier learned this material through a WR assignment.

MA 154 Learning Objective 4 (Levels 1 and 2)
Solve a complex trigonometric equation over a given interval and report the exact value(s) of the angle θ in radians.



Level 1
Remove a greatest common factor.

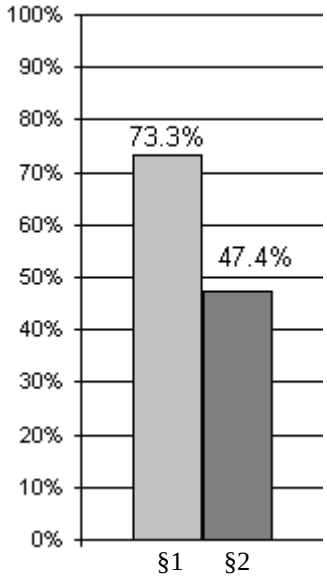
Level 2
Factor a trinomial

MA 154 Learning Objective 4	Level 1	Level 2
Section 1: eHW (n=30)	17/30 =56.7%	7/30 = 23.3%
Section 2: WR (n = 19)	5/19 = 26.3%	5/19 = 26.3%

The first student learning objective seems to be where eHW was least effective. On the writing assignment and eHW for the fourth student learning objective I repeated a question related to the first student learning objective, i.e., solve an equation such as $\sin\theta = 0.1234$, but this time in degrees instead of in radians, and use a calculator. The same underlying concepts are involved. It appears that using eHW students were able to learn this skill better than those who used written homework, as the data shows below.

MA 154 Learning Objective 1 Repeated

Solve $\sin\theta = 0.1234$ in degrees



MA 154 Learning Objective 1 (in degrees)	
Section 1: eHW (*n*=30)	22/30 = 73.3%
Section 2: WR (*n* = 19)	9/19 = 47.4%

Faculty Response

For uniformity of sections, all MA 153 instructors were required to use eHW in Fall 2008, and then all MA 153, 154, and 159 instructors in Spring 2009, along with a pledge of a high level of support. Prior to the semester they were sent a letter from me and the associate chair with suggestions on how much they should have eHW count toward their grade. There is a fine balance in having it weighted just enough so that students think it is important but not so much that someone who can't perform on in-class exams would pass the course.

At the end of the semester, a questionnaire was given to all MA 153 instructors to ask them about their experience using eHW. Thirteen of the fourteen questionnaires (92.8%) were returned. Instructors were overwhelmingly convinced that eHW helped their students learn the material.

The MA 153 instructor whose students were a part of this study (and who had past experiences as a student where the frustration of electronic instruction outweighed the benefit) had this to say:

> *"I was begrudgingly talked into using eHW. I was convinced it would be a pain for me and worthless/frustrating for students. After a minimal learning curve I was able to set up a semester in about 15 minutes. Grading takes even less time. On the students' end, I have not had a single complaint about it being complicated. Some have said it was tedious but others commented that it has helped (and it should be easy points) so they have no sympathy from me."*

Another colleague who teaches at Ivy Tech where *MyMathLab* is used, shares how essential it is to use this kind of technology. She points out that the *MyMathLab* interface is much better, but acknowledges it is much more expensive (four times the price of MapleTA).

Faculty repeatedly mentioned that without eHW, some students would not have passed the course.

> *Several students commented that using the eHW was the most helpful tool for learning the material.*

> *There were several students in class who remarked how helpful eHW was. They liked the feedback, fast and informative. There were at least two students who used eHW to push their grade up a letter grade. One older student was particularly diligent in doing eHW and commented on how much she liked it. There was at least one student who would not have been able to earn a C if she had not had the eHW to help her. One of my students is in my current MA 229, and she expressed regret that we don't have eHW for MA 229. We'll have to work on that one. There were a few students who did little or no eHW and their final exam grade and semester grade reflect that.*

Four of the fourteen surveyed shared that eHW helped enhance classroom discussion by generating more questions in class and outside of class.

> *Whenever a student asked a question from eHW, it helped a lot of the other students to see the example from eH, and they asked even more questions then.*

One instructor pointed out eHW helped the class move through the syllabus, while another noted how, through formative assessment, eHW helped the instructor make the best use of class time.

