AC 2010-848: INDIVIDUALIZED HOMEWORK: AN EFFECTIVE LEARNING STRATEGY

Ronald Goulet, University of Tennessee-Chattanooga

Individualized Homework: An Effective Learning Strategy

Abstract

Although evidence that homework improves learning outcomes at the university level is sparse, instructor opinion about the importance of and the role of out-of-class assignments suggests that homework is the most important factor to maximizing achievement of learning outcomes, when it is significantly weighted, relevant, promptly scored and returned. That said, these same instructors express a reluctance to assign much homework or to adjust the syllabus to weigh it substantially because of the well founded suspicion that many students cheat and submit work that is not their own by copying the work of others including the solutions manual. As a result, homework if assigned often carries far less weight than exams and is often cursorily graded before its eventual return to the student, thus nullifying any benefit to achieving learning objectives.

While student are predictably opposed to any out-of-class work, most recognize that practice strengthens understanding and builds problem solving skills. However, these same students complain that homework counts too little in the computation of final grades that it is rarely graded or promptly returned and that the scores earned are skewed by the dishonest behavior of students who cheat, copy work of others including solutions manuals.

To maximize the likelihood of achieving learning objectives, the author developed an approach to incorporating out-of-class work into an undergraduate mechanics of materials course that effectively compels students to invest heavily in the assignments by a 50% weighting in the computation of the final grade; that effectively incentivizes students to improve their final grade by a correction policy where a student may recovers half of any lost points by finding and perfecting their errors; and reduces the likelihood of cheating by individualizing the assignment.

While the basic question, "Does homework improve learning?" remains unanswered, the paper describes the details of course delivery, preparations of individualized assignments, grading and correction policy. The paper also presents the results of a student survey and the author's observations that include: a) increased student preparation for in-class lecture evidenced by Q&A, b) increased student engagement evidenced by office visits and email, c) increased student motivation to learn on their own as evidenced by the improvement of final scores through finding and correction of errors, d) an increase in learning suggested by the significant correlation homework scores and exam scores and e) a surprising reduction in the time required scoring and grading the assignments!

Keywords: Homework, individualized, customized, weighting homework

Introduction

The purpose of this paper is to describe the system developed to deliver out-of-class assignments to an undergraduate mechanics of materials course. The system incorporates heavily weighted

homework scores to increase student engagement and compliance, a correction policy that compels students to find and correct their own errors and individualized assignments to reduce cheating. Moreover and surprisingly, the system reduces the demand of the instructor's time for grading and scoring.

That homework improves learning is the subject of debate. Keeping in mind that correlation or lack thereof does not prove or disprove causation, significant correlations between homework and exam scores have reported[1,2,3] to suggest homework improves learning while little or no correlation has been reported by others[4,5].

Solid evidence aside, I agree with Feldman[6] that the use of homework as a learning technique is intuitively obvious. I suppose that makes me a believer, that homework is the practice that makes perfect; is the preparation that causes students to better exploit lecture time; and is the opportunity for students to extend or extrapolate[2] simple classroom concepts to wrestle with more complex and interesting applications.

The paper describes course background, features of the individualized homework system including the significant weighing of homework, the sourcing of and preparations of individualized assignments, the mandatory correction policy and the work of correcting and grading, especially the surprising reduction of time required to grade, score and return the assignments. The paper also presents the author's reflections regarding class delivery and student behaviors, and results of informal student and instructor surveys.

Background

This report pertains to the mechanics of materials, a required core course offered to all undergraduate engineering students of the College of Engineering and Computer Science at the University of Tennessee at Chattanooga. The catalog description of ENGR 246 reads:

> UTC ENGR 246 Mechanics of Materials, 3 credit hour lecture: Stress-strain concepts and relations. Bending, shear, torsion, and deflections. Euler columns, repeated loading and connection. Co-requisite Lab: 1 credit hour ENGR 247.

