Efficient Statics Lecture Through the Use of Worksheets

Eunice E. Yang, Beverly W. Withiam
Engineering Technology Division
University of Pittsburgh at Johnstown, PA 15904

This paper presents research on the effectiveness of the use of lecture worksheets and 3D computer models to assist students in understanding 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 of student learning through in-class individual and group problem solving activities.

The Statics Concept Inventory developed by Steif and Dollàr was used to assess the effectiveness of the lecture worksheets and the exposure to solving additional problems in class. Student performance in terms of test mean score was similar to a university presented in the research by Steif and Dollàr. Survey results showed that approximately 50% of students who's GPAs were between 2.0 and 2.9 (on a 4.0 scale) felt that the lecture worksheets were helpful. Thirty-three percent of the students who's GPAs were between 2.0 and 2.9 received course grades of B or better. For students whose GPAs were between 3.0 and 4.0, 89% of these students were either neutral or felt it was not helpful. Such results indicate the effectiveness of these teaching tools for those students who would have found Statics challenging.

Introduction

Statics is a challenging course and is part of the engineering curriculum for civil and mechanical engineering programs. 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. Statics 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 trying to be taught during lecture. To address this concern, lecture worksheets can be utilized. It can be used to minimize transcribing time and maximize student learning. Redish[9] indicates the importance of facilitating note taking for students towards improved student learning. Danielson and Mehta[2] established complete lecture materials for instruction in engineering mechanics incorporating Kolb learning model[5] and accounts for different student learning styles which assists students to be accountable for their learning, allows instructors to foucs on main concepts, and yields a engaging learning/teaching environment for students and the instructor.

As teachers and instructors, being autonomous in our own lecture delivery, content, and style allows our own passion to become evident to the students thereby making the lectures robust and engaging. This paper brings to attention that a deviation from traditional lectures can result in improved student learning.

Approach

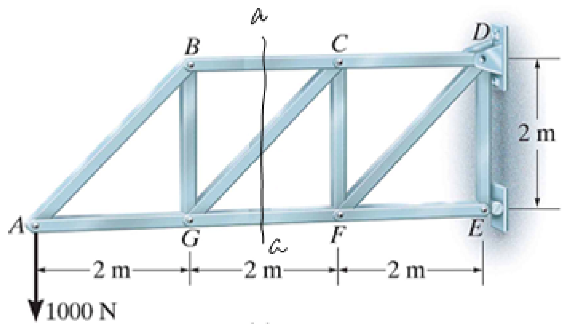
Lecture worksheets consisting of pre-drawn diagrams, sketches and problem statements were used for the entire statics curriculum were distributed to 38 students in an engineering technology program. A typical lecture worksheet is shown in Figure 1. Time saved by the use of these worksheets was used to solve additional problems by the students as well as the instructor. These additional problems facilitated peer-to-peer instruction in small groups as well as in-class discussions of difficult concepts. In general, the lectures were conducted in a two-way conversational style between the instructor and the students rather than one dimensional instruction from the instructor to the students. There were 32 lecture worksheets consisting on average of two problems solved by the instructor and one in-class problem solved by the students. During the time the students worked together to solve the problem, the instructor was able to wander through the class and assist those needing help and assess class understanding of the lecture material. After majority of the students completed the in-class problem a short discussion on approach and the correct solution were made.

SECTION 6.4 THE METHOD OF SECTIONS

Use this method when you want to find:

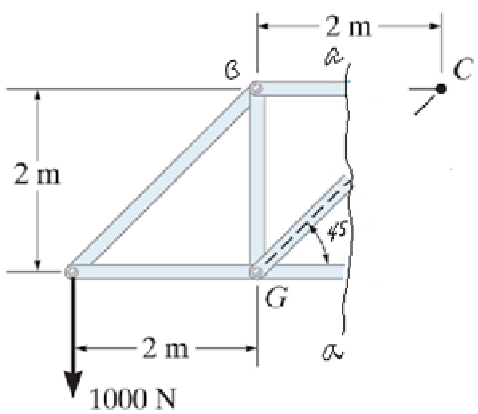
____

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.

