AC 2010-2131: USING FILL-IN WORKSHEETS IN MECHANICS CLASSES

Rungun Nathan, Pennsylvania State University, Berks

Dr. Rungun Nathan is an assistant professor in the division of engineering at Penn State Berks from the fall of 2007. He got his BS from University of Mysore, DIISc from Indian Institute of Science, MS from Louisiana State University and PhD from Drexel University. He worked as a post-doc at University of Pennsylvania in the area of Haptics. His research interests are in the areas of ornithopters, mechatronics, robotics, mems, virtual reality and haptics, and teaching with technology. He has active research in the area of lift in Porous medium with Dr. Qianhong Wu (Villanova Univeristy) and in the area of non-linear control with Dr. Sergey Nersesov (Villanova University). He is an active member of ASEE and ASME and reviewer for several journals.

Using fill-in worksheets in mechanics classes

Introduction

A decade ago, classroom instruction was limited to the use of blackboard to lecture and solve problems in most institutions for many engineering courses across the USA and the world. The technique adopted was called the "no-note" method[1]. As described by Pytel, the "no-note" method on information transmittal, the instructor prepares his lectures notes for his own personal use and then uses this to lecture, discuss and write on the board. While many of the baby-boomer generations learned most of their engineering by this modality along with self-study, which included solving **several** problems from many textbook, present day students are exposed to a very different set of learning experiences and generally are a very different set of learners. They generally operate on an optimization principle based on "minimize effort for maximum grade", which includes solving **least** number of problems. (typically assigned homework) From personal observations and discussions with K-12 teachers in neighboring school districts in Pennsylvania, (Exeter Township, Muhlenberg, Lower Merion, Reading, Wyomissing) it is evident that there is an increased use of handouts, workbooks and worksheets in grade school education, which could be categorized as "all-note"[1] method OR a minor variation of "Teaching-Note" [1]. These implements are used for both in class learning and for homework assignments. As described by Pytel, in the "all-note" method, the instructor discusses his lecture notes after providing them in their entirety to the students for the class period and the "teaching note" lies somewhere between the no-note and all-note approach. From the previous conversation with grade school faculty, it is also apparent that for in-class assigned problems and some of the homework assessment, the teachers read out the answers and generally the students verify their own work or in some cases exchange papers and corrects the answers. Even though the teachers insists and requires that steps and work be clearly and neatly shown, most students do the work in any convenient manner and just make sure they obtain the answers, because finally answers are being checked and graded.

It is a common understanding that problem solving skills are one of the major components of engineering learnt in introductory mechanics courses. Hake[2] has shown that interactive engagement increases the conceptual understanding and problem solving ability of students in a mechanics course. Cooperative learning[3, 4], and peer instruction[5] have shown to be beneficial in classrooms and in the enhancement of student learning and engagement. Using ideas and concepts from previous work listed here, the author undertook a redesign of his mechanics classes (statics and strength of materials) to include interactive engagement, cooperative learning and peer instruction. The idea of "teaching-notes"[1] was modernized by the faculty's use of current technology consisting of a media projector and a tablet-pc with ink technology. Digital ink-technology is the term used for writing on a tablet-pc screen using free hand writing. The students in the class did not use tablet-pc.

Beginnings

To begin the process, the concept of mini lectures based on informal cooperative learning experiences of Johnson, et al.[3] and book-ends from Smith, et al.[6] was designed. Figure 1 shows a variation of the mini-lecture that was used by the author to divide up a class of approximately one hour. The mini lectures were used to introduce new topics, work or develop theory and derivations or for solving problems. The activity was used for student interaction in self selected peer groups or for problem solving. Sometimes the mini-lecture was reduced and activity times increased, but the three to five minute time limit was maintained. This time limit helps keep the student's attention rather than delve into unnecessary chatter.

