An approach for in-class learning of mechanical engineering design subjects

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Abstract

The objective of this paper is to present a simple approach currently being used by the author for teaching mechanical engineering design courses at Kettering University.

Most basic engineering design courses currently being taught at the university are four-credit courses. These usually follow a format of two blocks (two hours) per week, with four hours of lecture or, when the course requires, a lecture and a laboratory (both consisting of two hours).

For basic design courses, where no laboratory is included or in-class activities are not required, the two-hour lecture blocks can be more efficiently utilized if part of the block is used for student learning of the material presented by the instructor instead of using the entire block just for instructor presentation.

This paper presents a simple idea for achieving this goal. The idea was implemented and tested in three distinct engineering courses, namely ME-309 (Vibrations), MECH 210 (Mechanics I – Statics), and MECH 310 (Mechanics III – Dynamics). For evaluation purposes, student feedback and comments are included in the text. An example that relates to the subject discussed is also given.

Introduction

In many universities basic mechanical engineering design courses are still taught in a traditional manner. The subjects are presented during lectures, following a textbook, and students are asked to solve homework problems in order to prepare for tests. Students are expected to follow and understand the lecture subject and, on their own time, work on homework problems. Following this approach, it is not uncommon to find a good amount of students trying to learn several distinct subjects and solve large amounts of homework (if the class does not require, for example, weekly homework) just before a scheduled exam.

Since this is a common issue confronted by instructors that teach these courses, one can find several references in the literature that provide information and distinct approaches to deal with the problem. This problem can be mitigated by improving student learning during lecture time.

Several approaches aiming to improve student learning in the classroom have been discussed in the literature recently. Some of these approaches focus on student collaboration with their peers [1], which suggests that by working in a collaborative problem solving effort, student learning can be improved. Another approach is the integration of assessment tools into student activities in order to provide feed-back on their learning [2]. Also, the idea that students can improve their learning by taking on an active role has been discussed by Dufresne et al. [3], Wenk et al.[4] and Mestre et al.[5].

In reference [6] the authors discuss ways by which some of these approaches could be used for improving student understanding of basic mechanical engineering design subjects. The techniques are contained in "learning modules" which may include, for example, Power Point ® presentations and concept questions.

"Hands-on" experiences have also been presented as tools for learning improvement. For example, in references [7], [8] and [9] efforts to incorporate these experiences into Statics teaching are discussed. In this approach, experiments were developed to help understanding of basic mechanics concepts. Also, multimedia tools, physical models and cooperative learning are used. (Cooperative learning here means using groups of students to solve a common problem.) Some of the results obtained by the authors show that it is difficult to assess the effectiveness of the "hands-on" approach when compared to a traditional approach for teaching the subject.

Incorporating web-based tools as an aid for teaching the subjects aforementioned has also been presented in recent publications. In reference [10] the authors discuss web-based homework and interactive software for use in engineering Dynamics courses. In this case it was claimed that some improvement in student performance can be obtained by the use of these tools.

In a previous paper [11] the author discussed his experiences on using simulation software (commercially available) for Dynamics teaching and improving learning. Feedback from students showed that the simulations can help visualize and understand mechanical systems dynamic behavior.

However some of the approaches mentioned above can sometimes be difficult to implement. Some of the reasons for that could be software availability, difficulties integrating software and web tools into an already long syllabus, class size and lack of laboratory time for the discipline.

For these cases, a simple approach to help improve student learning is discussed in the following.

In-class learning

The concept of cooperative learning is not new (see for example reference [12]). Also, several authors (as cited above) have discussed student active participation as an aid for learning. The general conclusion is that for improvements in learning, it is very important to promote student

participation in the subject being discussed and taught during the lectures. One way of achieving this goal is via in-class problem solution with student participation. The instructor can use the time allocated for the lecture in a more efficient manner if part of this time is used for, for instance, quizzes. This simple approach involves giving students a problem to solve during every lecture of the course.

