
AC 2011-54: ENHANCED STATICS LECTURES VIA IN-CLASS WORK-SHEETS

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Enhanced Statics Lectures via In-Class Worksheets

This paper presents research on the effectiveness of the use of lecture worksheets to assist students in understanding and learning concepts taught in the undergraduate Statics course. Statics is a course that requires many students to reproduce time consuming schematics during lecture. These schematics begin with simple 2D systems at the start of the semester and progress towards more complicated 3D systems taxing lecture time even further. To address this problem, lecture worksheets containing pre-drawn schematics were developed for the entire Statics curriculum and provided to the students. The use of lecture worksheets decreased the time spent by students towards reproduction of lecture notes and allowed additional time for higher level learning through in-class individual and group problem solving activities.

Approximately 72 students at the University of Pittsburgh at Johnstown participated in this research to determine the effectiveness of lecture worksheets. Learning of Statics concepts for an Experimental group consisting of 38 students and 24 students in a Control group was measured using the Statics Concept Inventory (SCI). Furthermore, students' spatial visualization skills as well as their academic GPAs were correlated to their Post- SCI scores. Results showed more students with GPAs lower than 3.0 in the Experimental group scored above the mean Post- SCI score than students in the Control group. In addition a statistically positive relationship between spatial visualization skills and performance on the SCI was observed for both groups.

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Introduction

Statics is a general undergraduate engineering course commonly enrolled by students in their sophomore year and is part of the engineering curriculum for civil and mechanical engineering programs. It is a course that provides a basic foundation for understanding and mastering engineering mechanics concepts that students will encounter in their junior and senior years. Statics applies the knowledge that students have learned in Calculus I and Physics I and uses it to analyze forces in 2D and 3D mechanical structures such as in trusses and machines. Lectures inherently require extensive 2D and 3D images/schematics to be drawn by the students and the instructor. Transcribing such schematics is time consuming and may even distract the student from what is being taught during lecture. To address this problem, lecture worksheets can be utilized. It can be used to minimize transcribing time and maximize student learning. Redish⁹ indicates the importance of facilitating note taking for students towards improved student learning.

Approach

Approximately 72 students at the University of Pittsburgh at Johnstown participated in this research to determine the effectiveness of lecture worksheets facilitating the learning of Statics. An Experimental group consisting of 38 students was given lecture worksheets and was taught by the instructor who developed them. A Control group consisting of 24 students who did not use the worksheets was taught by another instructor. A typical lecture worksheet is shown in Figure 1. Lecture worksheets consisted of pre-drawn diagrams, sketches and problem statements. It included an average of two problems that were solved by the instructor and one in-class problem solved by the students. Time saved by the use of these worksheets was used to solve and discuss problems and allowed the instructor to pause and provide time for students to absorb lecture material. Frequently, problems were solved by teams of students working in groups of two or three while the instructor wandered through the class to monitor class progress and assist students needing help.

To evaluate the effectiveness of the lecture worksheets the SCI was administered to all students at the beginning and end of the semester. Concept inventories were pioneered in 1992 by Hestenes¹ resulting in the widely utilized Force Concept Inventory. Since then multiple engineering and physics disciplines now utilize concept inventories for teaching and learning assessments. The SCI utilized in this research was developed by Steif, Dollar & Dantzer^{2,3}. The 30-minute exam consists of 27 multiple choice questions covering nine Statics concepts (three questions for each topic) as categorized in Table 1.

This research also investigates students' spatial visualization skills and how it relates to their learning of the Statics concepts. Spatial visualization is defined as the ability to mentally, rotate, twist, or invert pictorially presented stimuli⁴. Ample research shows that some students, both men and women, have difficulty with spatial visualization⁵. Spatial visualization skills are necessary for students to succeed in engineering⁶⁻⁸. To measure the effect of students' spatial visualization skills the Purdue Visualizations of Rotations (PVR) test developed by Bodner and

Guay⁹ was used. It is a 15-minute exam that consists of 20 multiple choice questions that asks users to predict the views upon rotation of three dimensional objects.