The principle learning objective of the course is to develop and refine the student's problem solving skills. Therefore the syllabus for ENGR246 states:

> *Course Learning Objective: Problem Solving Skills*
> *The principal objective is to learn, develop and refine problem solving skills. Therefore most of the work of the course will involve out-of-class problem solving assignments that require knowing and applying the principles governing (the basic engineering sciences or statics or the mechanics of materials).*

The method of course delivery generally follows the traditional teacher-centered lecture/homework/exam format. The course includes a series eight (8) of heavily weighted individualized chapter-based homework sets that are intended to encourage students to prepare for lecture, to practice solution techniques and to apply concepts to solve multi-step problems. The course also includes two projects designed to familiarize students with modern tools. The

first project requires the student to create a tool to compute the centroids, moments of inertia of channel, T, modified I sections using Excel®. The second project requires the use of Maple® for the analysis of an individualized simply supported beam. The analysis requires the student to: a) Derive and plot the shear and moment diagrams; b) Select the lightest beam and c) Derive and plot slope and deflection curves. Two exams are administered, one midterm and one final. The exams are individualized, closed book and supplemented with an official crib sheet.

A System of Individualized Assignments

The following describes a system of delivering assignments that are individualized, substantially weighted in the computation of the final grade, challenging, readily scored for prompt return to students then corrected by student for additional credit. Features of the system include the substantial weighting of homework grades, preparations of individualized assignments, an exemplar answer key, sourcing the problem set, the work of grading the assignments and the mandatory correction policy and portfolio requirement.

Weight of Homework Grades

Achieving good grades, for better or worse, is a motivating factor that actively engages students in the work of learning. Apply a significant weight to an out-of-class assignment and the student will invest more time and energy to complete the task correctly to the best of their abilities. Assignment scores for the course carry a weight of 50% in the computation of the final average, equal to the weight of exams. Given such weight, the homework and project assignments are individualized to minimize student cheating and are comprised of problems from multiple sources to minimize unfair advantage to students using unauthorized sources such as solutions manuals or fraternity files. Furthermore, the assignments are responsibly and consistently scored and graded in accordance with a published rubric described below in *Scoring of Assignments*.

Individualized Assignments

The issue that drives the use of individualized (or customized or personalized) assignments is cited using a variety of interesting euphemisms: uncertainty of ownership[3], individual accountability[5], uncritically copying another's answers[7], non-compliance and evasion strategies[8], excessive reliance on peers and deleterious study group habits[6]. But in a word it's all about cheating. By individualizing the assignment and by requiring hand-written supporting work, the cheater must work harder to submit the work of others as the cheater's own. The typical individualized assignment includes 10 problems. While a typical problem uses identical diagrams, graphics, given statements and find statements, each student is assigned a unique set of numerical parameters which yield unique results.

The individualized assignment is created in MS Word document. This Cover Sheet contains the Student Name, Due Date, Instructions, Scoring rubric and 8 to 10 individualized problem blocks.

> Individualized assignments are prepared on a chapter by chapter basis. Each chapter's assignment is distributed to the class before the first lecture in a new chapter. The due date of the assignment is the first lecture following completion of the chapter. Late work receives no credit.

Typical instructions include: *Solve ALL problems below. Enter correct answers with correct dimensions/units in the space provided ON THIS COVER SHEET. Express all results with a minimum of 3 significant figures. Attach hand-written supporting work to this Cover Sheet. Remember: No Work = No Credit.*

Problem blocks contain the problem's value (e.g. 10 pts), problem statement with given parameters and find statement, and labeled blanks where result is filled in by student.

Generation of the individual assignment is accomplished using MS Word to create the assignment Cover Sheet document, Excel as a database and the MS Word Mail Merge tool. The Excel worksheet contains at least one row per student with column headers to hold the unique field names for first and last name, email address, problem number, parameters and solutions. After a problem set is created in MSWord and Excel, the individualized files are posted for downloading via a Blackboard link. The linked folder name corresponds to the assignment name. For example, assignment 2 is named A2. The public folder is named www.utc.edu/rgoulet/ENGR246/A2. This public folder contains an index.htm file, all individually named assignment files and the exemplar answer key named Instructor.doc. The index.htm file contains a tabulation of each student last name; each hyperlinked to that student's individualized Cover Sheet always named "lastname.doc". The set of all individualized cover sheet filenames is created using a macro contained in the MSWord normal.dot template. A typical macro for this purpose is shown in Figure 1.

