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

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Dr. Shane Brown conducts research on cognition and conceptual change in engineering. He received his bachelor’s and Ph.D. degrees from Oregon State University, both in Civil Engineering. His Ph.D. degree includes a minor in Science and Mathematics Education. His master’s degree is in Environmental Engineering from the University of California-Davis. Dr. Brown is a licensed professional civil engineer and has six years of experience designing water and wastewater treatment facilities in central California. He was the recipient of the NSF CAREER award in 2011. Dr. Brown’s research focuses on theoretical approaches to understanding why some engineering concepts are harder to learn than others, and how the concepts are embedded in contexts.

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Dr. Poor has been teaching many of the integral undergraduate civil engineering courses at Washington State University for the last six years, including seven mechanics of materials courses. She received the departments’ Outstanding Teaching Award in 2010 and Outstanding Advising Award in 2012. Dr. Poor is a licensed professional engineer with ongoing research in hydrology, water quality, and engineering education. Her education research includes contributing to the design of an innovative peer-tutoring program, which she continues to implement. Dr. Poor is co-author, with Dr. Brown, of a book of ranking tasks for use in interactive mechanics of materials courses.
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To Improve Conceptual Understanding in Engineering Education

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.

<table>
<thead>
<tr>
<th>Publication</th>
<th>Key Findings</th>
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<tbody>
<tr>
<td>Brown, S., Montfort, D., and K. Hildreth. (2008). <em>An Investigation of Student Understanding of Shear and Bending Moment Diagrams</em>. Innovations 2008: World Innovations in Engineering Education and Research.</td>
<td>• Students struggle with shear and moment diagrams and have limited understanding of how point loads and reactions affect internal forces</td>
</tr>
<tr>
<td>Montfort, D., Brown, S., and D. Pollock. (2009). <em>An Investigation of Students’ Conceptual Understanding in Related Sophomore to Graduate Level Engineering and Mechanics Courses</em>. Journal of Engineering Education</td>
<td>• Students have low conceptual understanding of the stresses developed in bending throughout their academic career</td>
</tr>
<tr>
<td>Brown, S. and D. Lewis (2010). <em>Student understanding of normal and shear stress and deformations in axially loaded members</em>. ASEE National Conference and Exposition, Louisville, KY.</td>
<td>• Many students are unable to answer qualitative questions about even the simplest loading cases</td>
</tr>
<tr>
<td>Brown, S., D. Lewis, D. Montfort, and R. L. Borden. (2011) <em>The Importance of Context in Students’ Understanding of Normal and Shear Stress in Beams</em>. American Society for Engineering Education Annual Conference, Vancouver, BC.</td>
<td>• Small changes in how a problem is presented can significantly change students’ reasoning</td>
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</table>

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.

<table>
<thead>
<tr>
<th>Publication</th>
<th>Key Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montfort, D., Brown, S. and J.M. Pegg. (2012). <em>The Adoption of a Capstone Assessment Instrument</em>. Journal of Engineering Education</td>
<td>• As in many other contexts, participants’ perceptions of the relative advantage and compatibility of the innovation with their values are highly important</td>
</tr>
</tbody>
</table>

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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VI. REFERENCES