1- 2 min. Announcements	5 min. Review, Homework	1 min. Today's topic	10 – 12 min. Today's topic & mini lecture	2-3 min. Activity	10 – 12 min. Today's topic & mini lecture	2-3 min. Activity	8 - 10 min. Today's topic & mini lecture	2-3 min. Activity	1- 2 min. Summary and next class

Figure 1. Approximate template for one hour class (slight modification needed for one and half hour class)

Prior Knowledge

To design the fill-in worksheets which were used for theory and problem solving, the author started from his "no-notes" lecture notes. Using these notes, every class lecture was categorized into theory or derivation or ones that involved solving example problems. In addition an inventory of topics that were considered "prior knowledge" was made. The pool of prior knowledge topics only grew as the semester progressed. For example, students were expected to come to the statics class with basic or prior knowledge of trigonometry, geometry, algebra and some calculus. (An evaluation quiz was given out in the first class to gather information. This assessment was loosely based on the mechanics readiness test[7].) Similarly students entering the strength of materials class were expected to have prior knowledge of vectors, resolving vectors, free body diagram, setting up equilibrium equations and solving for unknowns, etc. but there was no evaluation test administered.

Theory OR Derivation Fill in worksheets

For creating fill-in sheets related to theory, the instructor categorized material into what was important or what was new to the student and what the students already knew. For example, figure 2 shows the fill-in sheet that was used for deriving the relationship between the internal shear forces and bending moment of a beam with uniformly distributed load. In this case, the derivation by taking a small section of the beam and applying calculus to derive the relationship was considered important. Based on this assumption, a clear and neat figure and associated statements are already typed in using word processing software as part of the handout that was going be given to students. Drawing the free body diagram and writing the equilibrium equations gives the student a better understanding of how the relationship is derived. In the figure, all the typed information was part of the handout, while the inked information was written in class using the Tablet-PC by the faculty. The students copy the inked portion in their notes following along with the instructor. Similarly, figure 3 shows the derivation of the bending deformation (the flexure formula is not shown). Notice that in this handout there are blanks (highlighted) in the text part that will have to be inked in by the instructor while the students wrote this down in their handouts. (The highlights are used in the publication for emphasis, while the real handout had only blanks) It was the instructor's opinion that this information about various fibers undergoing different deformation was required to understand that there is a neutral surface in which the fibers have no deformation. The inked information shows further details of the derivation of the concept as used in class. In a similar way all the theory and derivation had to be categorized into information as *going to be inked* OR *typed in beforehand*. Before the handouts were given, the instructor first showed and briefly discussed the derivation using PowerPoint with the class. Then immediately after the handouts were given, students were asked to sit in self-selected peer groups to discuss the derivation. Later on, the instructor and the students inked in the handouts and further discussions and questions were entertained.

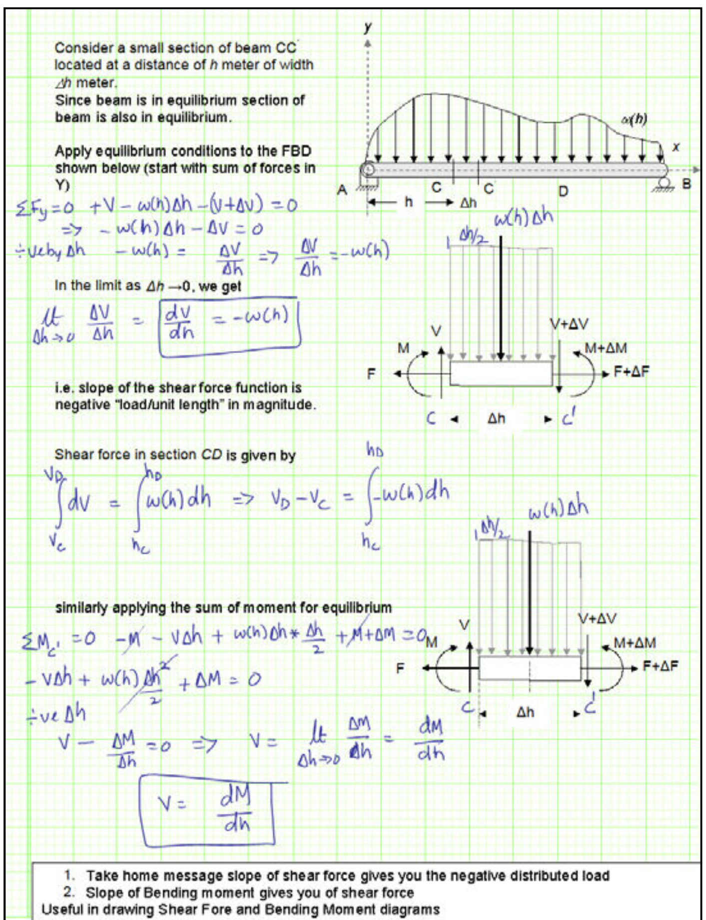

Figure 2. Fill-in sheet for derivation of relationshipbetween shear force, bending moment in a structural member with uniformly distributed load.

