Can Enforcing an Organized Solution Lead to Better Grades?

Dr. Julian Ly Davis, University of Southern Indiana

Julian received his Ph.D. from Virginia Tech in Engineering Mechanics in 2007. He spent a semester teaching at community college in the area and then spent two years at University of Massachusetts continuing his research in finite element modeling and biomechanics and continuing to teach. In 2010, he began his current tenure track position at the University of Southern Indiana.

Dr. Thomas McDonald, University of Southern Indiana

Tom McDonald is an Associate Professor in the Engineering Department at the University of Southern Indiana. Prior to joining USI he taught for six years in the School of Technology at Eastern Illinois University. He earned his BSIE and MSIE degrees in Industrial Engineering from Clemson University and his PhD in Industrial and Systems Engineering from Virginia Tech. His research and teaching interests primarily include lean manufacturing, discrete event simulation and modeling, and engineering economy. Tom has been involved in lean manufacturing and modeling of production lines since 1999 and has worked with private organizations such as Danaher/Kollmorgen and AT&T.
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Abstract

Online homework systems have been used in math, engineering and other sciences for several years to distribute, collect and assess homework problems. As these systems have grown publishers have added beneficial features such as hints, based on student input and the ability to assess electronically drawn diagrams. Many studies have shown that there is no significant difference between different modes of homework delivery (handwritten, online or a hybrid of the two) and the success of a student within the class. However, missing from online homework systems is the assessment a student’s ability to present a clear and logical solution: technical communication.

The objective of this study is to assess the relationship between student's ability to present a clear and organized solution and their ability to correctly solve a problem. A 4 section rubric is used to score homework and exam problems over 3 semesters of mechanics classes (Statics and Dynamics). Included in the rubric are scores associated with solving the problem: the Solution score, and a Presentation score evaluating the organization of the solution.

Analysis of these data (over 1,000 samples), indicate a significant positive relationship between the Presentation score and the Solution score. With such a strong correlation between a students’ ability to present a logical problem solving process and their ability to formulate & solve engineering problems, should we not consider teaching students how to effectively present their work?
Introduction

How often does it take more than once or twice through a problem to get to a correct solution? And how often are the encountered errors due to sign, typographical or calculator mistakes? It doesn’t matter if you are a student or faculty, we all make mistakes. It is especially important to be able to find errors in a solution before they propagate to critical parts of a problem. In addition, professionally or academically, it is important for others to be able to follow technical work in an effort to give feedback regarding conclusions from a solution. From a teaching perspective, faculty may discern critical errors/gaps in knowledge that may be addressed in future classes. However, students must first be able (or know how) to communicate this technical information.

Efforts are being made to help students improve communication skills early in their undergraduate career.[1] One of the ways to enhance technical communication skills is to teach students what a proper solution looks like early in their academic career. This work does not suggest a specific format for a clearly communicating a technical solution; engineers often fall back onto a “Given, Find, Solution” format. We do suggest that with increase in class sizes and therefore a demand for easier ways to assign and grade homework, one skill in particular is quickly diminishing; technical communication.

Students who only work with online homework systems, or those who do not get faculty input on homework solutions, may not ever be taught how to present an understandable technical solution. There is no doubt that online teaching tools are beneficial and that students perceptions and interactions are positive.[2] Some students, at the moment of the interview, state that they prefer online homework systems. However, these students are NOT surveyed at a later date and asked to reflect on their freshman learning experiences.

Although many studies have investigated the use of online homework systems in math [3], science [4–6], or engineering [3,7–10] courses, few have assessed the ability of a student to present a logical solution during the course. Authors in these studies usually correlate homework grades to final course or final exam grades. These studies did not show conclusive evidence that there is a significant impact of the homework different delivery methods on student’s grades. However, Davis & McDonald [11] proposed the use of online homework software does not instill the importance of presenting a logical and organized solution process.

Among many advantages of online homework, there are several disadvantages. One disadvantage is that online homework systems provides a “fill-in-the-blank” path to the final solution. Online homework systems do not allow for independent thinking by the problem solver. Since most online homework tools require numeric answers to be input, there is no assessment of the student’s ability to communicate a technical solution, understanding of details of a solution or their graphical/sketching skills.[12] Sketching has been noted as an important characteristic that is missing in recent engineering graduates [13].

The objective of this study is to assess the relationship between student's ability to present a clear and organized technical solution and their ability to correctly solve a problem. In this study, we assess student work using a four section rubric. The rubric includes scoring the 1)
problem set up, 2) generation of systems of equations, 3) mathematical execution for solution and finally, 4) overall presentation. The motivation for this work is to investigate the effect of requiring students to present their work in a clear, organized and logical manner on their overall performance of solving problems using both homework and exams. We aim to provide guidelines for students to learn how to present work to others. In addition we hope to instill an ability to communicate technical information – something that ABET looks for in our graduating students\[14\], and something that is currently missing from online homework systems.

