A System of Individualized Homework Assignments in Core Mechanics Courses

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Abstract -Does homework improve learning? Although convincing evidence answering this question is sparse, it is this instructor's conclusion that homework is the most important factor to maximizing achievement of the learning outcomes provided it carries sufficient weight in the computation of the final grade and is challenging, individualized, promptly scored and returned to student for correction by student. The author has developed a system of individualized homework assignments for 1st and 2nd year core mechanics courses that effectively compels students to invest heavily in out-of-class assignments by substantial weighting in the computation of the final grade and by a correction policy that incentivizes correction of errors by returning half of any lost points. Observations reported include an increase in student preparation for in-class lecture evidenced by Q&A, an increase in student engagement evidenced by office visits and email, increase in student motivation to learn on their own as evidenced by the improvement of final scores through finding and correction of errors and perhaps an increase in learning suggested by the significant correlation of homework scores and exam scores. Moreover, the author reports that the system, once developed, surprisingly reduces the time consumed scoring and grading.

The paper describes the details of course delivery, preparations of individualized assignments, grading and correction policy. The paper also presents the author's observations and results of informal student surveys.

Keywords: Homework, individualized, customized, weighting homework

INTRODUCTION

The purpose of this paper is to describe an innovative system of delivering homework to 1st and 2nd year engineering courses: engineering physics, statics and the mechanics of materials. The system improves learning with individualized assignments to reduce cheating, heavily weighted homework scores to increase student engagement and compliance and a correction policy that compels students to find and correct their own errors. The system, surprisingly, reduces the time required to grade, score and return the assignments.

In the spirit of full disclosure, allow me to explain that I've been reluctant to offer this contribution about homework to ASEE. Why? Because I would have to reveal that I'm a believer in homework! How else would I justify pouring countless hours to develop, refine and expand a homework system that is premised on the yet unproven: that homework actually improves learning?

For me, the use of homework as a learning technique is *intuitively obvious* [Feldman 3]. And like others [Doyle 2, Somerton 7, Wankat 8], I've observed positive correlations between homework and exam scores or mastery while others have not [Carpenter 1, Fernandez 4]. But correlation or lack thereof does not prove or disprove causation. So the fact is, I'm a believer in homework. I believe that homework is the practice that makes perfect; is the preparation that best exploits in-class time; and is the extension of simple classroom concepts into complex and interesting applications. It is no small consolation that other believers include most teachers of engineering and most of the contributors to the topic of homework in the proceedings of the ASEE.

The paper includes background about four courses that recently used the homework system, 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 engineering courses that I've had the pleasure of teaching comprised of 1st and 2nd year engineering students of the College of Engineering and Computer Science at the University of Tennessee at Chattanooga and to summer students of the College of Engineering and Physical Sciences at the University of New Hampshire in Durham, NH. The core mechanics courses include:

> UTC ENGR103 Basic Engineering Science, 3 credit hour lecture: Introduction to basic concepts of engineering. Physical quantities, units, dimensions, vectors; formulation of engineering problems. Calculus-based analysis of fundamental dynamics; motion along a straight line and in a plane. Newton's 1st, 2nd, and 3rd Laws of Motion plus applications. Work and energy. Impulse and momentum. Rotational motion. Co-requisite Lab: 1 credit hour ENGR 113.
>
> 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.
>
> UNH ME525 Mechanics I, 3 credit hour lecture: Introduces statics. Two- and three-dimensional force systems, the concept of equilibrium, analysis of trusses and frames, centroids, bending moment and shear force diagrams, and friction.
>
> UNH ME526 Mechanics II, 3 credit hour lecture: Introduces strength of materials. Analysis of members under torsion, axial, shear and bending stresses, superposition of stresses, stability of columns.

Although the courses may differ in content, the principle learning objective in each is to develop and refine the student's problem solving skills. Therefore the syllabus for the above courses contains words to the effect:

Course Learning Objective: Problem Solving SkillsThe 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 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 multiple step problems. The course may also include one or two projects that require the use of modern tools including Maple®, MathCAD® or Excel®. Two, three or four exams are administered including the final. Exams are individualized, closed book and supplemented with an official crib sheet.