At Kettering University most basic engineering design courses follow a four-credit format with two lecture blocks and, traditionally, these blocks have been used entirely for instructor lecturing (when laboratories are not included in the courses). It is suggested here that every two-hour block should include a problem solving section. The amount of time allocated for this section can vary depending on each subject. For example, 30 minutes before the end of the lecture, or more when more involved problems are used. If this approach is to be used, the first part of the lecture block should comprise of a traditional teaching section. The lecture subject is presented by the instructor and discussed in the usual format with theory and several application examples.

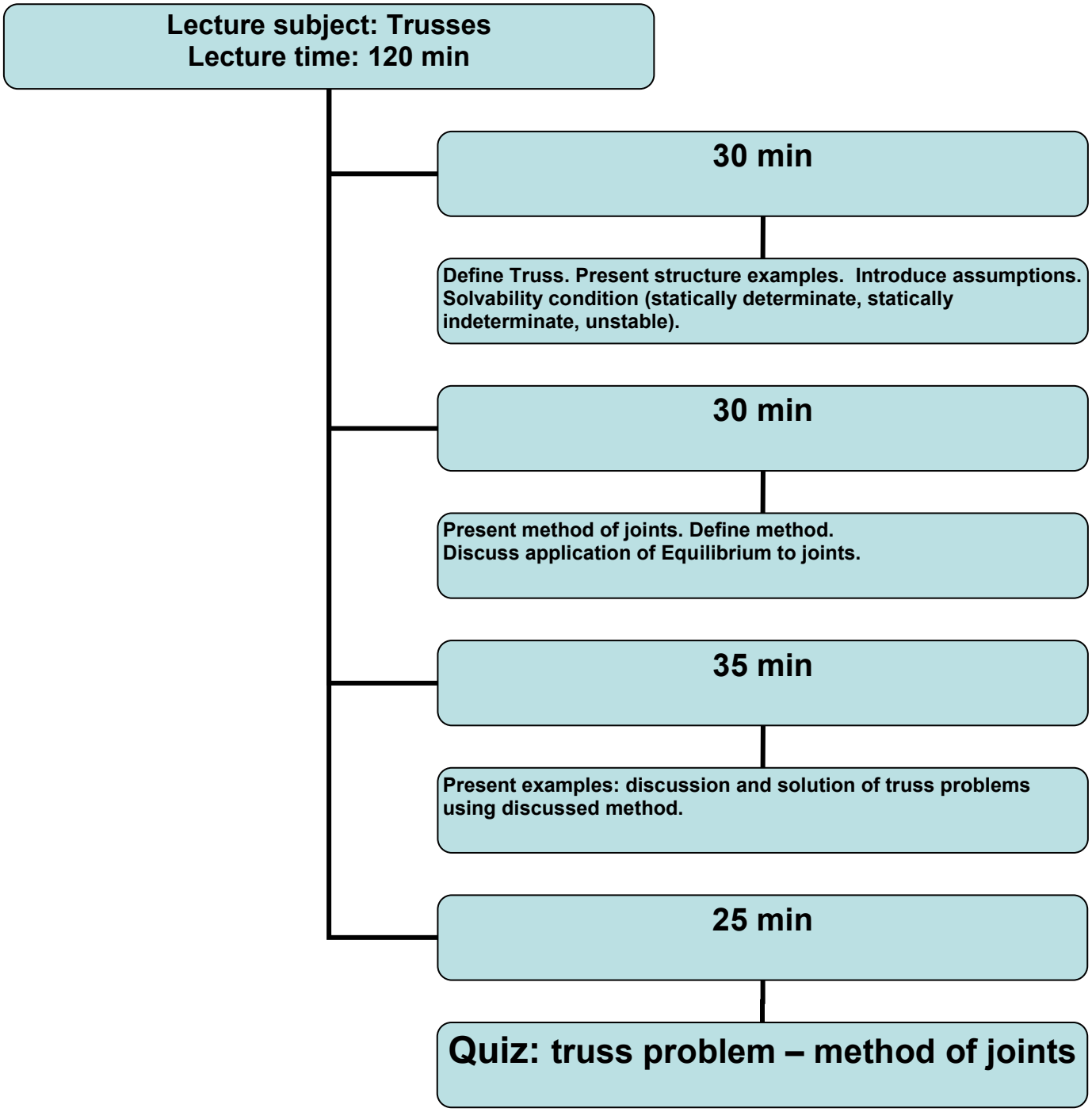
The second part of the lecture, the "in-class" learning part, should include a problem solving section. Here a problem based on the subject just presented by the instructor is given to the students. The author suggests using small groups of students (three to four) to work on the group quiz (the cooperative learning). While students are trying to review their current lecture notes and solve the problem, the instructor is available to answer questions and help students with the problem at hand. It was noticed that the use of small groups is helpful due to student interaction during problem solving. (Some students ask their peers for explanations and discuss procedures and solutions, an aspect that has been pointed in references dealing with cooperative learning; see for example [1].)

