AC 2008-787: DYNAMICS COURSE FOR SECTIONS WITH BOTH CIVIL AND MECHANICAL ENGINEERS

Yusuf Mehta, Rowan University

Dr. Mehta is an Associate Professor at the Department of Civil and Environmental Engineering at Rowan University. His research and teaching interests include pavement materials and design, service learning, and transportation safety. Dr. Mehta has published several technical and educational papers in leading professional organizations.

William Riddell, Rowan University

William Riddell is an Assistant Professor in the Civil and Environmental Engineering Department at Rowan University. His research and teaching interests include design, structural mechanics, transportation safety, energy efficiency and clean energy generation. Prior to Rowan University, he worked for the US Department of Transportation Research and Special Program Administration, and was a National Research Council Postdoctoral Fellow in the Mechanics of Materials Branch at NASA Langley Research Center.

Dynamics Course for Sections with both Civil and Mechanical Engineers

Abstract

The purpose of this paper is to present the pedagogical technique for a dynamics course taught to both civil and environmental (CEE) and mechanical (ME) engineering students. In this course, the instructor utilizes a combination of both problem-based-learning and traditional lectures. The students learn the concepts by solving example problems from the book without looking at the solutions and then these concepts are reinforced by solving problems of a broad range of difficulty provided at the back of the chapter from the textbook. The dynamics course is taught once a year to both CEE and ME majors. From the viewpoint of the students, dynamics appears to be only tangentially useful to the civil engineering majors, whereas the immediate use is more readily apparent to the mechanical engineering majors. In addition, the topics that are relevant to mechanical engineers may not necessarily be as relevant to civil and environmental engineers. To address this problem the instructor identified the concepts that are relevant to students from each major, for example, energy methods for CEE students and momentum methods for ME students. The course objectives, learning outcomes and assessment data are presented.

Problem-Based-Learning

As the label implies, problem-based learning (PBL) is an educational approach where learning is initiated through an ill-structured problem. PBL is necessarily interdisciplinary: By addressing real-world problems, students are required to cross the traditional disciplinary boundaries in their quest to solve the problem. One of the primary features of PBL is that it is student-centered. "Student-centered" refers to learning opportunities that are relevant to the students, the goals of which are at least partly determined by the students themselves [1]. This does not mean that the teacher abdicates her authority for making judgments regarding what might be important for students to learn. Rather, partial and explicit responsibility is placed on the students for their own learning. Assignments and activities that require student input presumably increases the students' motivation to learn.

A common criticism of student-centered learning is that students, as novices to a subject, cannot be expected to know what might be important for them to learn. The literature on novice-expert learning does not entirely dispute this assertion. However, it also emphasizes that students come to a course, not as the proverbial blank slates, but as individuals whose prior learning can greatly impact their current learning[2]. Often, students have greater content and skill knowledge than faculty, and they themselves anticipate. In either case, whether their prior learning is appropriate is not the issue. Irrespective of the state of their prior learning, it can both aid and hinder their attempts to learn new information. It is therefore imperative that instructors have some sense of what intellectual currency the students bring with them.

In a traditional course, instructors introduce students to teacher-determined content via lecture. After a specific amount of content is presented, students are tested on their understanding in a variety of ways. PBL, in contrast, is more inductive, and highly context-specific. Students are given an ill-posed challenge similar to one they might encounter as a real-world practitioner.

Students learn the content as they try to address the problem. The "problems" in PBL are typically in the form of "cases", narratives of complex, real-world challenges common to the discipline being studied. There is no right or wrong answer. Rather, there are reasonable solutions based on application of knowledge and skills deemed necessary to address the issue. The "solution" therefore is partly dependent on the acquisition and comprehension of facts, but also based on the ability to think critically. By having students demonstrate for themselves their capabilities, PBL can increase students' motivation to tackle problems. PBL can address three major complaints from employers about college graduates: poor communication skills, inability to problem-solve, and difficulty working collaboratively with other professionals.

Introduction

The course is taught in the fall of sophomore year as a required course for all civil and environmental engineering (CEE) and mechanical engineering (ME) students. At the end of this course, the students will be able to:

- Write and draw force, position, velocity and acceleration vectors in Cartesian and cylindrical coordinates;
- Construct and analyze free body diagrams (FBD) and write dynamic equations from Newton's and Euler's laws;
- Solve problems involving simple kinematics of particle and rigid body motion;
- Determine relative velocities and relative accelerations of two points on the same rigid body and two points on different rigid bodies;
- Solve problems using Newton's and Euler's Laws;
- Solve problems using work and energy;
- Solve problems using conservation of linear momentum and energy;
- Analyze a dynamic system.

