Imparting Relevant Retention of Fundamental Mechanics Concepts Using a Context-Rich Active Learning Approach

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Abstract

This work involves the development of an approach to significantly modify the introductory Mechanics of Materials (MoM) course to include viscoelastic material behavior as well as an immersive case-study based pedagogical strategy. Initial results show that the approach has helped students better understand polymers, address open-ended problems, and collaborate in their learning activities.

This work involves my activities focused on Active and Self-Directed Learning

Introduction and Objectives

The MoM courses in most mechanical engineering curricula focus very intensively on lecture-style presentation of concepts such as stress and strain through a formula-heavy approach. Follow up courses have shown that many students have very little retention of MoM concepts and poor understanding of their application. I focused on addressing these issues in CVEN 305, the introductory MoM course at Texas A&M.

The objectives of this work are to:

- Engage students in an active learning, context-rich learning environment using a problem-based learning approach,
- Incorporate viscoelasticity and design methodology into the course content, and
- Provide methods for students to monitor and track their learning outcome attainment.

Developmental History of Innovation

Industry partners and performance in follow-up courses indicate that many students do not have a strong grasp of MoM concepts, and that they have little understanding of polymer behavior. Such deficiencies put them at a disadvantage not only as they proceed through the curriculum, but also as they search for employment after graduation.

To address these deficiencies, we were awarded a CCLI grant to try a new pedagogical approach in the MoM course and evaluate the outcomes. I taught the course (CVEN 305) for four consecutive semesters, from fall 2009 until spring 2011, to develop, assess, and refine the approach.

Learning Activities and Materials

In order to address the objectives of the study, a number of tasks were executed. Firstly, in order to immediately impart context and relevance for the specific course concepts, a set of five realistic case studies were developed based on engaging engineering applications including aerospace and biomedicine. These cases are open ended and challenge the students to think like designers. The proper content and order of the case studies is based on a concept map of mechanics topics that was prepared.

Secondly, the syllabus of the course was changed dramatically to separate the discrete course learning outcomes, indicate the desired cognitive levels of understanding of the outcomes, and offer a mechanism for students to actively track outcome attainment. This produced a real-time learning outcome 'matrix' shown below that was filled with students' scores as assessments were completed. Each assessment question was tied directly to a particular learning outcome-cognitive level combination. This was intended to provide a high resolution picture for students to identify their areas of weakness.

Learning Outcome	Level 1 Identify/Calculate	Level 2 Apply	Level 3 Analyze/Evaluate
1. Functional Decomposition	1-1	1-2	1-3
2. Material Transitions Transition modes yielding fracture deformation buckling Concepts of failure Factor of safety Strength	2-1	2-2	2-3
3. Stress Normal stress engineering vs. true Shear stress Stress concentration	3-1	3-2	3-3
4. Strain Normal strain engineering vs. true Shear strain	4-1	4-2	4-3
5. Stress vs. strain behavior Elasticity Plasticity Viscoelasticity Thermoelastic behavior	5-1	5-2	5-3
6. Multiaxial loading behavior Principal stress Mohr's Circle Principal strain	6-1	6-2	6-3
7. Specific geometry behavior Beams bending shear torsion Thin wall objects	7-1	7-2	7-3

Learning Outcome Matrix used in the course grading. The scores in each cell are directly tied to particular assessments during the semester. The matrix is available online for students to examine during the semester in order to track their attainments and deficiencies

Execution

Lecture content (notes and audio) was delivered outside of class time using the Livescribe™ system. 'Pencasts' of the traditional formula-heavy lectures were made available online before class and were accompanied by open-ended problem solving assignments based on the lecture content. This allowed class time to be used for high Bloom's level discussions and activities involving the lecture concepts. Typically, an involved problem was given in class that required students to develop and diagram a solution approach to a problem. A cycle of pencast to assignment to in-class discussion to assessment was maintained in order to give multiple and immersive exposure to course topics.

The pencast approach has been widely enjoyed by the students, with the only concerns arising because of the third-party website hosting of the content. Other technologies could certainly be substituted. There has been some resistance to doing open-ended problems during class time because some students have expressed their desire for a definite 'right' answer. Finally, there was a concern among some students that they did not memorize mechanics formulas as well as their peers in the unmodified sections of the course.

Major Issues to Resolve

The issues that I would like to resolve are focused on three areas:

- Student understanding of and adaptation to non-traditional grading approaches
- Adoption of instructional technology and electronic assessment of high Bloom's level understanding
- Identification of a standardized concept inventory for introductory mechanics

Discussion

The following conclusions can be made thus far:

The approach does no harm to students. They perform as well as their peers in follow-on courses with respect to overall grade and individual assessment questions in the follow-on courses.

The students exhibit a collaborative learning attitude during the course to identify best practices for studying and class discussion.

Students show better preparation than their peers in addressing open-ended problems in the capstone design course one year later in their curriculum.

The results were presented at the 2011 ASEE Annual Conference:

- Froyd, J., Rajagopal, K., and Schwartz, C.J.: *Comprehensive Course Redesign: Introduction to the Mechanics of Materials*

Future work will include development of appropriate concept inventories and further dissemination of the model to spur collaborative contributions.

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