Page 1

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

Evaluation

To evaluate the effectiveness of the lecture worksheets a statics concept inventory was administered to all students at the end of the semester. Concept inventories were pioneered in 1992 by Hestenes, Halloun, and Wells[3] 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 Statics Concept Inventory[11] utilized in this research was developed by Paul S. Steif at Carnegie Mellon University and the co-developer was Anna Dollàr from University of Miami at Ohio. The 30-minute exam consists of 27 multiple choice questions covering nine statics concepts (three questions for each topic) as categorized in Table 1.

Table 1. Description of the concepts in the Statics Concept Inventory Exam

A	Free Body Diagram – Separating Bodies
B	Newton's 3rd Law
C	Static equivalence of combinations of forces and couples
D	Direction of forces at roller
E	Direction of forces at pin-in-slot joint
F	Possible directions of forces beetween frictionless contacting bodies (e.g. pin joint)
G	Representing a range of forces using variables and vectors
H	Limit on the friction force and its trade-off with equilibrium conditions
I	Equilibrium conditions

Results

The results of 27 students who took the concept inventory are compared to published research by Steif and Dollàr[11]. The frequency of the total score is shown in

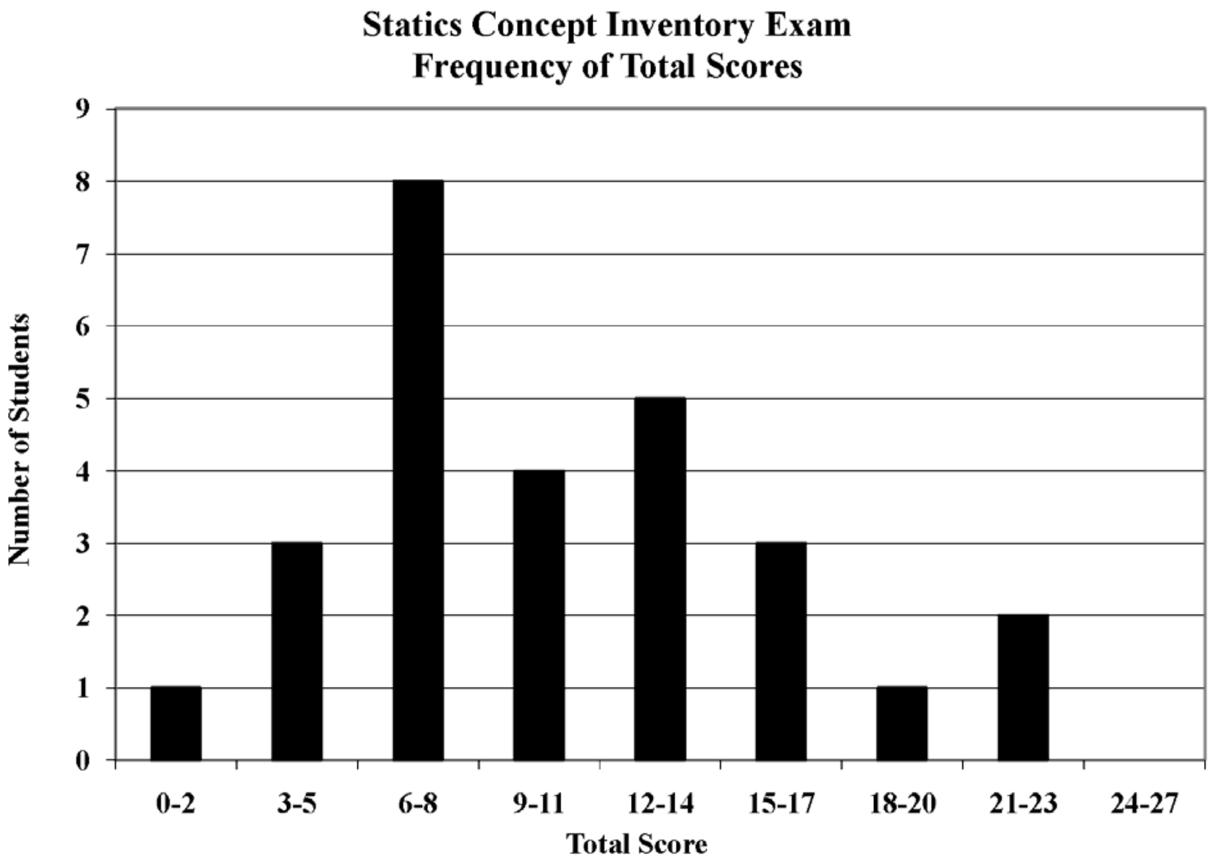


Figure 2. The mean score for 100 students at Carnegie Mellon was 21 (home institution of the primary developer). The co-developer of the inventory exam administered the exam to 60 students at University of Miami at Ohio and yielded a mean score of 14. A third university whose name was not specified in the research paper, but was in similar college rank to Carnegie Mellon University, had 225 students take the exam yielding a mean score of 15. The mean score for the students in this research was 11 with 31% of the students scoring greater than or equal to 14.

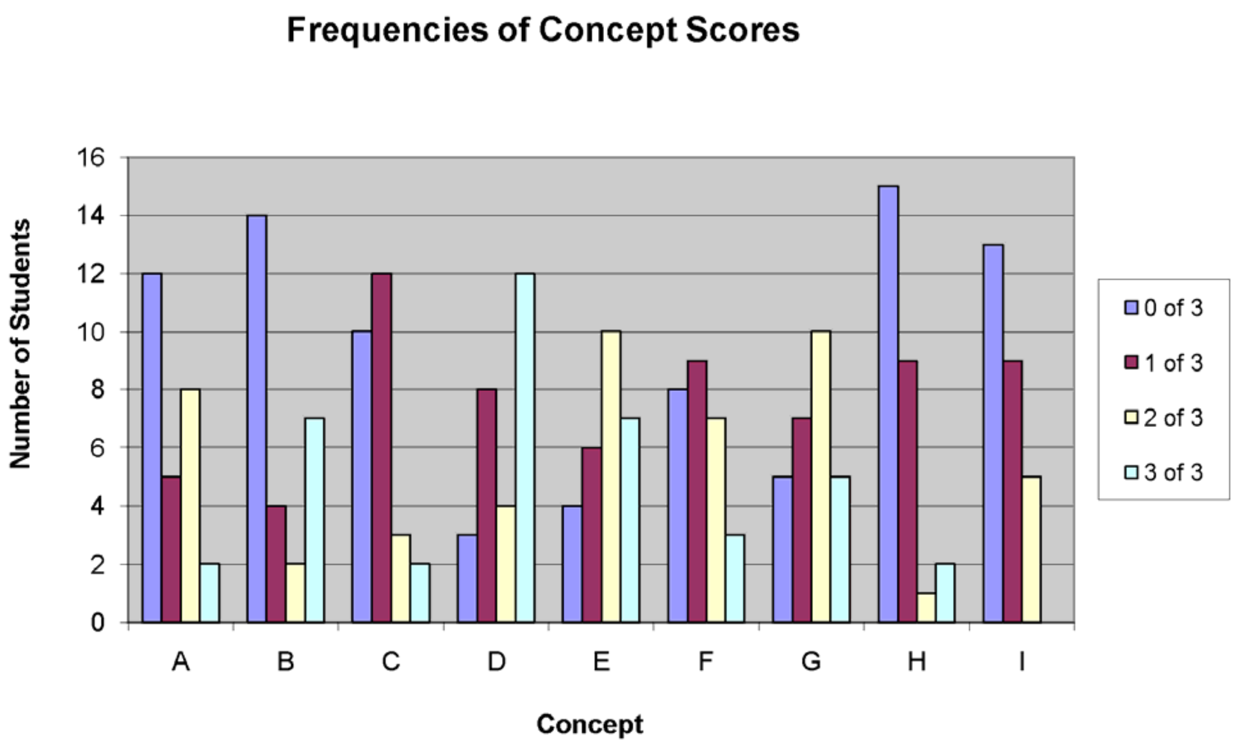


Figure 3 shows the frequency of the nine concepts that were answered correctly. For example, for Concept D, 12 students answered all three questions correctly, four students answered two out of the three questions correctly, and eight students answered one out of the three questions correctly.