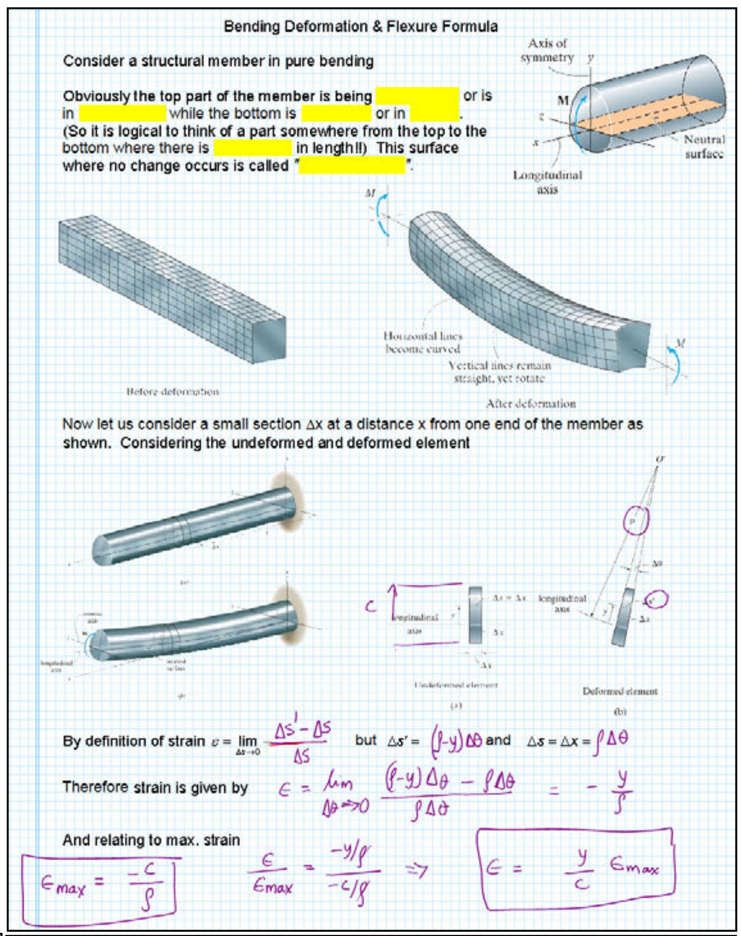

Figure 3. Fill-in sheet for derivation of theory for bending deformation and flexure formula of a structural member. (Partly shown to demonstrate fill-in used in text part.

Problem Fill in Worksheets

For creating fill-in sheets related to problems, a similar approach was taken. Information had to be categorized as prior knowledge or newly acquired knowledge which needed reinforcement and practice. For example, in the first few weeks of a statics class, writing a 3-D vector in component form was considered as newly acquired knowledge and would not be filled in. Figure 4 shows the detailed handout that was created for writing 3-D vectors and adding them. As many engineering students lack 3-D visualization, the handout clearly outlines the information with great details. The final notes that are posted to the class website contained additional information called "key-concept" as shown in the figure 4. When solving 3-D equilibrium problems, such details about vectors were not given in the handout and the students were expected to write them by studying the figure. Figure 5 shows another example that was used in the strength of materials class to draw the shear force and bending moment diagram. Notice here that in this case equilibrium is assumed prior knowledge and so the equations have been provided, but to increase practice for students, the actual equations have not been typed out, but rather inked in the class. When this problem is solved in class, the students are working on it together in self selected peer groups. The instructor actually leads the class, by providing stopping points (as suggested by book-ends in figure 1) like let us first finish the sum force in x, then move on to the next step and so on.