Posting the individual cover sheets to the web eliminates the need for printing, sorting and stapling of the problem sets (by the instructor or support staff) and use of class time for distribution of the sets. Web posting also makes it easy for absentees to obtain their assignments.

Sourcing the Problem Set

The individualized assignments described above pose problems with common structure and unique numerical parameters to yield unique results. The problem sources include the adopted textbook, other text books, exam prep materials and the troves of this and other faculty. With problems sourced from textbooks it is important to recognize the ease and speed that solution manuals find their way into the hands of a few students. While such text sources might be avoided, most compromised problems are effectively disguised by changing the associated diagrams and graphics and rewording the given and find statement(s). Constant vigilance is required to stay one step ahead of the misdirected. Fortunately, routine revision of assignment sets is a task that is accomplished with only a fraction of time and effort invested to initially create the set.

Exemplar Answer Key

The familiar textbook answer key is used by some students to verify the correctness of their solution. To accommodate this approach, an exemplar answer key is created and posted. The file named Instructor.doc contains answers to each problem based on its own unique set of parameters. The exemplar answer key permits students to verify the correctness of their solution process by computing a result then checking for agreement with the posted Instructor.doc.

```
Sub Macro246()

Dim stu_name(4) As String        'enter the number of stu_name()
stu_name(1) = "instructor"           'number in ( ) corresponds to record number in database
stu_name(2) = "Applebee"         'so the list of names must correspond to name of the record
stu_name(3) = "Cicero"           'for large classes, this stu_name() list is created in Excel using
                                 'Excel's concatenate() function

For n = 1 To 3                       '3 to merge and name first 3 records
  With ActiveDocument.MailMerge
    .Destination = wdSendToNewDocument
    .SuppressBlankLines = True
    With .DataSource
      .FirstRecord = n
      .LastRecord = n
    End With
    .Execute Pause:=False
  End With
ChangeFileOpenDirectory "C:\Documents and Settings\tech\My Documents\246Fall2009\A2"
  ActiveDocument.SaveAs FileName:=stu_name(n), FileFormat:= _
    wdFormatDocument, LockComments:=False, Password:="", AddToRecentFiles:= _
    True, WritePassword:="", ReadOnlyRecommended:=False, EmbedTrueTypeFonts:= _
    False, SaveNativePictureFormat:=False, SaveFormsData:=False, _
    SaveAsAOCELetter:=False
  ActiveWindow.Close
 Next n
```

Figure 1 VBA Macro written to the MSWord normal.dot template. Macro merges parameters of the 1st three records in the Excel database to create three individualized cover sheets which are then saved as files Instructor.doc, Applebee.doc and Cicero.doc to folder \My Documents/246\Fall2009\A2.

Grading Assignments

Grading is a two step process. First the correctness of results is verified. This step is facilitated by the Answer Key document, a modified cover sheet that displays the correct result with correct units instead of the labeled blanks on the student cover sheet. With a student's Cover Sheet in hand and the corresponding Answer Key file record displayed on the desktop or laptop screen, incorrect responses are quickly identified and marked with an "x". The second step is the assignment of partial credit. An incorrect result that flows from a student's genuine attempt contains more value than one from another's effortless guess. To differentiate, the attached hand-written work is inspected and partial credit is assigned using the rubric below:

0% deduct: Result is correct AND Attached hand-written work verifies the correct result
50% deduct: Result incorrect AND Attached work demonstrates significant effort
100% deduct: Result is incorrect AND Attached work demonstrates little effort
100% deduct: Result is correct AND Attached hand-written work does not verified result

The 50% deduct for incorrect results flowing from a genuine attempt may seem harsh or severe. However, through the correction policy described next, a student is incentivized to improve the score by finding and perfecting the error. In this way, any incorrect result that is perfected receives a score equivalent to a "C", which represents acceptable performance. The 100% deduct for lack of effort attempts to differentiate last minute guessing and filling in the blanks from the work of the genuine attempt. The 100% deduct for correct but unverified results curbs lucky guessing and cheating at the cost of annoying the few students who "plug and chug" the correct result without a paper record.

