AC 2010-1367: DYNAMICS BUZZWORD BINGO: ACTIVE/COLLABORATIVE/INDUCTIVE LEARNING, MODEL ELICITING ACTIVITIES, AND CONCEPTUAL UNDERSTANDING

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Dynamics Buzzword Bingo: Active/Collaborative/Inductive Learning, Model Eliciting Activities, Conceptual Understanding

Abstract

At most schools, dynamics does not have a pearly reputation among students; introductory dynamics has one of the highest failure rates of any course at our university. It is usually the first really difficult engineering course that students must take, and many of the concepts are not intuitive. To try to combat this, two instructors have tried to change their instructional techniques to more closely match current trends in engineering education. As in many universities, classroom time is largely spent having students work problems in groups, encouraging both active and collaborative learning. Before each class, one or two example problems are posted in order to help those students who insist that they learn best by "watching the instructor work problems on the board." At least one of these includes audio, where the instructor discusses the steps and thought processes while solving the problem.
We have also used two to three Model-Eliciting Activities (MEAs) during each quarter, which provides context to specific dynamics principles. Students apply particle work-energy and momentum principles by creating an accident reconstruction manual for a police department in Sri Lanka, and practice their rigid body work-energy, kinetics, and angular momentum principles by analyzing a catapult for a medieval exhibit at a British Museum. These projects are introduced before the material is covered, serving as a form of inductive learning and hopefully motivating the material. Finally, we have included conceptual questions during each class period to help the students think more deeply about the material (rather than just plugging numbers into equations). Assessment will be presented using three metrics: final exam averages, scores on the Dynamics Concept Inventory, and student attitudinal surveys.

Introduction

Landmark publications such as *How People Learn* and *Educating the Engineer of 2020* (along with numerous other publications) have suggested that we need to change the traditional way of educating engineering students. As most of you know, the traditional lecture-based way of teaching does not match the way that most people learn. Students have an attention span of 10-15 minutes before starting to lose interest, and do not have long-term retention of the material. Educators have now begun to stress using techniques such as active, collaborative, and inductive learning (Prince, 2004; Hake, 1998), and many stress the importance of conceptual knowledge versus simple algorithmic substitution.

At Cal Poly, we have attempted to combine all of these in a sophomore level dynamics class. Our course is a three hour per week lecture class, with approximately thirty 50-minute classes per quarter. Like at many universities, this course has one of the highest failure rates of any class. It is typically taught in a very traditional manner, with instructors lecturing on the material and then working out example problems for the students. In 10 different sections over three quarters, we have utilized all the techniques described above, stressed conceptual understanding through daily use of concept questions, and implemented two or three model-eliciting activities each quarter. Different authors have used many of these techniques successfully in the past; our experiences can provide guidance to those looking to implement them in their own mechanics courses.

Typical Class

Before each class, students are required to watch multimedia example problems over the web. Class begins with a concept question or two, then students are given the opportunity to ask questions about the example problem. After a short "lecture" introducing the new topic, student teams then worked on 1-2 problems that they set up (e.g., Given/Find/Assume) prior to the class. The instructor usually guides the students along, often asking questions to specific individuals about the process, including how and why they are approaching the problem in a certain way. The 50 minute class typically ended with a short concept quiz and a brief introduction to what would be covered in the next audio example problem. Depending on the class, other activities (both in and out of class) included Team Homework problems, Model-Eliciting Activities, and Just-in-Time Teaching online quizzes.

Audio Example Problems

Many students still say they prefer to watch their instructor work out example problems. This makes sense, since most tests require students to perform similar algorithmic substitution that they have seen on homework-type of problems. There is certainly merit to trying to model the thought processes of "experts" in the field. Too often, however, the students seem to simply search for an equation to apply and then substitute in numbers.