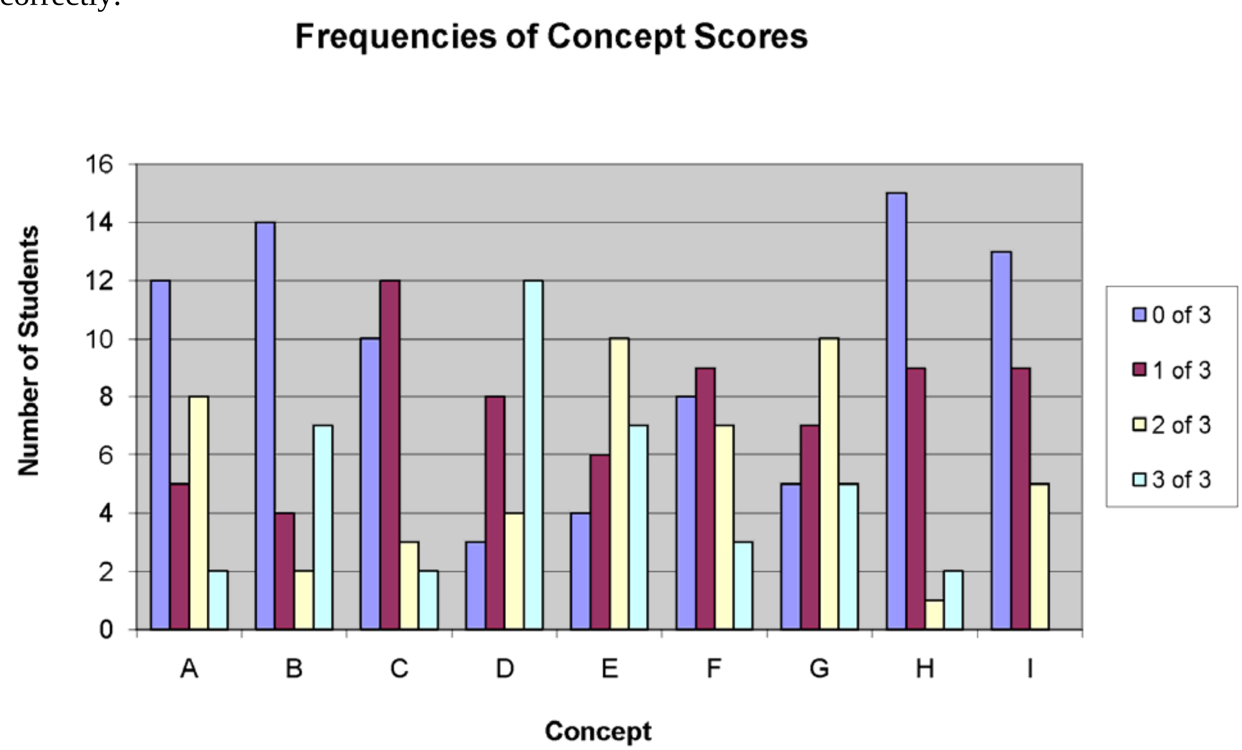


Figure 3 can also shows the strengths and weaknesses of students' understanding of each of the nine concepts. This figure shows that performance on Newton's 3rd Law (Concept B), limit on the friction force and its trade-off with equilibrium conditions (Concept H), and equilibrium conditions (Concept I) were the weakest identifying a need that these concepts should be emphasized when Statics is taught again.