The grading of individualized assignments might seem a daunting task. Surprisingly, experience indicates that grading the individualized work submitted on the Cover Sheet takes a fraction of the time it would take to responsibly grad the same work prepared and submitted in the traditional manner. In the mechanics of materials class of 34 students discussed here, a typical assignment of 10 problems took about one hour.

Mandatory Correction Policy

The severity of the partial credit rubric typically results in a bimodal distribution of scores grouped about 85% and 65%. Informal feedback from students suggests the low scores are attributed to the demonstrated lack of effort in the attached work caused by underestimating the time required to complete the assignment. When homework is weighted heavily, such low scores could seal the fates of those who do poorly. What should an instructor do? Flunk them? Give away more partial credit? Slide the scale?

The Instructor's approach to this issue again reveals a position without basis but again is so obviously intuitive: We learn from finding and correcting our mistakes. Therefore the homework system provides an incentive for students to remediate their low scores through a Correction Policy. The policy, incorporated into the course syllabus, typically reads:

> *Mandatory Correction of ALL Work*
> *It is said "We learn from our mistakes". But that's not entirely true. This Instructor believes the likelihood of learning is improved by finding and correcting our mistakes. Therefore any work (homework, project, or exam) returned to student with a score <= 75% must be corrected. As incentive, 50% of the lost points will be added back to the original grade for perfect correction of work. Those students with grades > 75% may at their option correct errors and recover 50% of lost points for perfect correction of errors.*
> *To facilitate re-grading of corrected work, students must maintain a portfolio containing all original work and subsequent corrections. All corrections shall be made on the original Cover Sheet and on the supporting work and shall be highlighted in yellow. The portfolio will be turned in for final grading on the day and time of the final exam. Students may verify corrected results before the end of the semester by e-mail inquiry to the instructor.*

The offer to verify corrections by email generated a constant flow of student email that increased as the end of the semester approached. The approximate volume totaled 300 for the section of 34 students. The portfolios and exams were collected on the day of the final exam. The re-scoring of a portfolio with 10 assignments and exams takes roughly 10 minutes per student or about 5 hours for the class.

Instructor's Observations

The following describes four examples of the positive influence the homework system has on the learning experience. The first of these is the improved delivery of in-class lecture. The second is the dramatic increase out-of-class student/instructor interaction. The third is the evidence of

student motivation reflected in the improvement of final grades. The fourth is the improved learning suggested by correlations of homework and exam scores.

Influence of Homework System on In-Class Lecture

Recall that assignments are posted and presumably in the student's hands before the first lecture of a new chapter. The pending assignment becomes a presence in the classroom, a presence that influences the lecture in some predictable ways. For example, because the sequence of an assignment's 8 to 10 problems follows the textbook's sequence then so does the sequence of the lectures; a predictable outcome that adds structure to the lecture, presents the content in a logical order and with fewer 'holes'. Also, because of the heightened importance of the pending homework assignment, many student questions and concerns about the assignment are raised during lecture; sometimes with such perfect timing they seem scripted!

However, students also ask pertinent questions concerning chapter concepts and applications not yet covered in lecture; teaching opportunities lost! To minimize such moments, delivery of new concepts and applications is frontloaded into the first half of a chapter's lecture series leaving the latter half for examples, for student questions and for discussions regarding "how to approach" the assigned homework problems.

Influence of Homework System on Student-Instructor Interactions

Another predictable outcome to the 50% weighting of homework assignments is the increase in office traffic during posted hours, in e-mail inquiries and phone calls. The most frequent inquiry concerns disagreement between the student result and the Instructor.doc result. If the question arises before the due date, the assistance is restricted to replaying lecture content especially the "how to approach" already discussed in class. If the question arises in the correction phase after the assignment has been scored and graded, then more specific assistance is provided such as inspecting the algebra of a solution or a preliminary numerical result.

Influence of Homework System on Motivation: Improving the Final Grade

Students respond favorably to the significant 50% weighting of homework and the incentivizing correction policy. After the first mid-term exam (which is individualized and scored using the same rubric discussed earlier), each class is given a 'pep talk' to remind them how the weighting and correction policy can improve their current standing. The pep talk is accompanied by a plot similar to those shown in **Figure 2** which displays the final raw and improved scores for students of for the ENGR246 class. Each vertical pair represents the improvement of a single student. Using common letter grade thresholds of 90, 80, 70, and 60, students improving one letter grade are identified. A full letter grade improvement was achieved by 25 of 34 ENGR246 students.

