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# Learning How to Teach Continuum Biomechanics: See One, Do One, Teach One*

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*Continuum Biomechanics is a graduate level course taught in the Department of Bioengineering at Rice University, Houston, Texas. The course is primarily a theoretical one, based on advanced mathematical concepts. An important element of this course is the development of a lecture by each graduate student. The project involves the entire process of developing a board-based, graduate-level lecture, including conception, presentation and post-lecture support. This project allows graduate students to develop and improve important teaching skills, including developing a lecture, managing a board legibly, and understanding how much material can be covered effectively in an allotted amount of time.*

**Keywords:** biomechanics; stimulent presentation; communication; assignments

## INTRODUCTION

THE CONTINUUM BIOMECHANICS course at Rice University has been developed to teach the basics of continuum mechanics with biomedical applications such that graduate bioengineering students can understand and apply theoretical models in the literature. Biomechanical analytical models are usually complex and require more than a basic solid or fluid mechanics course to understand. The course begins with an overview of continuum mechanics, including vectors and tensors, stress and strain tensors, constitutive equations, and an introduction to elasticity. Viscoelasticity and mixture theory models are also introduced. The course usually attracts 8–10, second-year, Ph.D. students from the Department of Bioengineering. In addition to learning basic continuum mechanics as applied to biomedical engineering, one of the major goals of this course is for students to engage in a comprehensive teaching experience.

To this end, a major component of this course is a teaching project, which requires every student to develop a lecture based upon a continuum mechanical model of biological materials, such as muscle, cartilage, bone, or cells. The teaching project is used to help graduate students develop a style of board lecture loosely based on the education philosophy often seen in medicine of, 'see one, do one, teach one'. In medicine, teaching in the clinics occurs by the students watching a procedure or history or physical exam, then actually performing the procedure in front of a doctor, and finally teaching it to someone else. In this way much of the clinical knowledge in medicine is passed down. Effectively, a portion of the course is taught by the students themselves on topics of interest to them, selected from a list of general topics. This part of the course includes creation of a homework problem graded by the presenting student. The lecture is to be completely performed by using only a whiteboard with colored markers, which is an important skill when teaching mathematical models. Using a whiteboard or a chalkboard to teach mathematical models is beneficial because it sets a reasonable pace for the class and is conducive to answering questions and promoting other interactions. As part of this project, faculty from Rice University's Cain Project in Engineering and Professional Communication assist with analyzing, assessing, and improving the board lectures.

The Cain Project in Engineering and Professional Communication was established through a gift from the Gordon and Mary Cain Foundation in 1998. The Project's mission is to prepare Rice University's science and engineering students to lead through excellence in communication. Instead of teaching stand-alone courses in technical communication, Cain Project instructors collaborate with faculty to integrate written, oral, and visual communication into existing science and engineering courses at the undergraduate and graduate levels. They support the Continuum Biomechanics teaching project by assisting with assignment design, communication instruction, individual coaching, and student assessment for the teaching project.

Similar types of projects with pedagogical experience have been reported in the literature, but most discuss using technology or the Internet to assist with teaching [1–7]. One project reported

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by Pollock [8] discusses teaching basic, non-continuum mechanics through 'learning by teaching'. This project required students to learn an undergraduate-level topic in dynamics and then teach it to their classmates. Other articles discuss using the computer or a networked classroom to aid in teaching soil mechanics [6], basic mechanics [3, 7], and mathematics [1]. As the popularity and interest of presentation software [9] and internet- [10–12] and television-based [13] courses increase, this project allows graduate students to develop basic teaching skills not otherwise covered in the curriculum. The importance of this project is that graduate students, who will soon be teaching in some form in either academics or industry, get the chance to develop a lecture from complex literature, as well as work on skills needed in all aspects of engineering didactics, such as being able to explain difficult concepts clearly and succinctly using only a whiteboard (or pen and paper) to colleagues. Bishop *et al*. [14] describe a similar experience where a group of students designed and taught a course in Civil Engineering, which could be extended to this project by having the students in the course go on to design and teach the course.

This teaching project allows graduate students to gain the experience of developing a lecture from conception to delivery with constructive evaluation from both peers and faculty. The class members choose, research, and develop their lecture topic within the area of continuum biomechanical engineering. This project is one of few where students experience the entire process of teaching a mathematically complex, graduate-level topic without using presentation software. The board lecture format has many challenges not as acutely experienced when using overheads or software, including the ability to simultaneously write, talk, think, and observe audience reaction in a complex cognitive talk. Presentation software can provide the instructor with cues as to what to discuss next and more opportunities for using visual media or animations. Other challenges of a board lecture are writing legibly, effectively covering a reasonable amount of material, and requiring a substantial knowledge of the material. While using presentation technology can be effective and captivating, the same technology can lend itself to trying to cover too much information in the allotted time or doing less preparatory work than is optimal [15, 16].