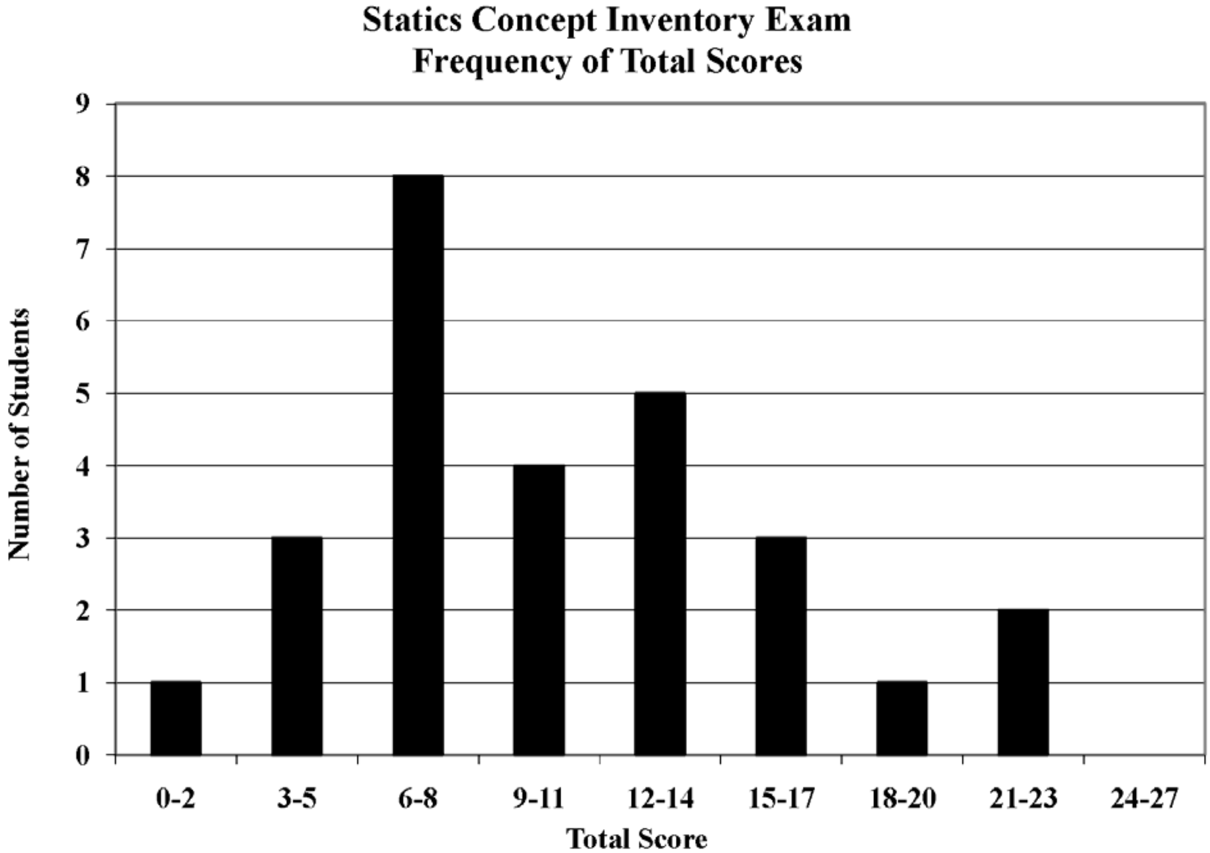


Figure 2. Statics concept inventory exam results.

