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Collaboratively Developing Research-Based Curricular Materials to Improve Conceptual Understanding in Engineering Education

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I. Abstract

This paper describes work in developing research-based curricular materials for students' conceptual understanding of mechanics of materials. The work will begin in summer 2013, and the paper outlines the proposed work as well as the preliminary research efforts supporting the launch of this project.

II. Introduction

Researchers have known for decades that students' conceptual understanding of fundamental engineering and science concepts starts low and does not change significantly after traditional, lecture-based education[1-6]. Theoretical and empirical research in conceptual change and conceptual understanding have shown that education that actively engages students and incorporates their own understandings of the material is more effective. Although some individuals are engaging students differently, for examples see[7, 8-11], a great many faculty members would need to be convinced to change their teaching methods or adopt new practices to significantly change the conceptual understanding of students.

The purpose of the work described in this paper is to develop curricular materials that address both the issue of encouraging broad adoption and the issue of effectively changing students' conceptual understandings in the context of mechanics of materials. To ensure that the developed materials address both issues, the following two specific aims will guide the proposed work:

- Specific Aim 1 (Adoptability) – Encourage the broad adoption of the developed materials by incorporating the perspectives of potential users in the development process.
- Specific Aim 2 (Effectiveness) – Ensure the effectiveness of the developed materials by utilizing existing research and conducting new research on student conceptual understanding and the materials' effectiveness in improving it.

The general approach of this project is to develop research-based curricular materials for use in mechanics of materials courses. A cohort of approximately 20 university and community college instructors will then implement, assess and improve the developed materials. Ongoing research on student understanding of fundamental concepts in mechanics of materials will help support the development of those materials. The graduate students and PI's conducting this research at Washington State University will also provide support and resources to assist the project team as they implement and assess the newly developed materials. This small effort can have a large impact because it allows the participants to spend their energy implementing new materials, rather than record-keeping while maintaining the vitally important feedback from actual users[12].

III. Project Activities

A. Previous Work

The work described in this project has not yet begun. The development of the curricular materials depends on research findings. Preliminary efforts describing students' understanding of concepts related to portions of mechanics of materials are summarized below in Table 1.

Publication	Key Findings
Brown, S., Montfort, D., and K. Hildreth. (2008). *An Investigation of Student Understanding of Shear and Bending Moment Diagrams*. Innovations 2008: World Innovations in Engineering Education and Research.	• Students struggle with shear and moment diagrams and have limited understanding of how point loads and reactions affect internal forces • Fundamental concepts like "moment" or "shear" are difficult for some academically successful students
Montfort, D., Brown, S., and D. Pollock. (2009). *An Investigation of Students' Conceptual Understanding in Related Sophomore to Graduate Level Engineering and Mechanics Courses.* Journal of Engineering Education	• Students have low conceptual understanding of the stresses developed in bending throughout their academic career • Students' abilities to draw diagrams did not assist them in reasoning about the distributions of stresses • Many students do not understand the differences between stress, strain, forces and deformations
Brown, S. and D. Lewis (2010). *Student understanding of normal and shear stress and deformations in axially loaded members*. ASEE National Conference and Exposition, Louisville, KY.	• Many students are unable to answer qualitative questions about even the simplest loading cases • Student understanding of shear in lower than their understanding of normal stresses and strains
Brown, S., D. Lewis, D. Montfort, and R. L. Borden. (2011) *The Importance of Context in Students' Understanding of Normal and Shear Stress in Beams.* American Society for Engineering Education Annual Conference, Vancouver, BC.	• Small changes in how a problem is presented can significantly change students' reasoning • Many students are better able to answer qualitative questions about a picture of a concrete cylinder in compression than a drawing of a generic axially loaded member

Table 1. Summary of preliminary research and findings about conceptual understanding of mechanics of materials

An equally important line of preliminary efforts has developed our understanding of how curricular materials are adopted by engineering education faculty. These efforts are summarized in Table 2 below.

Publication	Key Findings
Montfort, D., Brown, S. and J. M. Pegg. (2009). *An investigation of the adoption of an assessment instrument for capstone design courses.* 2009 ASEE/IEEE Frontiers in Education Conference. San Antonio, TX.	• Diffusion of Innovations theory can be used todescribe the adoption behavior in engineering education • As in many other contexts, participants' perceptions of the relative advantage and compatibility of the innovation with their values are highly important
Montfort, D., Brown, S. and J.M. Pegg. (2012). *The Adoption of a Capstone Assessment Instrument.* Journal of Engineering Education	Identified central importance of potential adopters' perceptions of the problem being solved, and the potential efficacy of involving adopters in development of innovations

Table 2. Summary of preliminary research on adoption and key findings

B. Proposed Work

The first step in this project will be a summer workshop in 2013 to bring together the project team and disseminate a first round of curricular materials for pilot testing and evaluation. Additionally, the previous research findings described in the previous section will be shared with the team. In the following semester, interviews will be conducted with students to begin to describe their conceptual understanding of concepts in mechanics of materials that have not already been researched. For example, these interviews might focus on torsional loadings and the stresses and strains developed. Throughout the semester the project team's experiences with the developed curricular materials will be collected and assessed. The first publication from this project will likely be a description of student understanding of the newly researched concept. In this first stage, the emphasis will be on developing sound, research-based curricular materials to share and develop with the team.

IV. Conclusion and Expected Significance

At the end of this project in 2016 we will have curricular materials intended to improve students' conceptual understanding for every concept in mechanics of materials, along with assessments of their effectiveness. Additionally, a key part of the collaboration with the project team is ensuring that those curricular materials are something they (and hopefully, then, faculty like them) would actually use. The materials developed in this project will therefore be adopted and able to benefit students at all 15 collaborating institutions. Materials developed by instructors for immediate use in their classrooms are also more likely to be adoptable by other faculty. Future work will focus on the dissemination of these materials as well as our findings concerning student understanding of mechanics of materials.

V. Acknowledgements

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