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## **Initial Investigation into the Effect of Homework Solution Media on Fundamental Statics Comprehension**

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## Introduction

Solutions to homework assignments are provided in many engineering science classes as a method of helping students see a “correct” solution procedure for the assigned problems. This work describes an initial investigation into the effectiveness of providing homework solutions in different media. Specifically, homework solutions are presented as either static PDFs of a completed analysis (Treatment 1) or annotated videos (sometimes called “screencasts”) of the analysis being developed (Treatment 2). Student performance on a pre/post Statics Concept Inventory and self-reported survey results are used as a measure of the effectiveness of the two different homework solution treatments.

## Background

The pedagogical theories that underlie this study are the existing work on a Statics Concept Inventory<sup>1,2</sup> and highly-guided instruction<sup>3</sup>. The Statics Concept Inventory (SCI) is used as a measure of student learning of fundamental statics concepts. In this study, an electronic version of the SCI (originally located at <http://dev.cihub.org>, now at <https://cihub.org>) was used. On cihub.org, the SCI is called the Concept Assessment Tool for Statics (CATS). In this paper, the acronym SCI will be used. The SCI was administered both at the beginning of the course and near the end of the course, measuring student performance gains. Using a concept inventory to objectively measure performance gains related to homework video solution media is a new effort introduced by this work. Some initial results of this investigation were previously presented as a work-in-progress<sup>4</sup>, but the full results are presented here.

The hypothesis underlying this study is that students will better learn the fundamentals of an analysis-type course if they can see solutions to typical problems being developed instead of just the completed analysis. If students watch the solution being developed, they can predict the next steps, think about what their analysis would look like, and check their solution step-by-step. If students have access to a completed analysis, they would be more likely to just check the “final answer” instead of checking the individual steps of their analysis. Additionally, watching an expert problem-solver (the instructor who prepares the solution) approach a problem can help students develop their own problem-solving strategies<sup>3</sup>. This instruction by example could be particularly effective if the rationale behind particular analysis steps, assumptions, and equations being used is given to the students (through written comments in the margins or audio commentary). Prior work supports the idea that students should find video problem solutions to be helpful and valuable<sup>5</sup>.

## Method

The participants in this study were undergraduate students enrolled in a first year required course “Statics and Mechanics of Materials.” Students were given access to the homework solutions (using the standard course management software, Angel) after the respective assignment was due. The homework solution provided was varied between a static homework solution (a simple PDF of a completed problem analysis from the instructor’s tablet PC, Treatment 1) and an annotated video of the homework solution (a screencast of the instructor’s tablet PC showing the problem analysis *as it develops*, Treatment 2). See Figure 1 for an example of a static homework solution. The annotated video of this homework solution consists of the lines of the solution appearing one by one, with a few seconds delay between each step. Therefore, the information presented is identical between the two treatments.

Given:

3-15 A farmer is extracting a post from the ground using the structure shown in Fig. P3-15. What force must the farmer apply to the cable system if the force required to remove the post is 2000 lb?

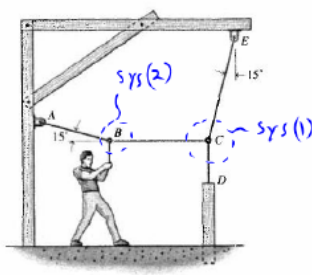


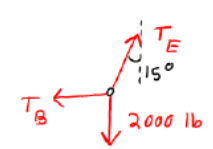
Figure P3-15

Find:  $\vec{F}$  that farmer pulls on cable

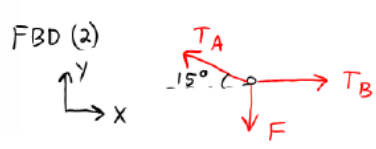
System: (1) p + C (2) p + B

Solution: First, draw the FBDs

FBD (1)



FBD (2)



Now, use equilibrium on each system

sys (1)  $\sum F_y = 0$

$$T_E \cos 15^\circ - 2000 \text{ lb} = 0 \quad \therefore T_E = \frac{2000 \text{ lb}}{\cos 15^\circ} = 2071 \text{ lb}$$