A SYSTEM OF INDIVIDUALIZED HOMEWORK ASSIGNMENTS

The following describes a system of delivering homework 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, the sourcing and preparations of Individualized assignments, an exemplar answer key, sourcing the problem set, the work of scoring 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 homework and student will invest more time and energy to complete the task correctly to the best of their abilities. Homework scores for the courses reported here carry a weight of 50% in the computation of the final average, equal to the weight of exams. Given such weight, the homework 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 [Somerton 7], individual accountability [Carpenter 1], uncritically copying another's answers [Henk 5], non-compliance and evasion strategies [Ristroph 6], excessive reliance on peers and deleterious study group habits [Fernandez 4]. 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 individualized assignments present problems with common givens, diagrams, graphics and find statements but unique 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 Mail Merge tool. The Excel worksheet contains at least one row per student with column headers for first and last name, email address, problem number, problem parameters and solutions. After an assignment's problem set is created in MSWord and Excel, these may be distributed as hard copy printouts directly to students in class or as web posted files ready for downloading from a Blackboard linked url.

Except for the first day of class when printed Cover Sheets are distributed to each student, the web posting is used routinely. The course's Blackboard site is linked to a folder named for each course assignment. The public folder contains the index.htm file, all individualized assignments and the Instructor.doc and exemplar answer key. The index.htm file is a tabulation of student last names with hyperlinks to that student's Cover Sheet file name, always named "lastname.doc". The set of all individualized cover sheet filenames is created using a macro in MSWord.

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 vary and 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 the solution manual will fall into the hands of some students. While such compromised text sources might be avoided, most 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 in the initial set creation.

Exemplar Answer Key

Many students are familiar with and routinely use the answer key included in their textbooks this for immediate verification of the correctness of their solution. To accommodate this approach, an exemplar answer key is posted. The file named Instructor.doc contains answers to each problem based on a unique set of parameters. The exemplar

answer key permits students to verify the correctness of their solution process by computing a result using the parameters of the exemplar then checking agreement with the answer posted in the Instructor.doc.

Scoring of Assignments

The instructional goal is to score and return graded assignments at the next class meeting. To achieve this goal, the grading process has been streamlined by use of the individualized Answer Key and a simple partial-credit rubric. The Answer Key document is the Cover Sheet document modified to display the appropriate result in place of the labeled blank. With a student's Cover Sheet in hand and the corresponding Answer Key file record displayed on the pc or laptop screen, incorrect responses are quickly identified and marked with an x.

Following the correctness check, points are deducted by comparing the Attached hand-written work to partial credit rubric as follows:

0% deduct:	Result is correct AND Attached hand-written work verifies the correct result
50% deduct:	Result incorrect AND Attached work demonstrates significant effort to solve
100% deduct:	Attached work demonstrates lack of effort

It takes approximately one hour to score a typical assignment of 10 problems in a section of 30 students.

Mandatory Correction Policy

The severity of the partial credit rubric typically results in a bimodal distribution of scores grouped about 80% and 50%. 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. This homework system provides incentives for those 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 portfolios are collected along with 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 a class section of 30 students.

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 weight placed on 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 incentivizing correction policy. After the first mid-term exam, 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 1 where students are shown the raw midterm average scores and the scores reflecting perfect correction of all errors. Figure 1 displays the final raw and improved scores for students of four mechanics courses. 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 of 9 of 18 students is observed in ME526; 9 of 17 in ME525; 25 of 34 in ENGR246 and 7 of 16 in ENGR103.

Influence of Homework System on Learning

As reported above [Carpenter 1, Doyle 2, Fernandez 4, Somerton 7, Wankat 8], 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 four recent classes: ENGR103Spr08, ENGR246Fa09, ME525Su09 and ME526Su09. The raw scores reflect scores without the 50% return of lost points per the correction policy. Scatter plots of the scores shown in Figure 2 reveal a coefficient of determination, R2, ranging from 0.3878 to 0.8634. These correspond to a Pearson's correlation coefficient, R, ranging from 0.622 to 0.923 and represent substantial degree of correlation.

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 30 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.