Participation in the problem session is achieved by using the solved problems as part of the final course grading.

Approach implementation

In order to implement this approach it is important that every course lecture be designed with a "class-participation" part in mind. For example, the Statics course mentioned above requires students to learn eight distinct topics (based on the adopted course textbook [13] - see Appendix A for course syllabus). These eight topics were divided by the actual number of lectures (about 17 lectures) with time allowances for the quizzes. Experience leads to the amount of time allocated for each topic and sub-topic that should be taught, and the time that should be spent on the quizzes, for the entire course schedule. The same approach was used by the author in his Vibrations [14] and Dynamics [15] courses.

As a simple example of time allocation for subject and quiz, a flowchart for a Statics lecture on trusses is given below. (The schedule for the course is given in Appendix B.)



It is important to note that this simple approach can be implemented very easily. It does not depend on computational tools, time consuming learning devices (preparation and implementation), development of extra material or restructuring of course syllabi. Based on student feedback given below and on observed student overall class performance, the approach can yield better results when compared to traditional approaches to teaching.

Student feedback

In order to obtain some evaluation of the student response to this simple approach, they were asked some questions at the end of the term (MECH 210). Below some of their comments are reproduced and an overview of their response is given in Table 1. Comments were edited for clarity and grammar only.

a. Did you like the lecture format of theory first and then a quiz at the end?

"Yes, I did. The format really helped me out."

"You probably spent too much time on the lecture part!"

"Yes, it was very helpful. The information was fresh in my mind"

b. Do you think that the quizzes helped learning the material?

"Yes, they gave me an opportunity to work out problems and get help right away if I needed it"

"Yes, I enjoyed the fact that we could work together and explain to each other what we learned"

"It forced me to learn the material!"

"I am not sure. I liked the work but it does not help if you can not get the right answer. "

c. Would you like to see this format applied to other courses that include two-hour blocks of theory only?

"Yes, definitely!"

"This is the most beneficial format I have ever seen."

"Yes, I can not stand two hours of theory"

Some general comments from ME-309 and MECH-310 students are included below.

"The group quizzes every class were an excellent way for us to learn the material. Every class we applied what we just learned so we understood and remembered."

"Liked the structure: lecture → examples → quiz."

"The instructor promoted class participation as part of learning!"

percentage of students that completed all assignments	***79%***
percentage of students that liked quiz format	***100%***
percentage of students that found that quiz format helped learn the material	***96%***
percentage of students that would like to see quiz format applied to other disciplines	***96%***

Table 1 – Student response to quiz use in MECH – 210

Conclusions

A simple approach to promote student participation and learning during mechanical engineering design lectures is discussed in this text. The approach requires lecture planning to allow for quiz solution and discussion time, but it does not require the use or development of new course tools and/or equipment. The author has used this simple approach successfully in three distinct basic engineering courses and has obtained positive feedback from participating students, leading to the conclusion that this can be an effective way of improving learning.

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Appendix A – MECH 210: Mechanics I

2001 catalog data: Credit: 4 (4-0-4)
Prerequisites: PHYS-112 Newtonian Mechanics;
Co-requisite: MATH-102 Calculus II.
This course deals with discussion and application of the following fundamental concepts: (1) static force analysis of particles, rigid bodies, plane trusses, frames, and machines, (2) first moment of area, and (3) internal forces. Topics covered will be (1) the static force and moment equilibrium of two and three dimensional systems; (2) resultant forces and moments due to the application of concentrated and/or distributed loads (3) couples (4) the center of mass and the area moment of inertia of a rigid body. Several open-ended homework and mini projects will be assigned in order to incorporate a design experience in the course.