$\sum F_x = 0$

$$-T_B + T_E \sin 15^\circ = 0 \quad \therefore T_B = T_E \sin 15^\circ = (2071 \text{ lb}) \sin 15^\circ = 535.9 \text{ lb}$$

sys (2)  $\sum F_x = 0$

$$T_B - T_A \cos 15^\circ = 0 \quad \therefore T_A = \frac{T_B}{\cos 15^\circ} = \frac{535.9 \text{ lb}}{\cos 15^\circ} = 554.8 \text{ lb}$$

$\sum F_y = 0$

$$T_A \sin 15^\circ - F = 0 \quad \therefore F = T_A \sin 15^\circ = (554.8 \text{ lb}) \sin 15^\circ = 143.6 \text{ lb}$$

so the farmer must apply a force of

$\vec{F} = -143.6 \text{ lb } \hat{j}$

Figure 1. Example static homework solution (Treatment 1)

(Problem from Riley, Sturges, and Morris, *Statics and Mechanics of Materials* 2<sup>nd</sup> ed., John Wiley and Sons, 2002)

The static homework solution and the annotated video were both posted on the online course management site where students log in to access the solutions. The annotated video was encoded into a standard format that allowed embedded viewing in the student's browser. Both Treatment 1 and 2 were administered to the class in the same quarter.

Assessment of the impact of these homework solutions was performed by administering a Statics Concept Inventory near the beginning and end of the quarter. The intent is to compare changes in scores of students, specifically those who did and did not access the different homework solution formats. However, the access records for the solutions show very infrequent student access yielding a small sample size that makes comparisons difficult. In addition to the Concept Inventory scores, the results of a self-reported student survey asking about student's attitudes towards the homework solutions are presented.

Students were not required to view the homework solutions. This may introduce a self-selection effect where the strongest students access the solutions the most and experience the largest gain on the post-course SCI. However, the main comparison being made in this study is between the two different solution formats. The highly-motivated student will likely use the resources available, regardless of format. Comparison between the results of the two treatments will still be possible even if some students do not access the solutions at all.

This study was administered to six sections of the course in the Spring 2012 quarter, taught by three different instructors. For each instructor's two sections, one section received Treatment 1 and the other section received Treatment 2. No student received access to both treatments. Since each section has a corresponding section receiving a different homework solution type, but having the same instructor, the differences should be attributable to the treatments themselves. The overall involvement in these sections was around 150 students.

## Results

### *Quantitative Survey Results*

Near the end of the term, students were asked to complete a survey regarding the homework solutions. The survey included both quantitative and qualitative questions. The student responses to quantitative questions regarding the homework solutions are given in Table 1. Note that the sample size is 31 out of a potential pool of 150 students (a response rate of 21%). The biggest difference in the survey responses between the two treatments was that 44% of the Treatment 1 respondents said that they reviewed the solutions "only before exams" while only 7% of the Treatment 2 respondents had the same response. However, a chi square analysis shows that this difference is not statistically significant (along with all other differences in Table 1). Also of note is the disappointing revelation that 40% of the respondents said that they "never" review the homework solutions.

Table 1  
Frequency of Homework Solution Access Survey-- Spring 2012 (n = 31)

PDF n = 17; Video n = 14	PDF (Treatment 1)	Video (Treatment 2)
Approximately, how often do you review the homework solutions posted on the class Angel page?		
A few times per quarter	6%	13%
Once every other week	6%	13%
Once or twice a week	6%	7%
For most assignments	0%	20%
Only before exams	44%	7%
Never	38%	40%
Why do you review the homework solutions on Angel?		
To review for an exam	63%	47%
To check your homework	13%	20%
To review for the concept inventory	13%	20%
Other	13%	33%

The attitudinal question responses shown in Table 2 indicate that students in both treatment groups felt about the same (based on a paired t-test) towards the homework solutions and how they fit into the course as a whole.

