Work In Progress: The Effect of Partially-Completed Worked Examples Applied to Statics

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Introduction

Traditionally, instructional strategies used for teaching engineering subjects revolve around a scaffolded type framework, where problems are solved in-class by the instructor whom provides guidance to students that are simultaneously engaging in the problem solving with the instructor. This type of learning strategy is based off of a guided problem-solving approach. After a number of problems are solved in this manner the next step is usually to assign problems for the students to solve entirely on their own, taking away all the instructor support from the problem-solving approach. Research suggests that entirely removing all guidance too soon generally results in a situation where student learning must then rely on randomness. This is where the learning process is accomplished by randomly combining elements of information and then determining which combinations are effective, which is very inefficient.[7]

This type of learning technique is very common within engineering subjects, as well as many other subjects and is based off of what is sometimes referred to as discovery learning.[2] Research has suggested that making use of partially-completed worked examples can reduce cognitive load by decreasing the burden on working memory, in turn leaving more memory capacity to acquire knowledge.[3] Cognitive Load Theory (CLT) should be considered when designing instruction in order to maximize student learning. Specifically, three types of cognitive load have been identified in affecting a student's working memory capacity (i.e. intrinsic, extraneous, and germane). Intrinsic cognitive load deals with the nature of the material being learned, extraneous cognitive load is affected by the manner in which the material is delivered to students, while germane cognitive load involves the effort involved to create a schema[4,8] Instructional design is important for both limiting extraneous load in order to maximize germane cognitive load (i.e. support for learning).[9] Unfortunately, the traditional approach to problem solving in engineering courses has a tendency to strain the working-memory of novices in introductory courses.

Alternatively, in partially-completed worked-examples learners are given a problem where certain portions of that problem are missing and they are required to fill in the missing steps. Implementing this instructional strategy can serve as a bridge between fully guided problem-solving and completely unguided problem solving. Adding the use of partially-completed worked examples to fill the gap between worked examples and independent problem solving has proven to be very effective in prior research.[5]

Purpose Statement

This study will examine the effectiveness of implementing partially-completed worked examples when directly applied to the field of Statics. Statics is a fundamental engineering course taken by a large number of students across engineering disciplines; it is also a course that requires students to problem solve. This study will specifically examine whether or not the use of partially-completed worked examples creates a more efficient and complete learning process when learning Statics, specifically truss analysis using the method of sections.

Design/Methods

We will utilize a quantitative quasi-experimental pretest-posttest study to gain a better understanding of the effects of partially-completed worked examples of Statics problems on student learning. Students within an engineering Statics course will be divided into two groups. Both groups will initially receive identical introductory instruction on how to solve for internal forces of a truss utilizing the method of sections. Following traditional instruction (i.e. instructor led lesson on truss analysis and the method of sections) the first group will be given partially-completed worked examples along with traditional problems, where they are to solve the partially completed problems first and then the traditional problems afterwards. The second group will be given only traditional problems to solve. During this time students are encouraged to work each problem independently, however the instructor will be available for instructional support as needed. Additionally, a subjective measure of cognitive load will be used to quantify between group cognitive loads, while a posttest will measure student learning of the topic in general. The instructional strategy will serve as the independent variable consisting of two groups, while the engineering concept knowledge of Statics, along with the subjective cognitive load scores will serve as the dependent variables to be measured using multivariate analysis of variance (MANOVA).

Pre-test

Students will first complete a pre-test to identify their baseline Statics knowledge regarding truss analysis and the method of sections. Figure 1 shows an example of a sample pre-test question where students will be asked to solve for internal forces of truss members using the method of sections.