Influence of Homework System on Learning

As reported above[2,3,4,5,6], correlations of homework scores to exam scores have been used to test the influence of homework on learning. Although correlations neither prove nor disprove causation, a similar treatment was applied to the raw homework and raw exam scores of the class. The raw scores reflect scores without the 50% return of lost points per the correction policy. Scatter plot of the scores shown in **Figure 3** reveal a coefficient of determination, R^2 = 0.3878 which corresponds to a Pearson's correlation coefficient, R = 0.622 and represent substantial degree of correlation.

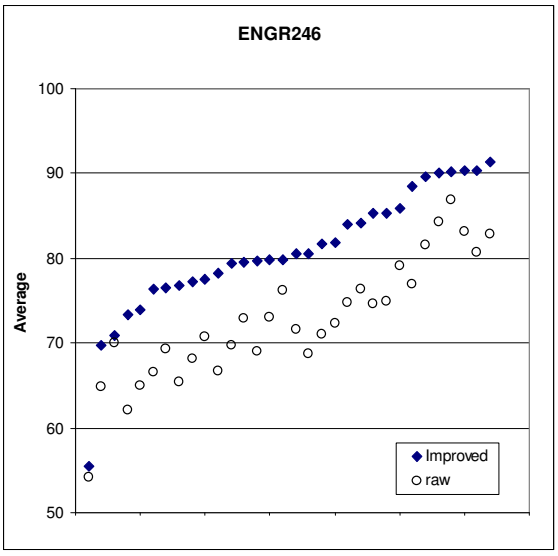

Figure 2 Comparison of raw and improved final semester averages for the mechanics of materials course demonstrates the incentivizing effect of the correction policy. Each vertical pair includes a raw score (○ circle marker) and the corresponding improved score (♦ diamond marker). Final grades A, B, C and D are determined by the 90, 80, 70 and 60 thresholds.

Influence of Homework System on Instructor Time for Grading

Earlier, it was estimated that it takes about one hour to score and grade a typical assignment for a section of 34 students. Based on my experience and considering the challenges of responsibly grading and scoring homework in the traditional manner with feedback and partial credit, I estimate the same assignment take three to four hours! Some of this time savings can be applied to other pursuits but not all because as mentioned above, student/instructor interactions will place additional demands on time in the form of office visits and email exchanges. Also, as mentioned above, a block of time of about 5 hours is required at semester's end for portfolio correction and final computation of semester grades.

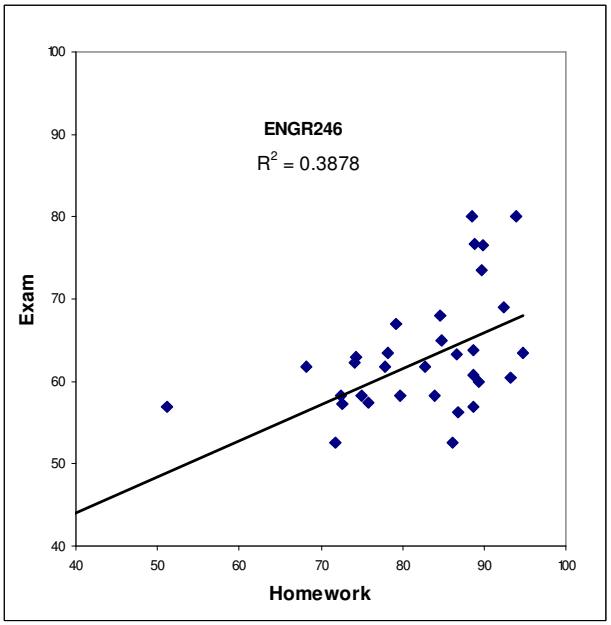

Figure 3 Scatter plots of exam and homework scores for the mechanics of materials course with the coefficient of determination R^2 of 0.3878 which corresponds to Pearson's correlation coefficient R of 0.622 and represents substantial degree of correlation.