Tufte has written that presentation software can place the audience in a more passive role or reduce complex information down too much in the form of bullet points [17]. While a board lecture can have many of these flaws, the preparation required to cover a new topic on a chalkboard can be more substantial. Also, many situations and courses exist in academics, industry, and general professional interaction that require or are well-suited to using board lecture format, from a formal class on continuum mechanics to explaining an idea or an experiment to a colleague in the hallway. Lastly, developing and giving a lecture on a complex topic with supportive homework is not as common to graduate student experience as giving a seminar presentation or grading papers.

## OBJECTIVES

The overall objective for the course project is to develop and teach a board-based lecture in continuum biomechanics. Within this objective, the students also are tasked with finding the journal articles and books that define their lecture topics and gauging how much material could be covered in their fifty-minute lectures. The goal of each lecture is to teach one or more continuum models of their chosen biological material, as well as to prepare the class to complete a homework assignment of the lecturer's conception on that topic. The homework assignment reinforces or demonstrates the utility of the model. The specific goals for the actual lecture include:

1. For the class to understand the mechanical model.
2. For the class to know how the model is used and its significance.
3. For the class to know how the model was derived (not have every step of the complete derivation, but to know what equations were used to derive the model and how the equations were manipulated to obtain the model).
4. For the class to be able to complete the homework assignment solely from the notes they take during the lecture in a reasonable period of time.
5. For the lecturer to further develop a clear, understandable, and organized lecture style.

These lecture aims define the scope and depth of the topic covered. To understand the significance of the mechanical model, some knowledge of the tissue physiology is necessary. Comprehending the mechanical model does not necessitate every single derivation, but a judicious approach is required to know what portion of the derivation to talk through and what parts to fully derive. The homework assignment has been in several past cases a derivation that was not completed during the lecture, a derivation using different assumptions from those given in the lecture, or an application of the model to a short problem. Developing a lecture style involves practicing with and without an observer, watching the lectures of other students, and noting the style of professors from courses they take. While noting the teaching style of the professors, the students hopefully also were able to select what they liked and disliked of the teaching styles.

## ASSIGNMENT

The students are initially tasked with searching through the literature and textbooks for their lecture material. Due to the specificity of the mechanical modeling community, researching mechanical models is not an insignificant assignment. The research process involves multiple databases, as well as library time. An outline of the topic with a summary of the models chosen for presentation and all major references is due three weeks before presentations are scheduled to begin. The outline provides an opportunity to insure the material being covered is appropriate in breadth and depth. Office hours are available weekly for assistance with researching the literature or learning how to use certain databases. Several students make use of the office hours to learn how to search through different databases, as well as learn how to follow up an initial article by using the references to find a more basic mathematical model. Students who do not already have substantial experience with literature searches need more specific direction.

The lectures, which are videotaped for subsequent viewing, are given using only a whiteboard and markers. A referenced, written report of the mathematical model with derivations and verbiage, and copies of the main literature articles and text chapters utilized for preparation are handed to the course instructor for evaluation and grading. The written report is due before the lecture is given.

The lectures are required to include all elements of a good presentation, including an introduction that establishes the significance of the biological material, the uses of mechanical models to understand the particular tissue or cell, well-organized sections with titles, good flow from section to section, and a conclusion that sums up the key points and reiterates the significance. Table 1 illustrates the weighting of the different parts of the teaching project, which is discussed in more detail later. An integral part of the board lecture is handling and responding to questions. The students' ability to answer questions on their topic is directly related to both their understanding of the model and their effectiveness as an instructor. In addition, effectively answering questions in the middle of the lecture and continuing with the flow of the lecture is also a goal. Questions on the material are to be answered by rephrasing the initial information or giving an example, not just repeating lecture material.

Table 1. Evaluation parameters for the teaching project

| | |
|---|---|
| Outline three weeks before presentations begin | 5% |
| Meet with CAIN Project faculty with lecture prepared | 10% |
| Typed Report | 25% |
| Lecture | 60% |
| • Content (relevance, model explanation) | 15% |
| • Delivery Style (volume, board, etc) | 15% |
| • Organization (intro, flow, conclusion) | 10% |
| • Answering Questions | 5% |
| • Homework Problem and Solution | 10% |
| • Time Management | 5% |

## EVALUATION

The teaching project is worth 33% of the overall course grade. Within the teaching project the grading is broken down into the outline, the rehearsal, the written report and the actual lecture. The grading of the lecture is further broken down into content, delivery, organization, ability to answer questions, the homework assignment, and time management, as seen in Table 1. The students are evaluated after a practice lecture and the actual lecture with the assistance of the Cain Project. A minimum of three days before their lecture, the students present the material to a Cain Project faculty to allow identification of areas that need improvement. The areas found needing the most improvement are different for different students, but usually include delivery style, content, organization, ability to answer questions, and time management. While basics, such as legibility, clear speech, organization, and effectively answering questions were encouraged, each student developed a different lecture style that varied according to pace, demeanor, choice of supporting material, and use of the board.