Table 1. Description of the concepts in the SCI.

1	Free Body Diagram – Separating Bodies
2	Newton’s 3 rd Law
3	Static equivalence of combinations of forces and couples
4	Direction of forces at roller
5	Direction of forces at pin-in-slot joint
6	Possible directions of forces between frictionless contacting bodies (e.g. pin joint)
7	Representing a range of forces using variables and vectors
8	Limit on the friction force and its trade-off with equilibrium conditions
9	Equilibrium conditions

Results

The PVR exam measures the ability of students to mentally rotate three-dimensional objects. Figure 2 correlates existing knowledge of students’ spatial visualization skills (Pre- PVR scores) on students’ success in learning Statics concepts which is measured by their Post- SCI scores.

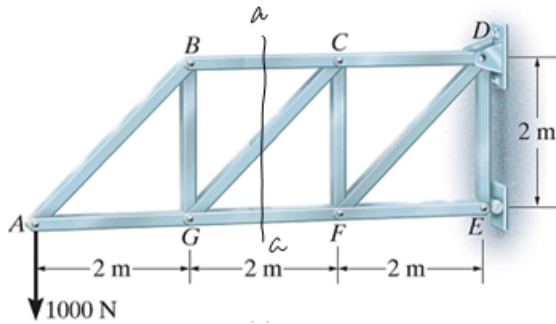
Students’ Post- SCI scores for the Experimental and Control groups were 9.3 and 9.6, respectively, and they are indicated by the horizontal lines in Figure 2. Students’ Pre- PVR scores for the Experimental and Control groups were 14.2 and 13.4, respectively, and are indicated by the vertical lines in Figure 2. The horizontal and vertical lines divide the graphs into quadrants with the lower left quadrant showing students coming into Statics with low spatial visualizations skills and who subsequently struggled with learning Statics concepts. The top right quadrant shows students who performed well in both the Pre- PVR and the SCI tests. Correlation coefficient for the Experimental and Control groups were 0.6 and 0.4, respectively.

Figure 3 shows the relationship between students’ GPAs to their Post- SCI scores. The figure has also been divided into quadrants using a GPA of 3.0 and the mean Post- SCI score for each group. Figure 3 shows that for both the Experimental and Control groups, majority of the students with GPAs higher than 3.0 performed above the mean Post- SCI scores. However, the distinction between the two groups is exhibited when analyzing the Post-SCI scores of students below the 3.0 GPA range. Although not shown in Figure 3, more students in the Experimental group (six out of 11 students) showed Post-SCI scores above the mean than students in the Control group (two out of seven students). This is noteworthy as students with GPAs below 3.0 is a group that are at risk of dropping out of the engineering technology program.

SECTION 6.4 THE METHOD OF SECTIONS

Use this method when you want to find:

For example, find the force in member _____.

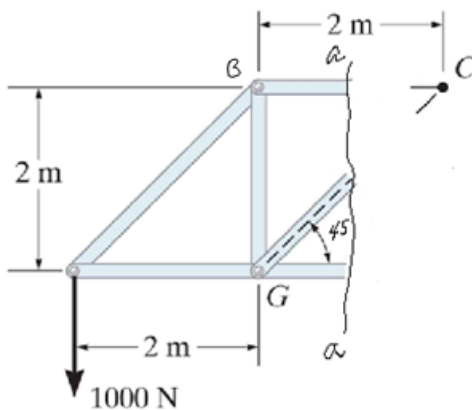


Step 1. To find the force in _____, “section” the body along $a-a$.

Step 2. Draw the exposed _____ as _____ on the sectioned FBD.

Step 3. Apply the equations of equilibrium to yield direct solutions, if possible.

ASSUMPTION: If the _____ is in equilibrium, then _____ are also in equilibrium.



Step 4: Apply the Equilibrium Equations

How to determine the proper sense of a force:

Option 1: ASSUME all internal forces are in _____.

If the final answer for the force is _____, then the sense of the force was assumed properly.