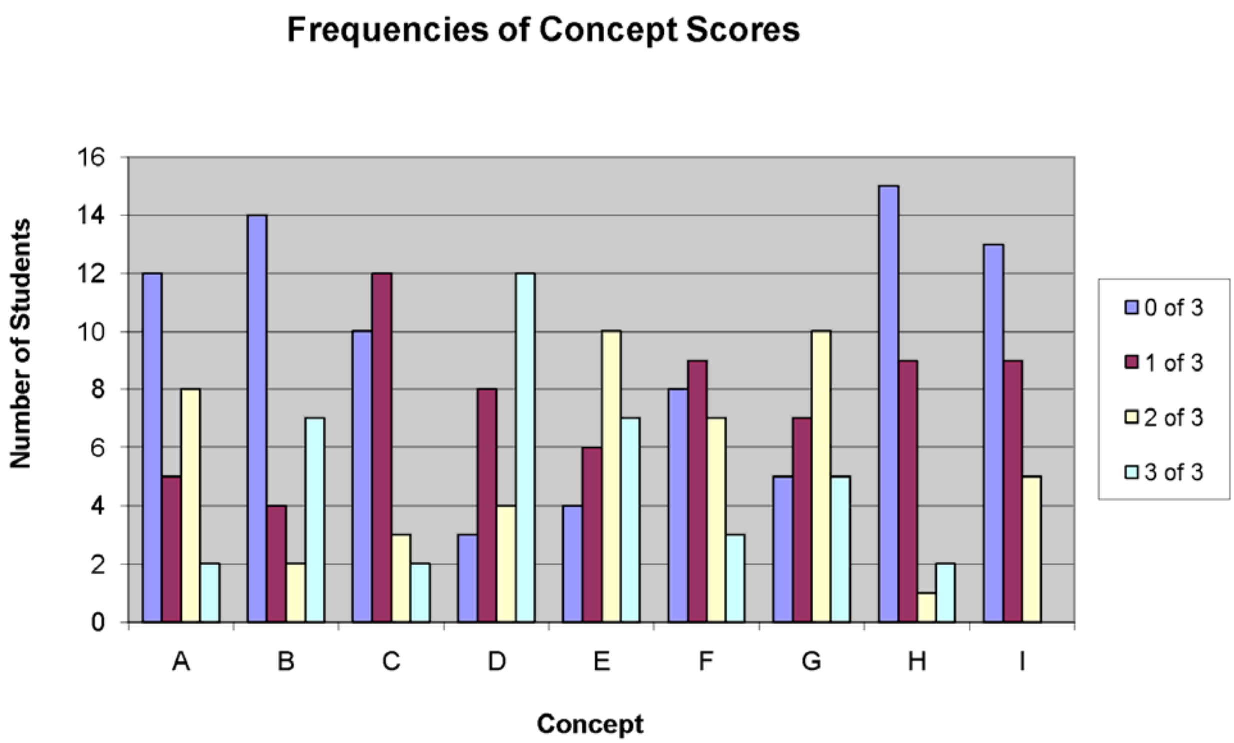


Figure 3. Number of students who correctly answered statics concepts A through I as categorized in Table 1.

At the end of the semester, students were asked if the lecture worksheets were helpful to them. Of 38 students who answered the survey, 8% of the students responded Strongly Agree, 21% of the students responded Agreed, 29% of the students responded that they felt Neutral, and 16% responded Disagree or Strongly Disagree. These responses were correlated with student GPAs and are shown in Figure 4. It is interesting to note that approximately 50% of those students whose GPAs were between 2.0 and 2.9 responded with Agree or Strongly Agree (dashed rectangle) and approximately 89% of the students with GPAs greater than 3.0 were either neutral towards the helpfulness of the worksheets (solid rectangle). It seems that the lecture worksheets assist those who struggle academically and help them to learn and understand Statics better. This type of improvement of poor to average student's learning was also observed by Mazur[6] in his use of diagnostics tests and is considered to be an important effect.

