Transitioning into Graduate Programs: A First Semester Graduate Course in Structural Dynamics

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Abstract

This paper presents a first-semester graduate level course in structural dynamics that utilizes active learning as a mechanism to address 1) higher expectations of learning, 2) varying levels or academic background and preparation, and 3) diverse cultural backgrounds. Active learning strategies used include cooperative learning, both as a full class and in small groups, and problem- and project-based learning experiences (PBL). When the full class cooperates in solving a problem, all students get exposed to the different possible solution strategies for tackling a problem. Small groups allow students who may be hesitant to ask questions in front of the entire class an opportunity to ask questions of their peers or even of the instructor in a more private setting. The use of PBL reinforces the concept that multiple strategies for approaching a problem are possible. Students are asked to produce a specific outcome, such as the development of a reduced order model, but they are not told what method or approach to use for this process. At the end, the students must evaluate the consequences of the choices made during the project process.

Introduction

As students enter a graduate engineering program, they are expected to have a higher degree of independence and self-motivation than the average undergraduate student. Students are expected to have a greater depth of understanding of the material and be able to synthesize material from various courses to develop their own solution approaches to tackle new problems, and to evaluate and make decisions based on their analyses.

The students entering the graduate program come from a variety of cultural and academic backgrounds. In a traditional lecture class format, this diversity can make it difficult for the professor to target lectures so that all students gain the most from the experience. Cultural differences may cause some students to hesitate in asking questions during (or after) lecture, while differences in academic background mean students have been exposed to different methods to solve the same problem.

This paper presents a first-semester graduate level course in structural dynamics that utilizes active learning as a mechanism to address these issues. Active learning strategies used include cooperative learning, both as a full class and in small groups, and problem- and project-based learning experiences (PBL). When the full class cooperates in solving a problem, all students get exposed to the different possible solution strategies for tackling a problem. Small groups allow students who may be hesitant to ask questions in front of the entire class an opportunity to ask questions of their peers or even of the instructor in a more private setting. The use of PBL reinforces the concept that multiple strategies for approaching a problem are possible. Students are asked to produce a specific outcome, such as the development of a reduced order model, but they are not told what method or approach to use for this process. At the end, the students must evaluate the consequences of the choices made during the project process.

Active Learning

Active learning is an attempt to expand the single one-size fits-all lecture approach to teaching to one that allows more students to operate in their comfort zone at least part of the time[1]. Benjamin[2] describes active learning in this way: "Active learning connotes an array of learning situations in and out of the classroom in which students enjoys hands-on and minds-on experiences." Active learning strategies have proven to be very effective in enhancing student learning.

Active learning is characterized by a commitment to the generation and sharing of new knowledge. Everybody learns. Nobody stands apart, pulling the strings for the sake of the others. By sharing, listening, imitating, and watching, all members of the learning community benefit. Those with greater expertise play critical roles in helping and modeling, yet they are expected to learn, solve problems, find answers, right along with the rest of the group[3].

High levels of connectivity are essential to the success of an active learning environment, and several learning communities can develop in the process. The class as a whole functions as a learning community, and smaller sub-groups are encouraged to form as students collaborate in both in- and out-of-class activities. Peer colleagues can provide non-evaluative feedback as well as socially supportive and positively pressuring environments, which can be particularly important for international students adapting to cultural changes. A neighbor may be doing great things, but if that information is not shared via constant communication, then other community members will not be aware of it. Information is what drives the feedback loops that lead to new learning for all participants.

Project Based Learning (PBL)

Project Based Learning (PBL) is centered on a project that is characterized by a well-defined outcome, or deliverable, and an ill-defined task. The project itself is generally information rich but the directions are kept to a minimum. The richness of the information is often directly related to the quality of the learning and level of student engagement. The information is often multifaceted and includes background information, graphs, pictures, specifications, generalized, and specific outcome expectations, narrative, and in many cases the formative and summative expectations. The process often results in the emergence of various learning outcomes in addition to the ones anticipated.