In the past these problems were written out on the chalkboard along with sketches. (loosing invaluable class time to less important or trivial information or to drawing a neat and detailed sketch). About thirty problems were solved in the strength of materials class when chalkboard was used exclusively. Transitioning to not writing and sketching the problem (provide student reference figure in the textbook) increased the number of solved problems to about thirty-five. Using the fill-in worksheet (figure 2 to figure 5) and the faculty using a Tablet-PC, the class went onto solving approximately fifty-five to sixty problems in a semester. Additionally many homework problems were also designed as fill-in sheets with varying degrees of hand holding.

By combining the bookends approach with fill-in sheets the author has been able to provide for active and cooperative learning in the classroom. The students have time to discuss content with instructor when material is presented with the help of PowerPoint and when handouts have not yet been given out. Later on when the derivation are being done, students have chance to interact with peers to incorporate collaborative learning and peer instruction. When solving problems, the instructor has observed that students instruct and help each other along the way. As an instructor it is rewarding to see these peer-to-peer instructions and active learning happening in the classroom. By walking around the class, the instructor is able to quickly assess the class and take corrective action immediately. The instructor has also been able to provide brief one-on-one instruction in some instances during these walk around the class.

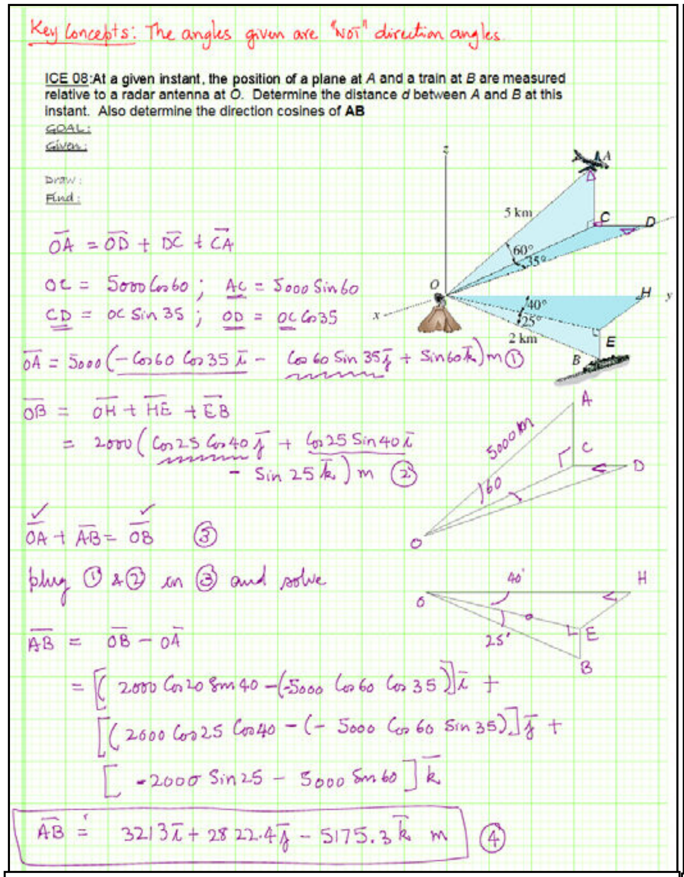

Figure 4. Fill-in sheet for solving problems on 3-D vectors in statics

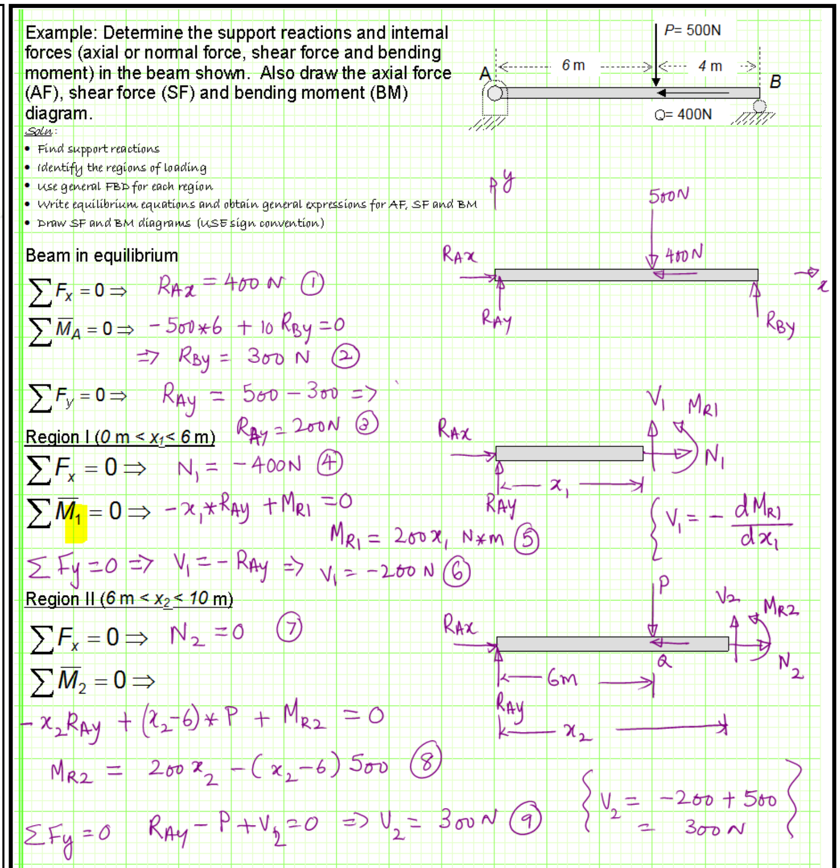

Figure 5. Fill-in sheet for solving problems in strength of materials for drawing shear force and bending moment diagram. (Part of the solution shown)

Student Survey

Mid-term and end of term student surveys have indicated a very positive impact on student learning. Below are selected (both positive and not so positive) comments to the following question: "Please give me your feedback on the use of the fill-in handout sheets that we work together in class using the Tablet-PC". {There were no negative comments in three classes that this survey was conducted in the past two years.)

- *It's great. It allows me to see the problem unfold before me so I can tag along, learn what to do and see how it works and then do it on my own.*
- *They help a lot because we learn as a group.*
- *I think they are fine because I think we jump right into the harder problems with no warm up.*