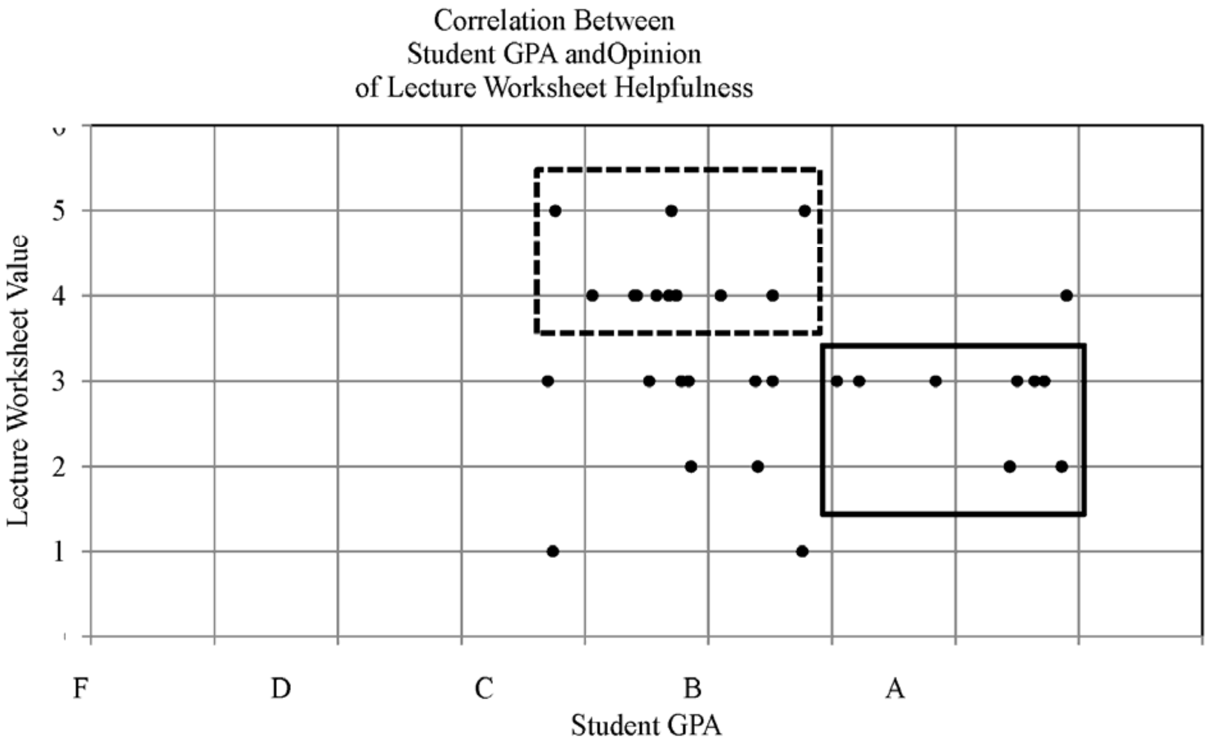


Figure 4. Student response to "Were the lecture worksheets helpful to you?". 1- Strong disagree, 2- Disagree, 3-Neutral, 4-Agree, 5- Strongly Agree. Each dot represents a student's GPA and his/her corresponding answer.

Correlation between students' Statics course grades and their GPAs are shown in Figure 5. Students with GPAs above 3.0 on a 4.0 scale performed as expected by earning grades of B or better (solid rectangle). Approximately 21% of the students in the class whose GPAs ranged between 1.9 – 2.9 received final course grades of B or better (dashed rectangle) indicating possible benefits of lecture worksheets and the opportunity to solve additional problems. There are those students in the GPA range between 1.9-2.9 that earned grades of D or lower. These students are considered to be outliers and their course performances are not taken into consideration in assessing the helpfulness of the worksheets. Help may need to be extended to these students differently and will need to be addressed in the future.