Often when the instructor works through an example problem, questions are fairly superficial (e.g., "why is that a negative number?"). It would be a much better learning experience if the student thought about it for a minute and figured it out for themselves. To address these different issues, we created simple animated audio examples that the students were required to look at before the class began. As one of us talked through the problem, different equations and text appeared, similarly to writing on the chalk board. At the beginning of class, an outline of the solution was presented and students were given the opportunity to ask questions about it. The entire worked-out problem appears similarly to an example problem in a textbook in text, with additional explanations in audio. Advantages to these example problems include allowing more time in class for other learning activities and their ability for students to use as a reference later in the quarter (e.g., right before the final exam).

In Class Problems

Each night before class two workout problems are posted to the BlackBoard Course site. Students were required to print these out or sketch them in their notebooks, write out their Given, Find, and Assumption statements, and state what type of problem they think it is (e.g., Rigid Body Work Energy). This saves valuable class time since the students will not have to spend time copying down different figures. During class, student teams then work through the problems with periodic guidance from the instructor.

Concept Quizzes

Concept questions are certainly nothing new in engineering education (Streveler, et al., 2008). Many have included these in different presentations, and one of the authors helped to develop the Dynamics Concept Inventory (Gray, et al., 2004). Multiple choice type questions can be presented where students think about questions individually and/or discuss them in small groups.

Team Homework Problems

At the beginning of the quarter, each student was assigned a letter A through D. Each week, each letter is assigned a specific homework-style problem to work out. Their solution should include guidance and explanation for their classmates, similar to a textbook example problem. On Mondays, pre-assigned teams (each with one A, B, C, and D member) met in groups and each member presented their solution to their team. By explaining their work and writing out their exact procedures, students should learn the material better than when they simply plug numbers into appropriate equations.

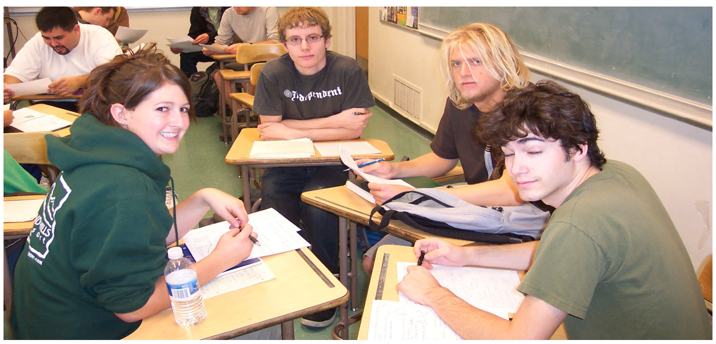

Figure 1. Students discussing team homework.

Just-in-Time Teaching

Just in Time Teaching (JiTT) was originally introduced in the physics educational community (Novak, et al., 1999). Questions about the reading are administered online, then the instructor modifies the lecture content depending on the results of student answers. Many instructors use the following format for their questions (although this is by no means mandatory): one multiple choice question, one essay format, and one estimation problem. The best questions ask the student to analyze a real world example, which will hopefully help develop critical thinking skills. The key is that the student answers to these problems are then used to shape the lecture. An example estimation problem asks the students to approximate the centripetal acceleration of San Luis Obispo. One of the essay questions asks them to discuss the design parameters to consider for the Beijing Olympics opening ceremony performance where harnessed athletes "run" around a globe. Generally the open-ended questions are graded based on effort, and the multiple choice ones are graded based on the correct answer.

The students should complete the web assignments prior to two hours before class to provide the instructor enough time to review their answers. From the student responses, the instructor can determine if certain material needs to be covered more in depth, if main issues can be skipped, or if supplemental reading material or tutorials need to be provided. The class time can be modified "just-in-time" to reflect student understanding and interest. Seasoned JiTT instructors use actual student answers to help build their lecture or explain a theory; they will typically put up overheads or PowerPoint slides of selected student responses. The class participants recognize their own words and feel more ownership of the course.

Model-Eliciting Activities (MEAs)

MEAs are team-based (usually 3-4 students) assignments where students attempt to develop models of problems with rich engineering context (Self, et al., 2008). Rather than focusing on the final answer, the MEA focuses on the problem solving process and the team's documentation of that process. After students develop their models, which may include mathematical formulas, decision algorithms, processes, or other information, they provide a deliverable back to the "client" – typically in the form of a memo.