**Methods**

We analyze homework and exam scores from 3 mechanics classes (two Statics and one Dynamics) over a 3 semester period. In each class, an average of 6 homework problems are assigned per week. Two of the six problems are graded each week. Each problem is graded using a 4 category rubric. The first three portions of the rubric all have to do with solving the problem: 1) problem set up, 2) generation of systems of equations, 3) mathematical execution for solution. For this analysis, these 3 categories are classified as the Solution of a problem. The final category of the rubric is 4) overall presentation. This portion of the rubric is evaluated for qualities such as:

1. Well sketched FBDs: drawn with straight edges, labeled dimensions, and reasonably accurate angles and dimensions.
2. Including fundamental equations used in analysis.
3. Aligned system of equations.
4. Matching symbols in FBDs with those in equations.
5. Indicating differences between vectors and magnitudes.

These qualities are required to present a clear technical solution. First, students are required to establish a clearly sketched technical diagram as the basis for their solution. In addition, students are required present a thorough solution process, by including the fundamental equation used in the problem solution. Requiring the alignment of the system of equations provides a method for students to assess their own errors. Finally, to show a clear understanding of the details of a solution, students are required to show consistency between diagrams and equations and to pay attention to the details of a vector versus a magnitude. We perform a regression of Solution Grade, an assessment of the solution, vs. Presentation Grade, an assessment of technical communication.

**Results**

Analysis of these data indicate that almost 70% of the Presentation Grade predicts the Solution Grade of a statics or dynamics problem.
Analysis of these data (over 1,000 samples), indicate a significant ($p=0.00$, $\alpha=0.05$) relationship between the Presentation score and a Solution score. The tables below show that the regression line is significant and that the intercept and slope components are significant.

Table 1: Regression of Solution vs. Presentation Grade

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.15386</td>
<td>0.01684</td>
<td>9.13</td>
<td>0.000</td>
</tr>
<tr>
<td>P-Grade</td>
<td>0.68284</td>
<td>0.01966</td>
<td>34.73</td>
<td>0.000</td>
</tr>
</tbody>
</table>

$S = 0.141391$  $R$-S$^2 = 54.4\%$  $R$-S$^2$(adj) = 54.4\%

The correlation coefficient is 73.76\% as calculated by the square root of $R^2$. In addition, the lack-of-fit test indicates ($p=0.077$, $\alpha=0.05$) that there is insufficient evidence to conclude that the model does not fit the data well.

Table 2: Analysis of Variance Results

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>24.107</td>
<td>24.107</td>
<td>1205.85</td>
<td>0.000</td>
</tr>
<tr>
<td>Residual Error</td>
<td>1010</td>
<td>20.191</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of Fit</td>
<td>51</td>
<td>1.311</td>
<td>0.026</td>
<td>1.31</td>
<td>0.077</td>
</tr>
<tr>
<td>Pure Error</td>
<td>959</td>
<td>18.880</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1011</td>
<td>44.298</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Discussion

Results indicate that there is a strong & significant correlation between how well students present their work and if problems are solved correctly. Here we show there is benefit to teaching students how to present a technical solution. Presenting their work in a clear and orderly manner can help students solve problems effectively. As young engineers still learning problem solving skills, we have an opportunity to positively affect a student’s abilities by educating and illustrating how to present a clear and orderly problem solution.

This work also makes the argument for faculty to encourage/enforce the presentation of a clear and orderly solution in student’s work. Online homework systems with “fill-in-the-blank” solutions does not alone instill an ability to communicate a technical solution. Therefore a hybrid homework system (online and handwritten) may be the best way to require homework. The online homework system can be used to assess problem solving and provide students practice in problem solving skills. A few handwritten (instructor graded) assignments should also be used as to teach students how to best present technical information in clear and logical manner. Previous work did see some benefit to this style of homework assessment.[11]

Conclusions

The increase of class sizes has led to new methods of homework assignment, problem solving and assessment. There is a general acceptance of these systems for their benefits, providing students an opportunity to practice solving as many problems with: 1) immediate solutions, 2) hints to answers if necessary, and 3) an easy assessment for faculty among many others. However there may be a long term effect that we are already observing[13] with a heavier reliance on computer technologies: a demise of technical communication abilities. We are not suggesting that online homework systems never be used; we are simply suggesting that one consider the skills that may be lost when there is no interaction or personal assessment of student’s skills. An optimal solution may be a hybrid option in which an online homework tool is used in conjunction with handwritten homework assessment. This has already been tested with positive results.[11]
References