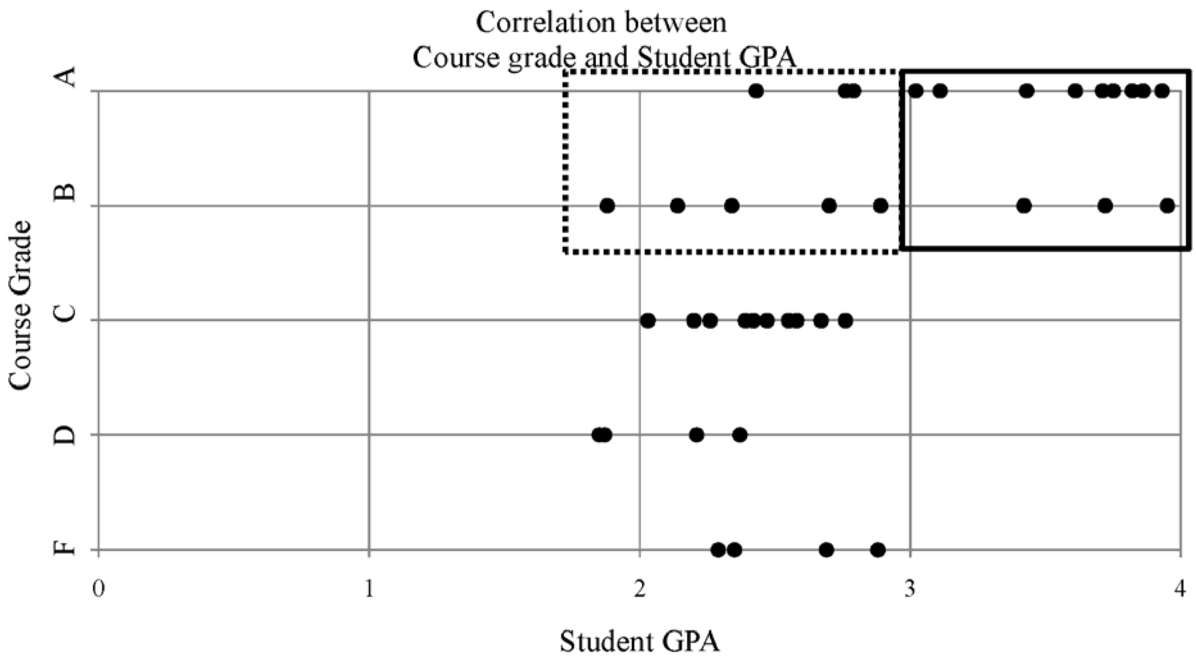


Figure 5. Correlation between students' Statics course grades and their GPAs.

Summary

Lecture worksheets were developed for the entire Statics course which allowed additional problems to be solved during lecture by the students as well as the instructor. The additional time gained allowed for in-class discussion and peer-to-peer instruction. These activities not only improved students' ability to recall the concepts taught during the lecture but to also remember the specifics of the concepts and how they were used to solve a particular problem. The effectiveness of these resources was assessed using the Statics Concept Inventory developed by Steif and Dollàr. The mean score for the students in this research was 11 with 31% of the students scoring greater than or equal to 14, a score comparable to a university similar in rank as Carnegie Mellon University as presented in the research by Steif and Dollàr. In addition, survey results showed that 50% of the students with GPAs between 2.0 to 2.9 valued the lecture worksheets. These results indicated that students who would normally find Statics challenging benefit from lecture worksheets and active learning.

Further research is currently being conducted to assist student with spatial visualizations by utilizing animations captured from 3D computer models from Autocad. It is known that a challenging part of Statics involves spatial visualization skills which are defined as the ability to mentally, rotate, twist, or invert pictorially presented stimuli[7]. Providing clarity of 3D concepts has been shown to improve student grades[4, 8, 10]. Lectures will be complemented with these models so that students are not 'lost' during lecture due to their weakness in spatial visualizations. The Purdue Visualization of Rotations Test developed by Bodner and Guay[1] will be used to assess the effectiveness of this technological resource in the classroom.

Bibliography

1. Bodner, G., Guay, R.B. The Purdue visualization of rotations test. Vol. 2. 1997.
2. Danielson, Scott, Mehta, Sudhir. "Teaching Resources for the New Millenium: Statics as an Example." Journal of SMET education (2001).
3. Hestenes, D., Wells, M., Swackhamer, G. Force Concept Inventory. Vol. 30. 1992.
4. Hsi, S, Linn, M.C., Bell, J.E. "The role of spatial reasoning in engineering and design of spatial instruction." Journal of Engineering Education 86.2 (1997): 151-158.
5. Kolb, D.A. Experiential Learning: Experience as the Source of Learning and Development. Prentice Hall, 1984.
6. Mazur, E. Peer Instruction. Benjamin Cummings, 1996.
7. McGee, M G. "Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences." Psychological Bulletin 86.5 (1979): 889-918.
8. Miller, C.L., Bertoline, G.R. "Spatial visualization research and theories: Their importance in the development of an engineering and technical design graphics curriculum model." Engineering Design Graphics Journal 55.3 (1991): 5-14.
9. Redish, Edward F. Teaching Physics with the Physics Suite. Wiley, 2003.
10. Sorby, S., Baartmans, B.J. "The development and assessment of a course for enhancing the 3-D spatial visualization skills of first year engineering students." Journal of Engineering Education 89.3 (2000): 301-307.
11. Steif, P.S., Dollar, A., Dantzler, J.A. "Results from a statics concept inventory and their relationship to other measures of performance in statics." ASEE/IEEE Frontiers in Education Conference . Indianapolis: IEEE, 2005.