Outline for Dynamics

Dynamics is a seven week (half-a-semester course) 2-credit course that follows a seven-week Statics course. The CEE and ME students meet for 75 minutes, three times a week. The required textbook is Bedford and Fowler, Engineering Mechanics: Dynamics, Fifth Edition, Pearson/Prentice Hall, 2007. The outline of the course is shown in Table 1.

Table 1. Schedule

<table>
<tr><th>Week</th><th>Subject</th><th>Chapter</th></tr>
<tr><td>1</td><td>Motion of a Point</td><td>13</td></tr>
<tr><td>2</td><td rowspan="2">Force, Mass and Acceleration</td><td rowspan="2">14</td></tr>
<tr><td rowspan="2">3</td></tr>
<tr><td>Midterm Exam</td><td></td></tr>
<tr><td>4</td><td>Energy Methods</td><td>15</td></tr>
<tr><td>5</td><td>Momentum Methods</td><td>16</td></tr>
<tr><td>6</td><td>Impulse and Momentum</td><td>17</td></tr>
<tr><td>7</td><td>Conservation of energy</td><td>18</td></tr>
<tr><td></td><td colspan="2">Final Exam</td></tr>
</table>

Pedagogical Technique

In the course, the instructor utilizes a combination of both problem-based-learning and traditional lectures (Figure 1). The students learn the concepts by solving example problems directly from the textbook and then these concepts are reinforced by solving problems of a broad range of difficulty from the textbook.