Table 2  
Homework Attitude Survey (mean response)-- Spring 2012 (n = 31)  
Scale: 5 = Strongly Agree, 4 = Agree, 3 = Neither Agree nor Disagree, 2 = Disagree, 1 = Strongly Disagree

PDF n = 17; Video n = 14	PDF (Treatment 1)	Video (Treatment 2)
The homework solutions are easy to follow.	3.56	3.53
The homework solutions help me to understand the proper solution method.	3.56	3.80
The homework solutions help me understand the course material.	3.56	3.73
I know where to access the homework solutions.	3.44	3.73
The homework solutions are easy to access.	3.88	3.93
A video explanation of the homework solution being developed would be more useful than the pdf.	3.25	3.00
I have greater understanding of the basic fundamental concepts because of the homework solutions.	3.31	3.00
I have greater understanding of the basic fundamental concepts because of the examples worked in class.	4.19	4.07
I have greater understanding of the basic fundamental concepts because of doing the homework.	4.00	4.27
I have greater understanding of the basic fundamental concepts because of another aspect of class not previously mentioned.	3.00	2.80

### Qualitative Survey Results

The survey also included open-ended qualitative questions regarding the homework solutions. When asked what students liked most about the posted homework solutions, common responses (for both treatments) included the immediacy of the feedback (that the solution was made available before the submitted homework was graded and returned), emphasis on the solution process steps, showing the correct solution format, and that the solutions were great tools to study for the exam. The least liked aspect of the posted homework solutions was that many students indicated that they didn't know they were available.

Finally, students were given a chance to give general comments on the homework solutions. Students in both treatments expressed a general appreciation for the resource, although many more responses echoed the claims of not knowing the resource was available or not knowing where to access the solutions.

### Quantitative SCI Results by Treatment

Underlying this analysis is the assumption that the two treatment groups have similar initial understanding of the subject, and thus, similar pre-class SCI scores. Possible sources of a non-equal initial understanding are students re-taking the class to improve their GPA (only likely for three of the participants, as judged by enrollment records) as well as a scheduling reason for stronger students all being in the same course section. Figure 2 shows a histogram of the pre-class SCI scores for both treatments. From this data, there is no statistically significant difference in the pre-class SCI scores between the two treatments. Therefore, the assumption of equal starting points is supported.

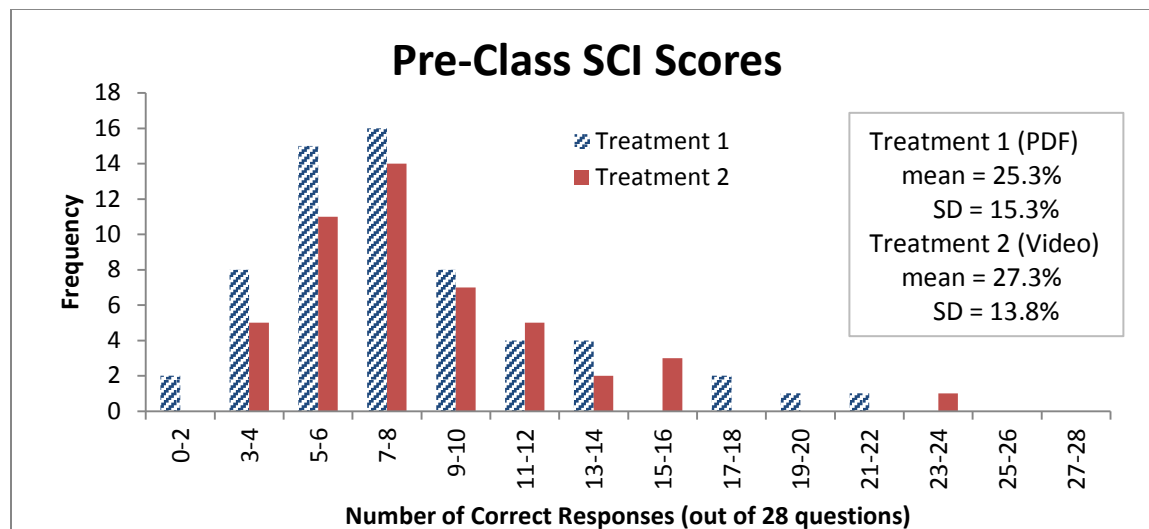


Figure 2. The histogram of pre-class SCI scores for both treatments shows statistically similar initial starting knowledge of statics fundamentals. Therefore, differences post-class should be attributable to the treatments themselves.