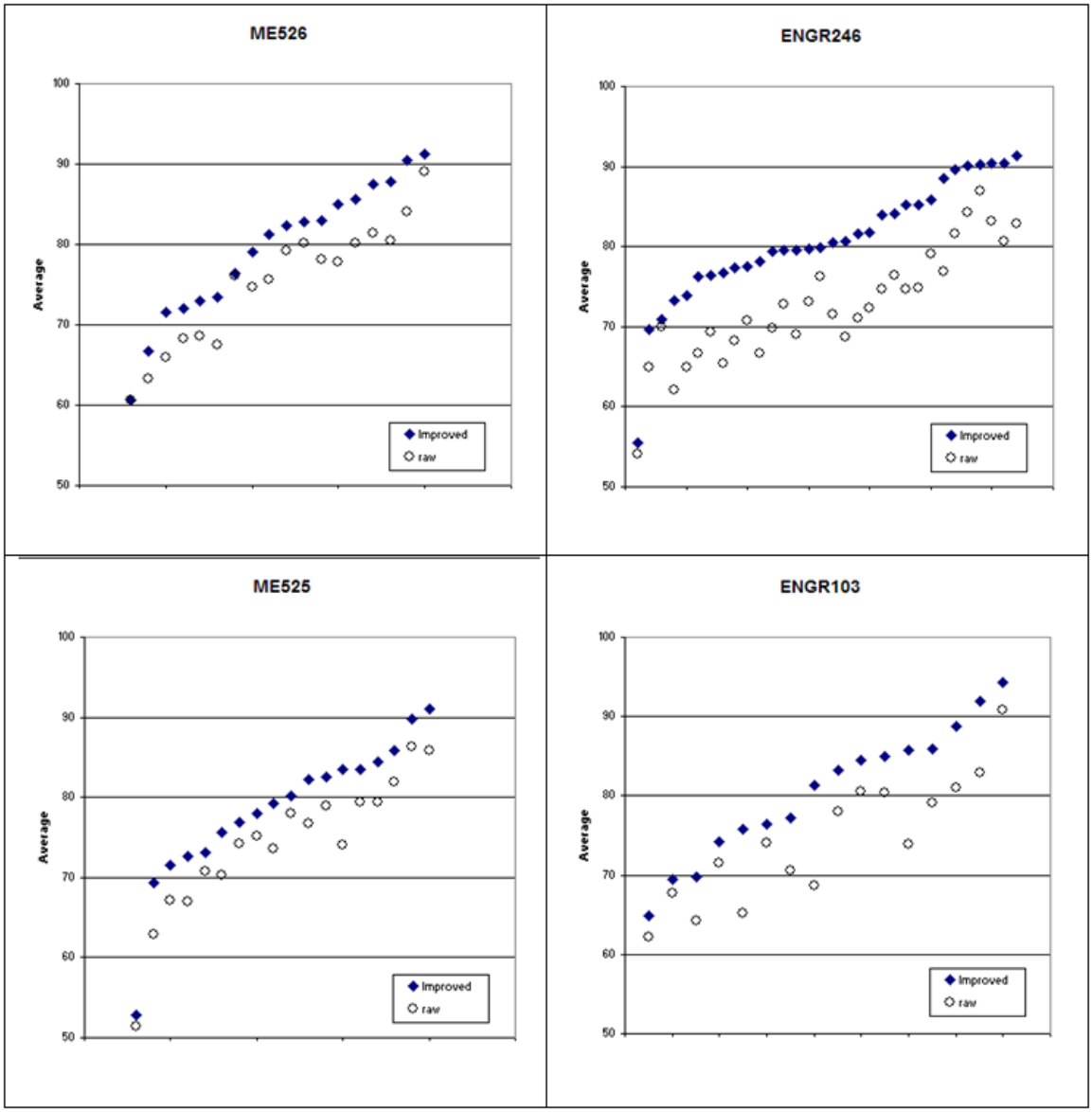

Figure 1 Comparison of raw and improved final semester averages for four mechanics courses demonstrates the incentivizing effect of the correction policy. Each vertical pair includes a raw score (○ circle marker) and the corresponding improved score (♦ diamond marker). Final grades A, B, C and D are determined by the 90, 80, 70 and 60 thresholds.

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 changed?" and 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.