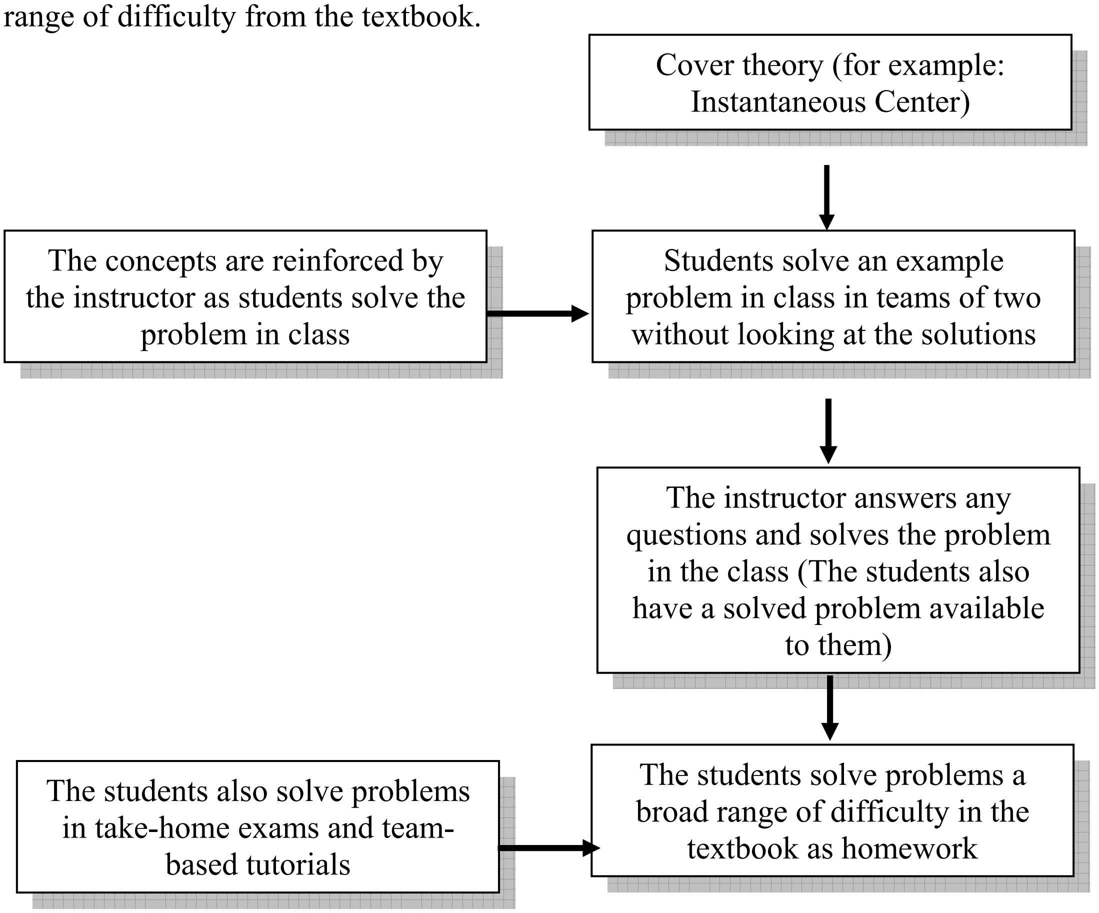

Figure 1: Pedagogical Technique Used in this Course

During the past four years the lead author has tried innovative teaching techniques in a wide range of classes such as pavement materials[3], surveying and engineering graphics[4], and civil engineering materials[5]. Throughout this course, the author required students to solve applied problems during class in teams of two immediately after covering the relevant theory. For example, immediately after a concept of conservation of energy was explained and its derivations from basic equations were covered, students solved an example problem from the textbook individually step-by-step. During the class, the instructor answered any questions the groups may have while solving the problems.

Impact of Technique

The above mentioned pedagogical technique requires students to understand the concepts as the example problems is solved and this is enhanced by solving them in two or more ways. The students have to assimilate the information provided and translate it to the problem at-hand. However, this exercise forced them to take the theoretical concepts and apply them to solving complex problems.

Homework, Exams, Quizzes, Tutorials

The grading scheme for the course is summarized in Table 2. The individual homework assignments were to be submitted within a week and the team-based take-home exams were submitted within 48 to 72 hours, in which the team-members could discuss their effort as they presented their solutions to complex analysis and design problems. The teams were self-chosen, and the students selected their colleagues from their own major as their team partners. The take-home exams allowed the instructor to push the students to solve challenging dynamics problems. These exams required them to refer to all available resources, beyond the textbook and the class notes to solve the problems. On the other hand, the quizzes, mid-term exam and final exam were to be attempted by each student individually and were closed book. The purpose of these was to evaluate if the students understand the concepts taught in the class. In this process, the students solved a wide range of example problems, from the most simple to the most difficult problems in the textbook. Such a breadth of exposure of problems provided the necessary breadth and depth of the knowledge of the subject matter. In addition, tutorials were introduced in the second half of the course, which will be discussed in detail later.

Table 2. Summary of grading scheme for course.

Evaluation	Format	Turnaround	Weighting
Homework	Individual, take home	1 week	15%
Quizzes	Individual, closed book	In class	20%
Take-home exams	Team-based, take home	72 hours	15%
Midterm Exam	Individual, closed book	In class	25%
Final Exam	Individual, closed book	In class	25%

Student Evaluation

The instructor evaluation (Table 3) was positive. The response to questions 1 and 2 showed that 75 % of the students found the notes and presentations enhanced learning. An overwhelming portion of the class (75-90%) found the class challenging. The comments (Table 4) clearly showed that the students perceived the class positively. The students found the class to be challenging. The negative comments in bold are primarily due to the need for the instructor to balance depth and breadth within a seven-week course. This concern is going to be addressed and is discussed in the following section.

Table 3. Student Evaluations (20 students)

		Student Scores (20 students)				
	Question	**1 (poor)**	**2**	**3**	**4**	**5 (excellent)**
1	Was your understanding of course concepts enhanced by your professor's presentation of the material?	2	3	7	6	2
2	Were your class sessions characterized by clearly presented lectures and/or learning activities?	1	2	4	8	5
3	Did the professor stimulate thinking?		1	5	2	12
4	Did the professor require a high level of student performance?			1		19

Table 4. Student Comments

No	Comments
1.	Standards for student are too high.
2.	Very challenging pace.
3.	**Sometimes went through the material/problems too quickly.**
4.	**Enthusiastic. Some material presented poorly. Confusing lectures.**
5.	Very tough but fair & interested in the students success.
6.	He is a great teacher really cares about his students know the material
7.	**Moves very quickly & often skips steps.**
8.	Very positive attitude. **More theory could have been taught.**

Student Assessment

A student assessment instrument is attached at the end of the paper. Almost 50% of the class (of 20 students) showed above-average confidence on the ability to solve complex problems and understanding of the three broad subjects covered in the course (Table 5). This trend was similar between the two majors.

In response to the question "What one change would have improved the course for you?" (Table 6); eighty percent of students felt that the dynamics course should not be a half-semester course. This concern has been addressed within the civil engineering department; beginning next academic year the dynamics course is going to be taught as an entire semester course for the CEE students. Mechanical Engineering students need dynamics course in the fall semester, as it is a prerequisite for a spring semester course. In response to the questions "What was the most important thing you learned in this course?"; "Solving complex problems and critical thinking" was the response of 5 out of 9 civil engineering students and 3 out of 11 mechanical engineering students. This suggests that the class was slightly harder for civil engineers than for mechanical engineers.