The projects promote study and investigation within authentic contexts; encourage the growth of student responsibility, initiative, decision making and intentional learning; cultivate collaboration among students and teachers; utilize dynamic, interdisciplinary, generative learning activities that promote higher-order thinking processes to help students develop rich and complex knowledge structures; and assess student progress in content and learning-to-learn within authentic contexts using realistic tasks and performances [4]. The projects encourage students to utilize everything they know, including life experiences from outside of school. This creates vital connections for the students, both between different courses as well as real-life situations. The learning students experience is dynamic as students use various processes and methods to explore the project.

The projects for the graduate structural course have several objectives: (1) to allow students to tackle a larger and more realistic civil engineering problem, (2) expose students to computational tools used in solving civil engineering problems, (3) evaluate critical thinking and communication skills. The projects are designed to be solved by student teams, who are told they are acting as consultants on the project posed. These projects are open ended problems with multiple possible solutions and are designed to emphasize interpretation of numerical results rather than pure numerical computations. The content objectives of the course are the focus of the project, but they also require a connection between previous knowledge to new concepts, and connecting new knowledge to concepts in other courses and/or disciplines.

How People Learn[5] is at the heart of the problem-based and project-based learning, and other active engagement pedagogies. To be effective activities must be learner centered, knowledge centered, assessment centered, and community centered. They must meet the students where they are, stretch them to develop meanings and assess how they know what they know. Projects provide a context for what they are learning, and if properly structured can lead students to probing questions and rigorous learning. While projects are common in engineering courses, outside of design courses they are more commonly an added course component that can be seen as a larger and more complex homework problem. This Project Added implementation has very clear instructions for completion and a very clear outcome for the project and are considered “well-structured”. This approach frequently does not fully prepare students for problems they’ll encounter in the future[6]. The problems are “ill-structured,” and students are asked to make decisions starting early on, such as “How will you choose to model your system?” The questions then progress in complexity to analyzing the consequences of their assumptions and being able to make a choice as to what solution is best for the problem, with the students themselves having to decide how to judge what is meant by best. The questions asked need to be at the “right” level of difficulty to challenge students without overwhelming them[7].

Implementation in Graduate Dynamics Course

In-Class Cooperative Learning

During class time, cooperative learning is utilized by getting the class to work as a whole to develop the ideas and theories needed to tackle different structural dynamics problems. The instructor’s role is to pose questions to probe the student’s knowledge and preparation. No specific textbook is required for the course; rather the students are given a list of recommended textbooks ranging from those specifically on structural dynamics to those on structural modeling and mathematics. Students are told from the beginning that they will need to explore different concepts and theories on their own, and that the choice of references they will use will be up to them.

The first class session is devoted to asking the students to recall what they know about dynamics from their undergraduate studies. Most students have forgotten many of the details, though they remember some basic principles such as Newton's Laws and conservation principles. During this process, the instructor starts to become familiar with the academic background of the various students in the class, which is important due to the wide variety in a typical graduate course with students from many different countries. Simple problems are posed during this problem, and students are asked how they can approach the solution to the problem. As some students will be hesitant to voice their opinions in front of the entire class, in many cases due to language barriers for international students, a "think-pair-share" approach is used. This allows students time to formulate their thoughts and decide how to present them to others, as well as to start to form smaller learning communities with other students.

At the beginning of the semester, the process is highly guided by the questions and example problems posed, with students only needing to make small progress on a derivation or problem before the class as a whole comes back together and agrees on what the solution is for a specific step. As the semester progresses, the students start to be able to work on more significant portions of the problem as individuals or small groups. This extended time allows the instructor to visit with the individual groups and provide direct feedback and answer any questions they may have. Again, this can be particularly beneficial to students who are struggling with a language barrier. This process allows for informal discussions between instructor and student even while in a class setting. At the end of the allotted time, the class comes back as a whole to discuss different solution approaches made by different groups.

Project: 3-Story Moment Resisting Frame for SAC Project

A term project is given for the class based on the 3-Story Steel Moment Resisting Frame Structure developed for the SAC research project. The students are given floor plan and elevations for the structure, as well as loading information. The students are expected to work in teams to evaluate the response of the structure using different models and analysis approaches, as well as to recommend a strategy for improving the structure's performance.