The Accident Reconstruction MEA involves the concepts of impact, particle work energy, and particle impulse momentum. The client is a Police Chief in Sri Lanka who wants a procedure for his police force to use when doing accident investigation. Different accident scenarios (most of which were obtained from a California police officer) were created for the students to use in developing their procedure. They had to have the foresight to think of different types of scenarios that might be involved and create a procedure that was general enough to apply to as many accident types as possible.

A second MEA that was used in two different quarters was the Multimedia Example Problem MEA. The client in this case was a textbook publisher who wanted to create multimedia example problems to go on their website. Many different professors were to make these example problems, and the publisher needed guidelines and an outline so that the different example problems would all have a similar format. In addition, the student teams wrote a memo to the publisher discussing what they thought was important for students in an example problem. Finally, they created their own multimedia example problem for the publisher.

During the final two weeks of class, the Catapult MEA was assigned. The Peterborough Museum in England holds a Medieval Machines display each year and had decided to hold a catapult competition. For bonus points, the participants can analyze their catapults and predict their range at different pullback angles. The curator has asked the student teams for guidance to provide to the participants so that they can calculate launch distances. To help test these models, he has also sent a scaled model catapult for the students to use. The teams then had to determine what measurements they needed to take, how to model the rubber band (linear vs non-linear), how to calculate mass moments of inertia (slender rod or parallelepiped, sphere or concentrated mass), and if drag would be a factor during the projectile motion. The students could then test their mathematical models on launch day – a competition was held where they attempt to hit a small picture of their instructor with a raw egg.

Figure 2. Catapult target.

Results

As might be expected, subjective feedback was mixed. Many students complained about the workload, but other sections of dynamics reported the same complaint (some assign four homework problems each class). Subjective survey results are shown in Table 1.

Table 1. Subjective survey responses.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
The individual homework problems helped me learn the material	25	33	4	1	0
The team homework problems helped me learn the material	11	27	18	5	1
The Accident reconstruction project helped me learn the material	6	34	14	8	1
The Catapult project helped me learn the material	13	25	16	8	1
The Individual HW problems were interesting and motivating.	1	28	21	12	1
The Team HW problems were interesting and motivating.	4	22	23	12	2
The Accident reconstruction project was interesting and motivating.	2	30	17	13	1
The Catapult project was interesting and motivating.	10	24	17	12	0

During the Fall of 2008, eight different sections of dynamics took the Dynamics Concept Inventory. Five of the sections used the techniques discussed in this paper (denoted "Bingo" in the table), while one did not ("Traditional" in the table). Table 2 shows the results of the DCI.

Table 2. Total pre and post DCI scores for all Test and Traditional participants.

	N	Value	Pre DCI Results [%]	Post DCI Results [%]	Overall Average Normalized Gain [%]	Overall Average Percent Improvement [%]
Bingo format	149	Mean	29.85	49.97	29.6	20.11
		Median	27.59	48.28		
		Standard Deviation	14.55	17.20		
Traditional format	80	Mean	32.97	46.64	21.1	13.66
		Median	31.03	44.83		
		Standard Deviation	14.19	18.33		

Finally, it was important to make sure that the grades on the common final examination were at least as good for our sections as for the traditional lecture sections. In Fall 2008, the Bingo format scored 105.4 ± 20.7 compared to 100.3 ± 25.2 for the traditional section. The p-value for the t-test was 0.077, which shows that there is not quite a statistical difference. It should be noted that the last problem on the common final consisted of several concept questions, which may have favored the Bingo classes somewhat.

Conclusions

The techniques utilized in the dynamics course are not new, but in general are not applied in undergraduate statics and dynamics classes. Many other instructors resist using more active learning or project based assignments in their class for fear of not getting through all of the material. The similarities in the final exam scores suggest that this should not be a concern. The more important aspect to consider, which is extremely difficult to actually measure, is the long term retention and understanding of the students. Problems based in engineering context (e.g., a catapult) should provide much better long-term retention than typical beam and spring problems seen in textbooks. Deeper conceptual understanding should also provide a framework upon which the students can build in their later courses.

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