The difference is because the ME students see a more immediate use for the material in the rest of their curriculum. Note that dynamics is a pre-requisite for a second semester ME course, where it is not a pre-req. for anything in the CEE curriculum. The CEE students don't see an immediate use for any of the material, but do acknowledge that learning more mechanics problems is probably an overall good thing. This suggests that the PBL approach is even more important for CEE students than for ME students, who really need the specific content. In addition, the CEE students appear to indicate that they are more confident in their abilities than the ME students, even though the ME students tended to earn better grades. This discrepancy may be because the CEE students do not see an immediate application to the course and hence set lower expectations for themselves than the ME students.

Table 5. Student Assessment – Multiple Choice Questions

Mechanical Engineering Students (11 total)						
Ability to	**Poor (1)**	**Below Average (2)**	**Average (3)**	**Above Average (4)**	**Excellent (5)**	**Average Response**
Take Simple Concepts to solve Complex Problems			7	3	1	3.45
Understand Force-Mass and Acceleration			4	5	2	3.82
Understand Conservation of Energy			6	4	1	3.54
Understand Impulse-momentum method			6	4	1	3.54
Civil Engineering Students (9 total)						
Ability to	**Poor (1)**	**Below Average (2)**	**Average (3)**	**Above Average (4)**	**Excellent (5)**	**Average Response**
Take Simple Concepts to solve Complex Problems			3	6		3.67
Understand Force-Mass and Acceleration			5	2	2	3.67
Understand Conservation of Energy			4	3	2	3.78
Understand Impulse-momentum method			4	3	2	3.78

Table 6. Student Assessment –Open Ended Questions

	Civil and Environmental Engineering (9 students)		Mechanical Engineering (11 students)	
	Comments	**Number of students**	**Comments**	**Number of students**
What one change would have improved the course for you?	Make it a full semester class	8	Make it a full semester class	8
	Same problems between exams and homework	1	No Homework grade; Better text book; Same problems between exams and homework	1 each
What was the most important thing you learned in this course?	No Comments	4	No Comments	1
	Solving complex problems and critical thinking	5	Solving complex problems and critical thinking	3
			Impulse-Momentum, Relative velocity	4
			Angular momentum; relative velocity; Newton's second law	1 each

Impact of Half-semester Class

The authors found that the half semester schedule made it harder to balance depth with breadth. Even though less material was covered than what was originally intended, the students perceived the class to be fast paced. This was overwhelming for the students and initially led to poor performance. However, to mitigate this problem, the tutorials were introduced. The tutorials allowed students to solve problems as a group. As the students worked in groups they got a chance to work on the problems together and helped get a better learn the concept. After the tutorials were introduced the performance improved. The tutorial grade replaced the lowest quiz.

Conclusions

Based on the student evaluations and the assessment data, the instructor believes that the pedagogical technique presented is helpful in enhancing the learning outcomes of the course. Based on the four other courses the lead author has taught using this approach, he strongly believes that the new technique is beneficial for both the instructor and the students. The methodology has been effective and the students are very involved in the learning process. The authors strongly believe that teaching is a learning process for the faculty. The authors are continuously evolving and improving the technique to ensure that the students stay current with the latest developments and have a fruitful learning environment.

Dynamics Course Assessment Instrument
Please rate the effectiveness of this course in the following areas.

1) To improve your ability to **take simple concepts to solve complex problems**
   ☐ Poor ☐ Below Average ☐ Average ☐ Above Average ☐ Excellent
2) To improve your ability to solve **force-mass and acceleration** problems
   ☐ Poor ☐ Below Average ☐ Average ☐ Above Average ☐ Excellent
3) To improve your ability to solve **conservation of energy methods** problems
   ☐ Poor ☐ Below Average ☐ Average ☐ Above Average ☐ Excellent
4) To improve your ability to solve **impulse-momentum method** problems
   ☐ Poor ☐ Below Average ☐ Average ☐ Above Average ☐ Excellent
5) What one change would have improved the course for you?
6) What was the most important thing you learned in this course?
7) What is your expected grade in this course?

☐ A ☐ A- ☐ B+ ☐ B ☐ B- ☐ C+ ☐ C ☐ C- ☐ D+ ☐ D ☐ D- ☐ F ☐ IN

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