If the final answer for the force is _____, then the sense of the force was assumed incorrectly. It is opposite of what was assumed.

Figure 1. A sample lecture worksheet. Image of the trusses are from Statics by Hibbeler 12th edition.

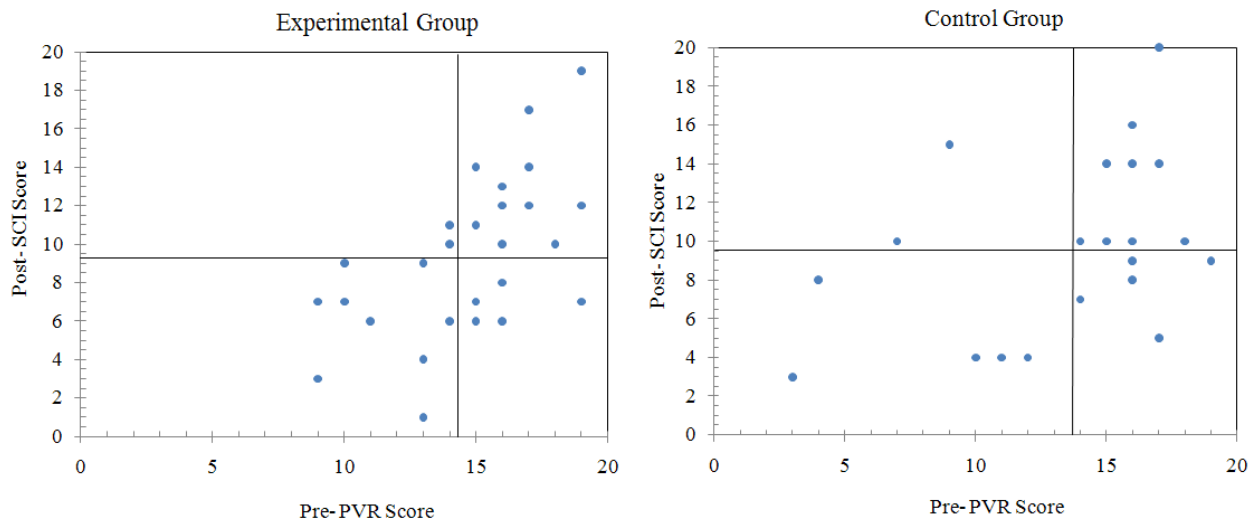


Figure 2. Post- SCI and Pre-PVR scores from both the Experimental and Control groups.