Our initial investigation of the results focused only on the post-class SCI scores of students who responded to the survey request (thus, students represented by Tables 1-2). The post-class SCI scores averaged 12.6% higher for the Treatment 2 students (video) than for the Treatment 1 students (pdf). This difference was statistically significant ( $M_{pdf} = 36.54\%$ ,  $sd = 13.42$ ,  $n = 17$ ;  $M_{video} = 49.14\%$ ,  $sd = 19.77$ ,  $n = 14$ ;  $t$ -test  $p = 0.051$ ). This result encouraged further analysis of the data. Specifically, when the sample is expanded to students who *did not* respond to the survey, do the differences remain? In addition, when the sample is restricted to the students who accessed the homework solutions most often, do the differences remain?

Due to a technical issue, access records of each homework solution file (both pdf and video) are not available. However, the access records for the master folders containing the solutions (one master folder for each treatment group) are available. Taking the master folder access records as a proxy for the number of solutions viewed yields a surprisingly low average of 1.4 access times per quarter ( $sd = 2$ ). The number of times accessing the homework solutions is not correlated to post-class SCI score or to survey responses, for either treatment. This result may be because of the relatively low access numbers. In addition, there were no significant differences in the access records between the two treatment groups.

Most access records for the homework solutions were in the 0 – 4 times per quarter range with a maximum of 9 times per quarter. In this quarter, there were approximately 35 homework assignments. Since there were only three exams and one final in this course, these results suggest truth behind the student claim that they mainly view homework solutions as a study aid for exams only. If a student were to access the solutions to study for an exam, they might conceivably only access the master folder once and navigate between the many available solutions. In contrast, a student who was using the posted solutions as intended to check their homework solutions after each assignment would necessarily access the master folder once for each separate checking session.

When only considering students who accessed the homework solutions at least once (regardless of if they responded to the survey) the change (post – pre) in SCI results are statistically insignificant ( $M_{pdf} = 20.4\%$ ,  $sd = 14.3$ ,  $n = 26$ ;  $M_{video} = 23.4\%$ ,  $sd = 18.9$ ,  $n = 22$ ). Analysis of the post-class SCI score also yields no statistically significant differences. Figure 3 shows a scatterplot of the absolute change in SCI score (post – pre) versus the amount of solution folder access. This data is presented as *change* in SCI score instead of *final* score to focus the analysis on the learning improvement due to the different treatments.