The outline and practice session are not graded on a scale, while the report and lecture are. The typed reports are usually much more detailed than the lecture.

## PRACTICE SESSIONS

The practice sessions reveal significant problems in four areas, including the introduction and conclusion, explanation of the models, board technique, and time management. The practice sessions are held at least three days before the actual lecture with the same lecture environment and materials available as on the day of the lecture.

*Introduction and conclusion*

Students often make no effort to motivate interest in their model or to describe the significance or applications in the practice lecture. For example, one student began with 'Today I'm going to talk about muscle. Let's begin with Hill's Equation.' Similarly, as students near the end of their practice lectures, some simply finish the last equation and ask if anyone has questions instead of summarizing the key points and reinforcing the significance.

*Explanation of the model*

During the practice sessions some students simply copy the equations from their prepared written notes onto the board without thoroughly explaining what they are doing and why they are doing it. Some do not include enough explanation on the board in full sentences to follow the derivations. In some cases, the gaps in students' explanations reflect an incomplete grasp of the model. Many need to be reminded to set up the main objective, define the variables, identify governing equations and assumptions, and to account for the relationships between variables, equations, and biological material physiology. In particular, they need help constructing high-level summaries of significant steps in the derivations associated with a model.

*Board technique*

The gaps and imprecision in students' verbal explanations translate into clutter on the board in the practice sessions. Students usually begin their practice lectures well—dividing the board into segments, using headings, numbering equations, writing large and legibly. However, as they become flustered or pressed for time, they forget to number equations and label drawings, or crowd equations into one another. Their handwriting, especially the variables and partial differentials, becomes small and illegible. In addition to confronting the challenge of managing the board, students also discover how long it takes to write out equations. Some students have to work on making their handwriting more legible from the very beginning.

*Time management*

The outlines prepared prior to their practice lectures reveal that several students want to cover material that would take multiple class periods, if not half a semester, to teach. So one challenge is convincing students what constitutes a reasonable amount of material that can be taught in an hour. Even after revising their ambitious plans, some students' practice lectures last almost two hours, which prompts them to prune more content and to improve their fluency so that they can articulate their explanations clearly and succinctly.

## LECTURE IMPROVEMENT

The in-class lectures are significantly better than the practice sessions. All students make progress in terms of their ability to organize and explain their models. Delivery markedly improves, both in terms of legibility, as well as organization. The lecturers interact with the class, speaking directly to them as opposed to mumbling to the board or staring at their notes as many do in practice. Time management for the actual lecture is good, and while some students have to wrap up faster than desired, no one ends up being cut off.

## STUDENT FEEDBACK ON THE TEACHING PROJECT

Evaluations of the teaching project are collected at the end of the course to assess the value of the assignment and coaching. Various students taking the course have described the project as 'valuable', 'incredible' and 'perfect'. Of the ten respondents in 2002, six described the practice session as 'very useful' and four found it 'useful'. One student commented that the assignment 'provided some insight into what teaching in academia would be like'. Another commented, 'The preparation for this talk required us to learn the concepts taught in this course.' When several students were asked about the project over a year later, their response was still positive. One student felt the project, 'taught (him) how much work can go into planning a good lecture', as well as felt the project 'extremely valuable to any student thinking they want to go into academia'. Another student felt that as he progressed through his graduate education, he continued to draw from this experience and also remembered 'how much effort goes into the preparation of a lecture and the process of educating others'.

The overall consensus is that the teaching project worked well. However, two proposed changes to the assignment may result in better lectures:

- Assign each lecturer a presentation partner from the class or have one of the teaching assistants attend the practice session to help identify problems and inaccuracies in the student's understanding of the model.
- Ask more clarification and elaboration questions during the practice session to test the speaker's ability to respond and to see how well he or she can adjust the original lecture plan to suit the allotted time.

## DISCUSSION

Many graduate students have multiple opportunities to give formal, PowerPoint talks on their research or a class project. However, there is a higher degree of complexity and accountability involved in teaching a board-based lecture because in addition to displaying an effective communication approach, the instructor needs to manage the board, respond to questions, and prepare others to use new information immediately to solve problems. This teaching project helps the students understand and overcome the difficulties of teaching analytical models and of developing a lecture at the graduate level based upon the literature. Further, the experience is one of few in graduate school that explores the entire process of developing and teaching a challenging, graduate level bioengineering topic.

The students improve their style from the practice to the actual event. Many of them discover the difficulty in covering all of the information they thought necessary and learn to make sensible choices about what to include.

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