Textbook(s): Statics by W. F. Riley and L.D. Sturges, 2nd ed., John Wiley & Sons

Course learning objectives and outcomes:

Objective 1: Model a real physical system of particles for force analysis [ME POs A, C, E, K, P]

1.1 Given the drawing or sketch of a physical system, students will be able to draw free body diagrams and determine the resultant or equilibrant forces acting on the simplified physical system.

Objective 2: Analyze a system of particles for static equilibrium [ME POs A, E, K, M]

2.1 The students will be able to apply the trigonometric rules to various problems concerning the static equilibrium of a system of particles.
2.2 The students will be able to apply vector methods to various problems concerning the equilibrium of a system of particles.
2.3 The students will be able to conceptualize concurrent force systems and parallel force systems.
2.4 The students will be able to understand the principle of transmissibility.

2.5 The students will be able to use free body diagrams to solve the static equilibrium of system of particles.

Objective 3: Model and Analyze the system of rigid bodies in static equilibrium using Newton's laws [ME POs A, C, E, H, I, L, P]

3.1 Given external force vectors acting on a system of rigid bodies, students will be able to determine the resultant forces and moments using vector concepts.

3.2 Given the type of support and connectivity in a system of rigid bodies in equilibrium (i.e. trusses or frames with pin-joints or rigid supports.), students will be able to fully analyze the force system using Newton's laws.

3.3 Given loads acting on planar linkages and mechanisms (machines), students will be able to determine the internal reactions at the joints.

3.4 Given loads on a planar system (i.e. a beam), the student will be able to determine reaction forces and moments.

3.5 Given a general distributed load, students will be able to determine the equivalent concentrated load and its location using both integration and summation approaches.

3.6 Students will be able to calculate the center of area (or center of mass) and the area moment of inertia of a system of rigid bodies.

Prerequisites by topic:

1. Ordinary derivatives, vector algebra
2. Basic trigonometry (sine and cosine rules)
3. Particle equilibrium
4. Newton's Laws of motion
5. Basics of free body diagrams
6. Basic Computer Skills

Topics covered:

Week	Topic
1	Introduction Review of Vector Mechanics, Free Body Diagrams and Trigonometry Concurrent Force Systems, Applications.
2-3	Rigid Bodies: Moment of a Force, Moment of a Couple Equivalent Force/Couple Systems, Applications.
4-5	Rigid Body Equilibrium 2D Systems and 3D Systems, Applications.
6	Trusses: Method of Joints and Method of Sections.
7	Distributed Forces: First Moment of Area, Applications. Centroids and Center of Gravity of Plane Areas and Volumes.
8-9	Frames and Machines.

Schedule: Two sessions per week of 120 minutes

Computer usage: Basic Computer Skills

Relationship to professional component: Four credits (100%) Engineering Science

Appendix B – MECH 210 – Course Schedule

Grading:

Homework and quizzes:	25%
Test 01:	25%
Test 02:	25%
Project:	25%

WEEK	CHAPTER	TOPICS	READING ASSIGNMENTS
1	02	Force Systems and Resultants Force Components	2.1 - 2.4 2.5 - 2.7
2	03	2-D Particle FBD & Equilibrium 3-D Particle FBD & Equilibrium	3.1 - 3.3
3	04	Moment of a Force (2-D) Moment of a Force (3-D)	4.1 - 4.2 4.3
4	04	Couples Simplification of a Force System	4.4 - 4.5 4.6
5	05	Center of Gravity Centroids (Integration) **Test I**	5.1 - 5.2 5.3
6	05	Centroids (Composites) / Pappus & Guldinus Distributed Loads Submerged Surfaces	5.4 - 5.5 5.6 - 5.7
7	06	2-D Rigid Body FBD & Equilibrium 3-D Rigid Body FBD & Equilibrium	6.1 - 6.3 6.4
8	07	Trusses Frames and Machines	7.1 - 7.2 7.4
9	08	Internal Forces	8.1 - 8.3
10	08	Shear & Moment Diagrams Project discussion **Test II**	8.4 - 8.5
11		**Project**	