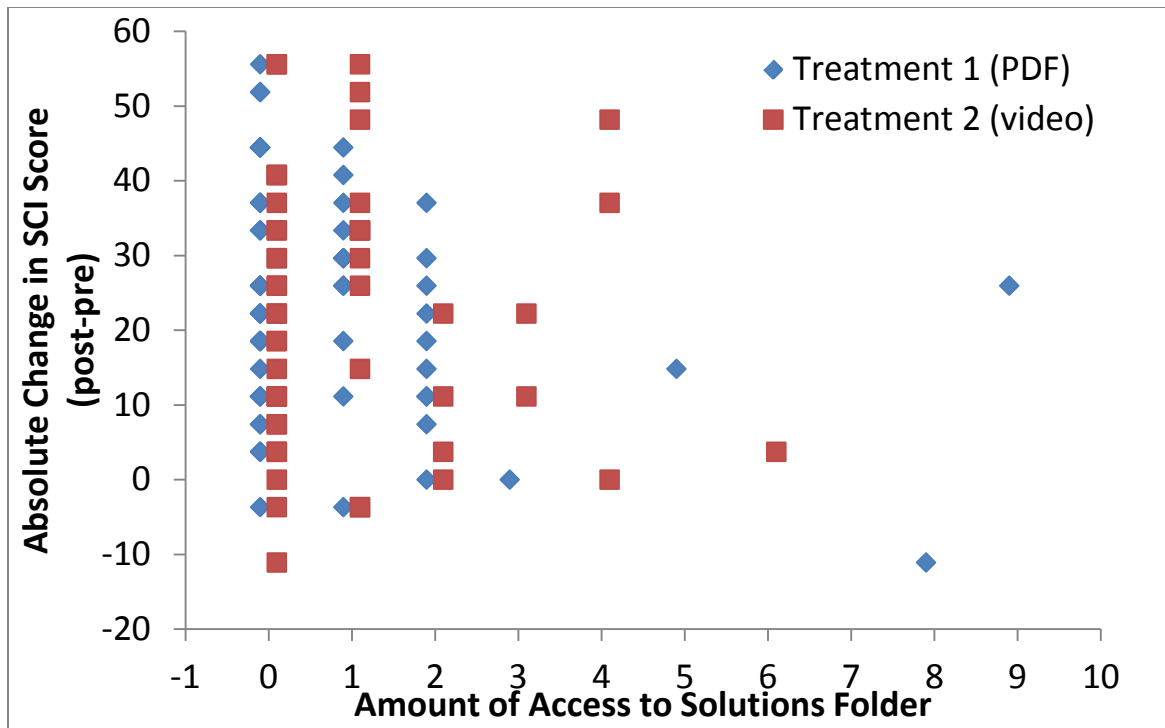


Figure 3. Both treatments show improvement in SCI score for most students. Additionally, the score improvements do not appear to be closely correlated to the solutions folder access records.

It seems reasonable that students might have accessed the solutions folder once or twice out of curiosity or to study for a test and not to actually use the solutions as intended. Restricting the analysis to students who accessed the homework solutions more than twice (regardless of if they responded to the survey) the results are not statistically significant ( $M_{pdf} = 7.4\%$ ,  $sd = 16.3$ ,  $n = 4$ ;  $M_{video} = 20.4\%$ ,  $sd = 19.1$ ,  $n = 6$ ;  $p = 0.15$ ) but are trending towards the results seen in the initial investigation. A similar trend is found when analyzing the post-class SCI scores. Further research is needed to determine if these trends hold for larger sample sizes and other courses.

The access records in combination with the survey results seem to show that the intent of using homework solutions to develop understanding of expert problem-solving on a repeated, regular basis does not seem to have been met. Coaching of students on the availability of the resource and how to best use the solutions on a regular basis might strengthen the results and trends seen in this study.

#### Conclusion and future work

The results of this study indicate that students do not seem to naturally use instructor-provided homework solutions as a way of checking their own individual homework assignments, despite the belief that the solutions help them understand the course material. However, they do seem inclined to use the resource when studying for exams. One possible reason for the low utilization



of the resource is that the course instructors for the quarter under study were not the ones creating the solutions. This single step of separation between the students and the resource creator may have significantly reduced the immediacy of the solutions. More frequent in-class reminders about the availability of the solutions may have increased the student's access frequency of the solutions. Finally, as the course studied is primarily a 1<sup>st</sup> year class, student maturity and professionalism towards the course itself may have also played a role.

The only strong difference in post-class SCI scores was measured between the two treatments for those who responded to the survey. For this group, the video solutions (Treatment 2) appear superior to the pdf solutions (Treatment 1) when measuring post-class SCI score. A trending, but not significant difference (both for post-class SCI score and for SCI score improvement) was seen between the two treatments for students who accessed the master solution folder more than twice over the quarter, but the sample size was small. When all of the students who accessed the master solution folder (even once) are included in the analysis, no statistically significant differences are found. However, the low overall utilization of the resource may be masking the potentially significant difference between the two treatments seen in the high-access group.

This investigation into homework solution format, as well as best-practices with regards to encouraging student use of the resource, will continue. Specifically, investigations are planned to study if providing students with a worked-out-homework solution (from a similar but not assigned problem) *before* the assignment is due is a more effective intervention than providing solutions after the due date.

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