> *I think the eHW answered a lot of questions that students would have needed to ask in class, so I had more time to get through the material I needed to cover.*

> *It didn't change my plan in going through the syllabus but helped students understand the material, and I found out what they needed to know. Also helped me to see where most students have problems so I could go over that again.*

Four instructors believed eHW helped them cover content more deeply. As mentioned above, they noted how students spent time outside of class testing themselves and studying their mistakes, which enabled them to use class time to take concepts to a deeper level and make connections. That is not to say that there were no deep questions in eHW, as this instructor remarked:

> *Some eHW questions get deeper than we can cover directly in class, so when students ask questions about eHW in class, this allows us to go back and cover the concept.*

All instructors shared that their interest in using instructional technology increased and that they would like to learn more about using Maple TA, as well as Blackboard Vista, Smartboards, graphing calculators, Powerpoint, and other tools. Two instructors have expressed interest in learning how to add their own questions.

Student Attitudes

Some of how the students felt about eHW has been mentioned above. At the time of this writing, I have yet to compile all of the data collected, and plan to hold a focus group in the Spring of 2009 to get more feedback. Originally this focus group was planned for Fall 2008, but that was not logistically possible. Also, students are likely to feel more at liberty to comment about the

instructional components of the course when they already have received its grade. By no means is eHW a magic bullet. As one instructor shared, "I remember one student telling me that they 'got' logs because of it. They said everything else was hopeless, but they could do logs." There are numerous factors which contribute to a student passing the course, and even this student recognized that eHW could not raise the Titanic once it had sunk.

Conclusions

Although eHW excels in assessing routing computations and basic skills, it strengthens students' abilities to think critically and solve nonroutine problems and can free up valuable class time for faculty so concepts can be explored in greater depth. A higher percentage of students in the eHW group performed better on the applied problems for MA 153 learning objective 1 and MA 153 learning objective 2 than those who completed graded writing assignments. A good eHW assignment is one that is not too long to be burdensome, but not too easy that it is never repeated. The students in the eHW group for MA 154 Learning Objective 1 had an assignment which did not help them practice as much as the written assignment did. They also need reinforcement on writing correct mathematics, especially use of parentheses. Not only must they write their answers correctly on tests, but type them correctly into their graphing calculator to properly check their work. Sometimes students complain that they must do the entire eHW assignment over, even if they miss just one item, or that the questions are hard and it is difficult to enter the answer into the computer. To that, I give no apology. Instead, the appropriate response might be: "No need to thank me, but, you're welcome!"

Acknowledgements

I am grateful to CELT for this learning opportunity and for the support and helpful comments I have received from the Gail Rathbun and the CELT Advisory Board, the department of Mathematical Sciences, and especially Yvonne Zubovic and Douglas Townsend, without whom none of this work would be possible.

Notes

[1] We looked at all of these possibilities for electronic homework systems. None were as good as *Maple TA*.

- *Respondus* (http://www.respondus.com/) through Blackboard.
  Limitation: Would not permit templates. Building question banks from scratch.
- *WebWorks* (http://webwork.maa.org/)
  Limitation: Perl-based system with a steep learning curve, and could not build upon previous work.
- *WebAssign* (www.webassign.net/)
  Limitation: Meager number of homework questions. Instructors could not author their own.
- *Diploma* (http://www.wimba.com/products/diploma)
  Limitation: The vendor, *Wimba*, was undergoing reorganization after a buyout. They actually recommended that we go to Maplesoft during their transition time.
- *MyMathLab* (www.mymathlab.com/*)*
  Limitation: Excellent package but very expensive ($60)
- *WileyPlus* (www.wileyplus.com /*)*
  Limitation: As *MyMathLab*, very expensive ($60), but an inferior package.

[2] In 2008 the price was $17.75, but in 2009 it is only $9.95 due to more students sharing the fee.

[3] *Classroom Assessment Techniques: A Handbook for College Teachers*, 2nd Ed. By Thomas A. Angelo and K. Patricia Cross