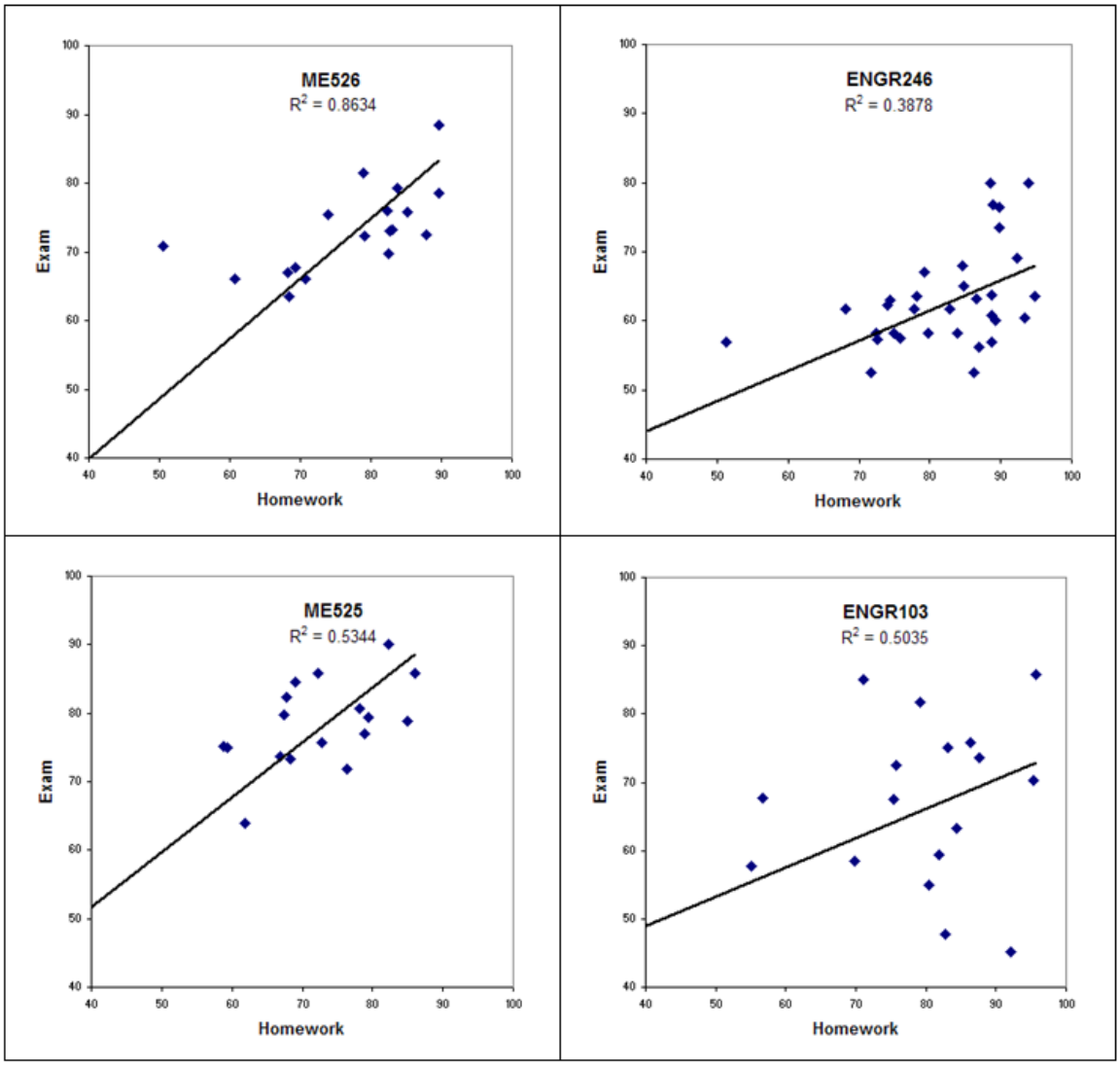

Figure 2 Scatter plots of exam and homework scores for four mechanics courses with R2 the coefficient of determination ranging from 0.3878 to 0.8634. These correspond to R, Pearson's correlation coefficient ranging from 0.622 to 0.923 and represent substantial degree of correlation.

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 mistake 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 core engineering mechanics 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 half of their lost points.

The System of Individualized Assignments has been observed to positively influence the learning experience by:

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.

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