- *It is a good way of preparing us for homework and tests. Working on them together gives a base of what to follow outside the classroom.*
- *They give a sort of "template" of how to do similar problems.*
- *Helpful. I've followed them to help me understand strategies I didn't understand during class. Also use them to study for tests.*
- *They are helpful, they keep me more attentive in class.*
- *I think it's a great idea. I can actually understand the notes better than my own. In reviewing notes uploaded to Blackboard, following the chain of thought, through the worked out problems, maximizes my personal study time.*

- *Very helpful. On a personal level, taking notes in a notebook can be useless sometimes if the drawing is not drawn well. Having everything I need in front of me to study helps. If possible three hole punch the pages so they can be put right into a binder.*
- *Absolutely love the handouts, they play a large portion of my understanding of course material and support the ability to look back and re-learn or re-interpret the material taught in class.*
- *I think it helps me a lot because I do not just copy it word for word. I make sure I understand what is going on before doing the problem. But again I like working in groups to help me improve on my skills to work on these problems.*
- *It would be helpful if you showed every step.*
- *These fill-in handouts sheets are a good thing in class. Sometimes the lines from the graph sheet can be frustrating and get in the way.*
- *It would be better if we figured more out on our own*

Conclusion

In this paper, the author describes the steps and thought process of developing the fill-in sheets that have enabled him to a) increase interactive engagement, b) include cooperative learning and c) implement peer instruction. The fill-in sheets have enabled the instructor to try differentiated instruction in the class room, by adding symbolic solutions to challenge the advanced student, while helping the average and below average student solve the basic problem using numbers. (Note : The author is making an assumption based on statics readiness test where student exhibit weakness in algebra). The number of example problems solved in class has been increased tremendously, while the mathematical rigor of derivation has not been sacrificed. Student survey comments have indicated that the fill-in sheets have been very helpful in student learning, active and collaborative learning and peer instruction. End of the semester teaching evaluation of the instructor has also improved since the implementation of the fill-in sheets.

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