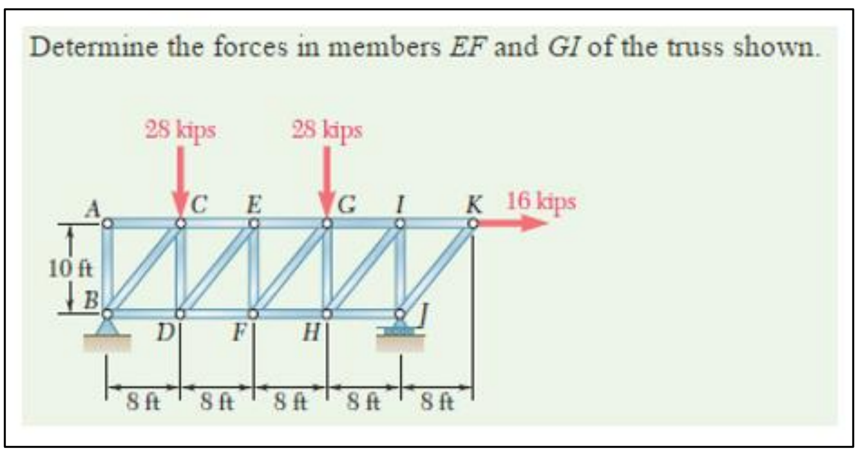
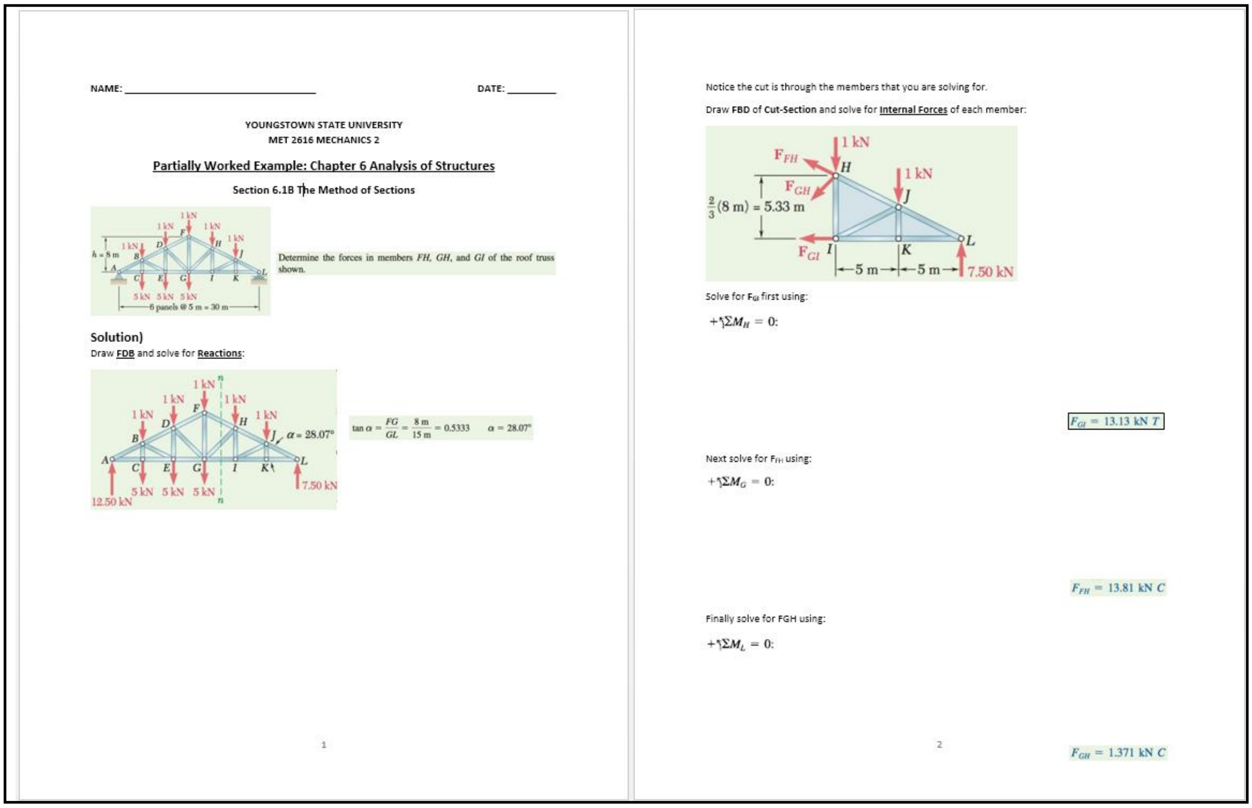


Figure 1. Pre-test sample question.[1] Reprinted from Vector Mechanics for Engineers: Statics & Dynamics, (p.320), F., Beer et al, 2016, McGraw-Hill Education.

Group 1: Partially-Worked Problems

Following traditional instruction students in this group will be given both partially-completed and traditional problems. The first two problems on the worksheet will be partially-completed examples, followed by two additional traditional problems. Figure 2 shows an example of a partially-completed worked example. At the end of class students will turn in their assignment and will take a three question post-test upon arrival of their next class.



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Partially Worked Example: Chapter 6 Analysis of Structures

Section 6.1B The Method of Sections

Determine the forces in members *FH*, *GH*, and *GI* of the roof truss shown.

Solution)
Draw FDB and solve for Reactions:

$\tan\alpha = \frac{FG}{GL} = \frac{8\text{ m}}{15\text{ m}} = 0.5333 \quad \alpha = 28.07°$

1

Notice the cut is through the members that you are solving for.

Draw FBD of Cut-Section and solve for Internal Forces of each member:

Solve for F_{GI} first using:

$+\circlearrowleft\Sigma M_H = 0$:

$\boxed{F_{GI} = 13.13 \text{ kN } T}$

Next solve for F_{FH} using:

$+\circlearrowleft\Sigma M_G = 0$:

$F_{FH} = 13.81 \text{ kN } C$

Finally solve for FGH using:

$+\circlearrowleft\Sigma M_L = 0$:

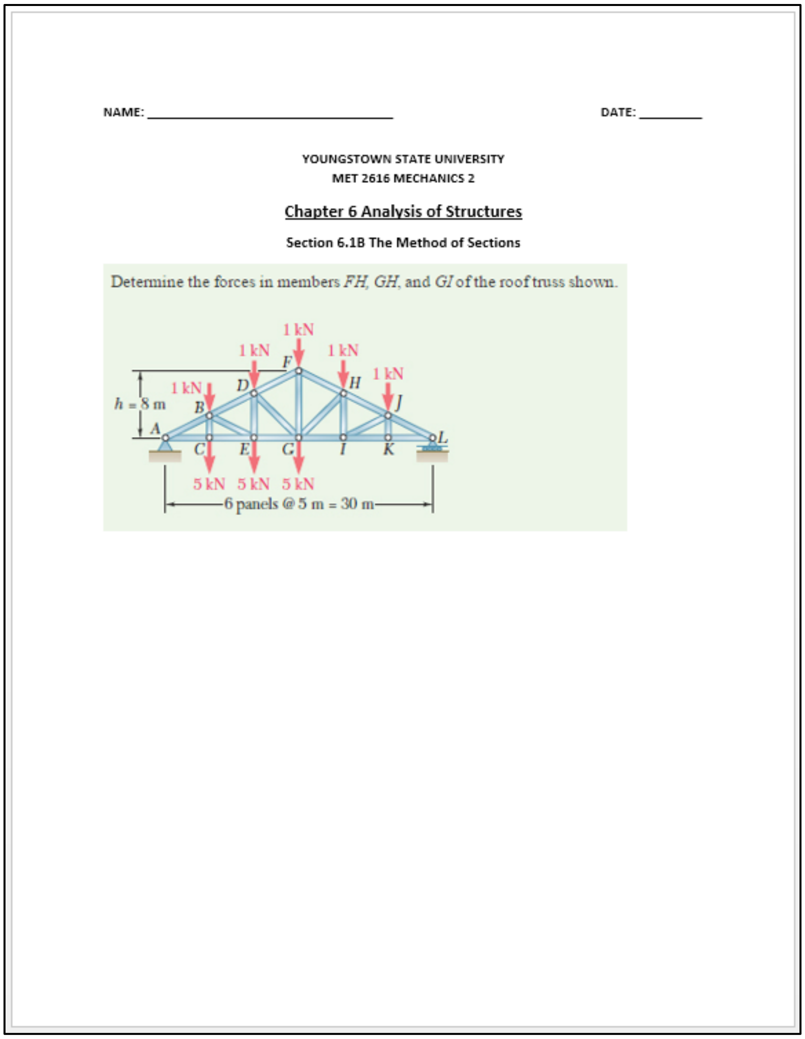
2

$F_{GH} = 1.371 \text{ kN } C$

Figure 2. Partially-completed problem example.[1] Reprinted from Vector Mechanics for Engineers: Statics & Dynamics, (p.322), F., Beer et al, 2016, McGraw-Hill Education.

Group 2: Traditional Problems

Following traditional instruction students in this group will be given only traditional problems. Students in this group will receive the same four problems as group one, however, all problems will be traditional. Figure 3 shows an example of the traditional version of the example shown in Figure 2. At the end of class students will turn in their assignment and will take a three question post-test upon arrival of their next class.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Chapter 6 Analysis of Structures

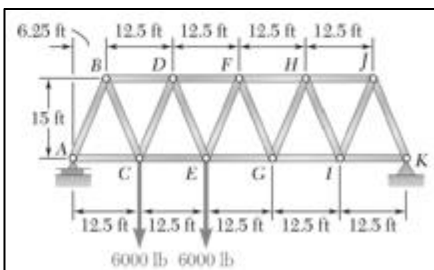
Section 6.1B The Method of Sections

Determine the forces in members *FH*, *GH*, and *GI* of the roof truss shown.

Figure 3. Traditional problem example.[1] Reprinted from Vector Mechanics for Engineers: Statics & Dynamics, (p.322), F., Beer et al, 2016, McGraw-Hill Education.

Post-test: Statics Concepts Involving Truss Analysis and the Method of Sections

During the next class (i.e. following the instructional period), both groups will be given the same instructions to complete a series of post-test tasks. During each task, students will also record how difficult they perceive the task to be (i.e. cognitive load assessment). Figure 4 depicts an example of a post-test task.



A Warren bridge truss is loaded as shown. Determine the force in members *CE*, *DE*, and *DF*.

Figure 4. Post-test sample question.[1] Reprinted from Vector Mechanics for Engineers: Statics & Dynamics, (p.345), F., Beer et al, 2016, McGraw-Hill Education.

Post-Test: Measuring Cognitive Load

Subjective measures of cognitive load will also be used to measure students' perceived difficulty when performing the post-test tasks. Student will rate their perceived mental effort based on a 7-point Likert scale, ranging from 1 – extremely east to 7 – extremely difficult, after interpreting the instructions for each task. This approach has been used in prior research and has been shown to accurately gauge the amount of mental effort exerted by participants.[6,8]

Implications

Strong student understanding of fundamental courses such as Statics is crucial for their success in subsequent courses, and is also vital in providing solid background knowledge to appropriately comprehend more advanced topics. In order to maximize the learning process a clearer understanding of how the role of guidance during engineering based problem solving impacts student learning is necessary. This study hopes to shed light on the way in which levels of guidance might impact learning of engineering concepts.

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