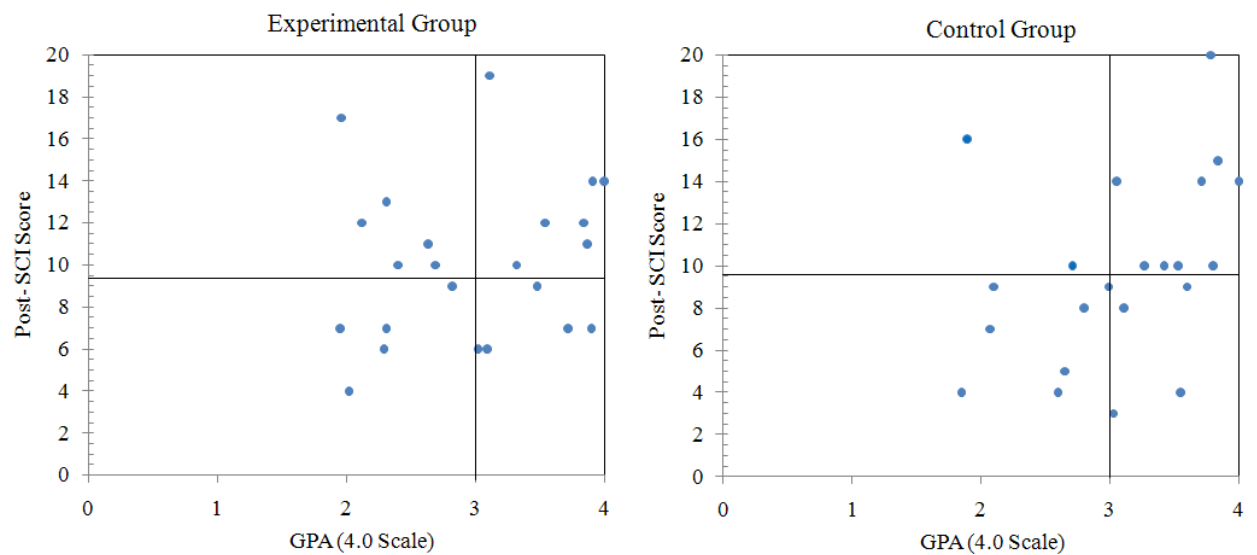


Figure 3. Post- SCI and GPA for both the Experimental and Control groups.

Students were surveyed about their perceptions of the lecture worksheets’ usefulness towards their learning. On a five-level Likert scale (1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4-Agree, and 5-Strongly agree), 14 students (48%) responded with a score of four or better, 10 students (34%) responded with a score of three, and five students (17%) responded with a score of less than three. Specific responses from the students are available in Appendix 1 and 2.

Based upon students’ comments, the lecture worksheets minimized the actual note taking time and allowed them to dedicate more time towards learning. In addition, the lecture worksheets presented information methodically which assisted them to organize their thoughts and remain

engaged in learning during lecture periods. Students used the following phrases to describe the benefits of lecture worksheets: “created good flow”, “organized the thoughts”, “organized method of notes”, “notes were organized and easy to review for exams”, “saves time in transferring figures and other basic info, so also to better focus on concepts of lecture”, “material already printed and you didn’t miss an idea during the lecture”, “more time to toy and understand concepts rather than writing/drawing problem statements”, and “saves time in class so we can cover more material”. It may be these beneficial attributes of the worksheets that allowed the students with GPAs below 3.0 to achieve Post- SCI scores comparable to those of students with GPAs higher than 3.0 as shown in Figure 3.

Students commented on the drawbacks of the lecture worksheets. Many of them felt pre-written procedural problem solving steps, summary of formulas for various sections, and fill-in-the blank sentences hindered their learning. The students indicated that they learned better when they write their own notes. They felt writing important concepts in their own words would have been more helpful to them. Comments such as “I remember better when I write things out myself.” were not uncommon in students’ responses. Based upon these comments the lecture worksheets have been modified and many of the fill-in-the blank items deleted to allow students to reflect and write in their own words the concept being learned.

Summary

Approximately 72 students at the University of Pittsburgh at Johnstown participated in this research to determine the effectiveness of lecture worksheet. Learning of Statics concepts for an Experimental group consisting of 38 students and 24 students in a Control group was measured using the SCI. Furthermore, students’ spatial visualization skills as well as their academic GPAs were correlated to their SCI scores. Results showed that statistically, there is a positive relationship between spatial visualization skills and how well they learned Statics concepts. It was also found that more students with GPAs lower than 3.0 scored above the mean Post- SCI value in the Experimental group than students in the Control group. Possible reasons for this difference may be due to the use of lecture worksheets allowing additional time for more problems to be solved, opportunities for in-class demonstrations, and a slower paced lectures that allowed students to think about concepts or problems. In Fall 2011, this research will be continued with the sample size doubling and providing stronger statistical conclusions. In addition, 3D computer models to assist students with poor spatial visualization skills and improved lecture worksheets will be utilized.

Acknowledgement

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Appendix 1. Responses from students to the question: What were the benefits of the worksheets to you?

Thirty-one students participated in a written response survey. Nine comments (#1-10) indicated that the lecture worksheets helped the flow of lecture, allowed them follow lecture, and kept their thoughts organized; five comments (#11-14) indicated the time-saving benefit of the lecture worksheets.