Student Survey

A survey of the Fall 2009 ENGR246 class provides some indication of student reaction to the course and the individualized homework system. The survey responses were collected after the final exam was administered but before scoring of the final and portfolio and before posting of final grades.

Most negative reactions were responses to "What did you like least about the course?" and "What should be change?" and predictably pertained to the time the course demanded: 40% felt the assignments required too much time; 43% reported that they expended over 16 hours per week on out-of-class course work, 25% spent between 12 and 16 hours and 28% spent between 8 and 12 hours. But when prompted by "I learn in proportion to the work I expend", 70% agreed. Criticisms about the difficulty of the problems were also leveled by 21% who opined that the assignments were too tough and took too long.

Most positive reactions were in response to "What did you like most about the course?" and "What should not be changed?" The grading standards and weighting of the homework were favored by 90% who agree that the standards are clear and fair. When asked what grade they expected in the course:

Expected grade distribution: A: 33% B: 46% C: 21%
Actual grade distribution: A: 21% B: 46% C: 27% D-F: 6%

The correction policy also drew support from 58% who valued the opportunity recover lost points by correcting mistakes while 21% opined that they learned the material more thoroughly by finding and correcting errors. 9% appreciated the exemplar answer key as a tool to verify their solutions were correct. A handful of students expressed an appreciation for the effort to reduce cheating and made suggestions to further that end.

Conclusions

A system of individualized homework assignments has been developed and applied to an undergraduate mechanics of materials courses. The system effectively compels students to engage in out-of-class assignments through substantial weighting of homework in the computation of the final grade and through a correction policy that incentivizes students to correct their work to earn back half of their lost points.

It has been observed that the system of individualized assignments positively influences the learning experience by:

- Improving the level of student preparation for in-class lecture
- Improving the content, sequence and focus of in-class lecture
- Increasing out-of-class student/instructor interactions
- Increasing student motivation reflected in the improvement of final grades
- Improving learning as suggested by correlations of homework and exam scores

Further, once developed, the system surprisingly reduces the time demands related to scoring and grading homework in the traditional manner.

The basic question, “Does homework improve learning?” remains unanswered. The positive influences cited above reflect the experiences of a single instructor and are anecdotal. Clearly, further study is required to compare learning outcomes of the individualized system to a control of the traditional approach.

Ron Goulet

Ron Goulet is an associate professor of mechanical engineering in the College of Engineering and Computer Science at UT Chattanooga where he teaches engineering physics, statics, dynamics, mechanics of materials, material science and perennial student advisor for the SAE MiniBaja Runnin’ Mocs race team. He received a Ph.D. in Engineering from University of New Hampshire in 1997. His research interests include experimental mechanics and the development of individualized assignments and projects in undergraduate engineering education.

References

1 Doyle, M., Barber, B., Homework as a Learning Experience, What Research Says to the Teacher, 3rd Ed. Nat’l Educational Association, Washington D.C., 1990.
2 Somerton, C.W., Homework: To Do (assign and grade) Or Not To Do (only assign), Proceedings of the 2003 American Society of Engineering Education Annual Conference, 2003.
3 Wankat, P., The Role of Homework, Proceedings of the 2001 American Society Engineering Education, Annual Conference, Albuquerque, June 2001.
4 Carpenter, J., Camp, B, Using a Web Based Homework System to Improve Accountability and Mastery in Calculus, Proceedings of the 2008 American Society of Engineering Education Annual Conference, 2008.
5 Fernandez, A., Saviz, C., Burmeister, J., Homework as an Outcome Assessment: Relationships Between Homework and Test Performance, Proceedings of the 2006 American Society of Engineering Education Annual Conference, 2006.
6 Feldman, L, Designing Homework Assignments: From Theory to Design; Proceedings of the 1999 American Society of Engineering Education Annual Conference, 1999.
7 Henk, R., Personalized Thermodynamics Homework Problems-Pilot Study, Proceedings of the 2005 American Society of Engineering Education Annual Conference, 2005.
8 Ristroph, J, An Alternative Paradigm for Engineering Homework: The Case of Engineering Economics, Proceedings of the American Society of Engineering Education Annual Conference, 2006.