An advantage to using this structure is that it was designed by independent structural consulting firms based on existing seismic design criteria and that it is well known in the earthquake engineering research community. As a result, this serves to motivate those students going into practice as this is a "real" problem tied to the course content. For those students who are interested in research, they can explore the existing research work done on this topic and begin to see the ties between coursework and research.

While some guidance is provided as far as the models and analysis procedures to be investigated, the students must still make many decisions regarding how to approach the process. For example, one of the first tasks is to develop a single degree of freedom model of the structure. However, no instruction is provided on how to develop the model – what should be the equivalent stiffness and mass? When each team presented the periods for their models to the class, no two teams had the same answer and the results varied by more than 20%. While some teams had similar approaches, they each had made slightly different modeling assumptions. An entire class period was devoted to discussing how the different teams approached the process and discussing possible consequences. A major part of this discussion was to emphasize that each approach had benefits and drawbacks, and one needed to consider the final use of the model in order to evaluate which model better served a specific need.

It is essential that the instructor balance the student need (or desire) for explicit instructions with the learning which comes from struggling with[6, 7]:

- Choosing the best approach/theory to tackle the problem;
- Making appropriate assumptions; and
- Evaluating (often conflicting) results.

Students had to bring in knowledge from other courses to tackle the problem, most obviously their finite element and steel design courses. Additionally, they were also encouraged to research different structural dynamics analyses on their own – such as the use of model condensation techniques and the basics of seismic isolation.

The deliverable is a written team report that is evaluated on two criteria: (1) the quality and accuracy of the work/analysis performed by the team (70% of project grade), and (2) the quality of the report submitted documenting your work (30% of project grade). The first criterion evaluates how well the students applied the concepts of the structural analysis and supporting courses to solve the problem posed. It considers the approach taken as well as the accuracy of the student computations. The second criterion evaluates the report submitted presenting the work the team has done. It considers organization, grammar, and content of the report.

Results and Observations

Active learning has been proven to be highly effective in teaching engineering to undergraduates. The approach is also highly effective in teaching graduate courses, particularly so as to encourage students to become more independent learners and develop their meta-cognitive skills. The active learning strategies used include cooperative learning, both as a full class and in small groups, and problem- and project-based learning experiences (PBL).

Cooperative learning strategies allow for discussion and incorporation of a variety of academic backgrounds into the course, which are typically in an introductory graduate course with students from diverse countries and cultures. When the full class cooperates in solving a problem, all students get exposed to the different possible solution strategies for tackling a problem. Small groups allow students who may be hesitant to ask questions in front of the entire class an opportunity to ask questions of their peers or even of the instructor in a more private setting. The use of PBL reinforces the concept that multiple strategies for approaching a problem are possible.

After the course was completed, the students were surveyed as to how the different course components and teaching methods aided their learning. The following Table 1 shows the number of students that selected each perceived level of help an activity provided.

Additionally, a couple of international students sent the following unsolicited emails:

"I feel very fortunate to have taken your course in Dynamics in Fall 2008. I thoroughly enjoyed being a part of your course. The brainstorming sessions experienced while solving the assignments and tests helped me a lot. The project was also a great learning experience. I take this opportunity to thank you."

"I would like to say Thank you for your devoted class. I really had spent hard time to catch up your dynamics class, but it was interesting and a good experience. It was my first semester in the U.S. so I am not going to give up. When I look back my last semester, I was first too shy or scared to tell something. But I now know I can talk to you and counsel with you. I believe that I will do better next semester."

Table 1: Results from Final Course Evaluation in Fall 2008

	No Help	Little Help	Moderate Help	Much Help	Very Much Help
Class presentations	0	0	2	23	18
Interactive problem solving in class	0	0	0	17	26
Discussion in class	0	0	3	21	19
Group work in class	0	0	0	19	24
Homework	0	0	0	20	23
Realistic problems/projects	0	0	0	21	22
Teamwork	0	0	0	15	28
Report Requirements	0	0	3	23	17

Over the course of the semester, all students in the course made significant gains in being able to tackle problems independently as well as collaboratively with other students. Since they were encouraged to try different solution approaches, the students investigated different topics and became comfortable asking for guidance without needing detailed instructions on how to solve a problem.

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