1. Didn't have to use a lot of loose-leaf paper. Everything was laid out in the order you thought necessary. The diagrams were already drawn precisely.
2. Notes were organized and easy to review for exams. Problem statements in notes made working problems faster because you didn't have to write out problem or draw diagram.
3. Problems were presented in a similar manner to exams knew what to expect.
4. Organized the thoughts.
5. It was nice to have an organized method of notes. The drawings were much better than hand drawing everything. I thought they were very helpful and I liked them. Created good flow.
6. Organization of course materials and concepts. Saves time in transferring figures and other basic info, so also to better focus on concepts of lecture.
7. Time in class was focused on how to do the problem rather than drawing each figure, which takes a great deal of time. Notes were kept more organized.
8. The diagrams were already drawn for me to see clearly, more examples were done this way.
9. Physically took less notes by hand- material already printed and you didn't miss an idea during the lecture-i.e. if instructor went too fast-had basic idea already typed out.
10. They were my class notes but they had more to help me study.
11. There was less note taking included and more time to toy and understand concepts rather than writing/drawing problem statements.
12. If I miss class I know what was covered. Saves class time writing notes and drawing diagrams. Diagrams are much neater than I could quickly draw, gives good example problems to do.
13. Diagrams were already drawn and notes were in a good format. It cuts note taking time down.
14. Saves time in class so we can cover more material.
15. Didn't have to take notes.

Appendix 2. Responses from students to: What were the drawbacks of the provided worksheets to you?

Thirty-one students participated in a written response survey. Twelve (#1-12) comments indicated that students realized that writing notes help them learn, three responses (#13-15) indicated that more complex problems should be presented during lecture, one student (#16) wanted additional problems to be solved during class, seven students commented (#17-23) that they did not like the fact that some of the notes provided were never used and additional notes provided during the semester was not easily incorporated into their lecture notebook, four students (#24-27) indicated difficulty on writing on them due to the pre-drawn ruled lines.

1. It is sometimes good to write things to help commit them to memory better. Though we usually wrote in important equations, so overall, I think they're helpful.
2. Much of the time we just filled in a word or two here and there. Many people learn by writing notes, not fill in answers. Also, the examples in the notes were not as difficult as many of the homework problems.
3. The not taking of notes could have prevented one to not write notes in their own language they could understand.
4. I remember better when I write things out myself. May not have written things I typically would in a normal lecture because was following notes.
5. Notes weren't explained as well as if you write everything by hand.
6. Since we weren't actually writing a lot of notes it became harder to learn the material. Fill in the blank isn't very good for getting students to memorize/learn how to do a problem.
7. For me, I remember and understand information more when I write it out completely instead of just reading it. So not being able to write out my notes was a slight drawback.
8. Caused me to not study as much because I used them as a crutch. Wasn't forced to learn the concepts as well as possible because I wasn't forced to memorize the formulas.
9. Didn't write down everything since it was already written for you, so I didn't retain as much information. The problems were basic compared to the mastering engineering assignments.
10. I remember better when I write things out myself. May not have written things I typically would in a normal lecture because was following notes.
11. Didn't have to take notes, resulting in not learning the material.
12. I learn things better when forced to copy down and put it into my own words, so the sheets somewhat hurt me there.
13. I felt that the examples we did in class were rather basic compared to the homework problems, which wasn't always helpful. Some examples were not as in depth as the hw so it was hard to understand some of the hw problems because the examples on the worksheets were less involved.
14. Not enough variety of examples.
15. Need more examples to help us better understand concepts?
16. Didn't use half of them, and they took up too much space.
17. Didn't use a lot of the pages in the worksheet packet.
18. Didn't use half of them, and they took up too much space in the folder.
19. They become jumbled with other course notes. If together with auxiliary notes, they become hidden and hard to find. If kept separate homework and studying involves a lot of switching back and forth.

20. I wish we would have stuck to the notes instead of staying away.
21. Too many unused pages. Felt like that hindered studying.
22. Too much paper wasn't used.
23. The lines through the paper made it hard to read my own notes at times.
24. None really just that writing on them was difficult.
25. Most weren't used, hard to find correct page example: (number system 1,2,3,4,1,2,1.. Not 1,2,3,4,5...).
26. Not enough space for amount of writing and work on drawings and solving problems.