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Extended Faculty Development Effort Based on Faculty Needs

Dr. Shane A. Brown P.E., Oregon State University

Shane Brown is an associate professor and Associate School Head in the School of Civil and Environmental Engineering at Oregon State University. His research interests include conceptual change and situated cognition. He received the NSF CAREER award in 2010 and is working on a study to characterize practicing engineers' understandings of core engineering concepts. He is a Senior Associate Editor for the Journal of Engineering Education.

Mr. Matthew Stephen Barner, Oregon State University

M.S. student at Oregon State University working under Dr. Shane Brown.

Research interests include: engineering education, dissemination and adoption, case-study research, conceptual change theory, and earthquake engineering.

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Introduction:

Extensive research in student learning has led to the development and dissemination of several pedagogical innovations aimed at enhancing the learning experiences of students. Adoption of these innovations in classrooms at all levels has been less than desirable even though educators are often well aware of their benefits.[1] Traditional professional development efforts, such as seminars and workshops, aimed at providing educators with the most up-to-date research-based instructional strategies have been limited in their impact for several reasons. Most prevalent of these reasons are that instructors are not involved in the development of these innovations, little to no effort is made to follow up with instructors after the workshop or seminar, instructors are not provided with enough training and resources to adopt new curriculum during the academic year, and these professional development efforts typically focus on universal learning rather content-specific learning.[2] The research activities and findings presented in this paper discuss efforts to address all of these limitations and their potential impact on future professional development directed more towards faculty needs.

Activities and Findings:

Activity 1: Students Conceptual Understanding of Fundamental Mechanics of Materials Topics

Detailed analysis of all data collected in this, and previous projects related to mechanics of materials (MoM), has been completed and student misconceptions identified. We have about 100 interviews with students about their understanding of MoM.

Findings

It was found that students oversimplify the relationship between applied loads and resulting internal stresses in two primary ways:

(1) They assume that stresses are greatest nearest to the applied load because the effect of the load is less far away from its point of application. This is an oversimplification because the internal stresses are influenced by factors other than the load itself, such as the shape of the object or the ways it is restricted from moving. Although students are able to calculate values of stress using these other factors, they ignore them in generating causal descriptions of the phenomena.

(2) They do not believe that axial members have shear stress, that bending members have normal stress, and that torsional members have normal stress. For axial members they believe that since there are no loads perpendicular to the member that there cannot be shear stress. For bending beams they believe that since there are not loads parallel with the member there is no normal stress. And, for torsional members they believe that since there are no axial loads there can be no normal stress. In sum, this provides evidence that students believe stresses only occur in the direction of the applied load. This finding suggests that students have misconceptions that transcend individual loading cases.[3]

These results were interpreted in relation to Stella Vosniadou's framework theory of conceptual change. The framework theory suggests that people have epistemological and ontological commitments that their beliefs about individual phenomena are filtered through.[4] Students' naïve theories limit their abilities to develop correct understandings. The following quote from a paper in review explains this approach. "This naïve framework theory does not take into consideration the effects of the applied force on the solid object that are not easily observable. Students develop explanations based on the epistemological assumption that predictable observable behavior is simple, and should be explained primarily by observable precedents. […] In practice this means that people will focus more on observable phenomena as causes, effects and explanations, and value their own experiences above generalized laws. The naïve framework theory of mechanics of materials is related to Vosniadou's framework theory where the underlying epistemological commitment is that things are as they appear to be.[5]

Our hypothesized mechanics of materials naïve theory, similarly to initial models of the Earth, has its beginning 'in a related set of beliefs (specific theory)' about how objects behave when force is applied that 'are based on interpretations of observations and cultural information.'[6] Such interpretations are limitations of mechanics of materials naïve theory. For example, mechanics-specific theory includes observations that as objects are pushed or pulled, they move or deform at the locations where they are pushed or pulled and in the direction where they are pushed or pulled. From these observations, a student may create the belief that pushing and pulling causes objects to move, deform, or break. These beliefs are rooted in students' epistemological commitment, where predictable observable behavior is simple, and should be explained primarily by observable precedents. And in their ontological commitment that stress is local and directional."[7]

Activity 2: Co-Development of Curricular Materials amongst Engineering Educators and Education Researchers

A two-day summer workshop has been held in August for the past 4 years (2013-16) in Portland, Oregon with 15 – 25 engineering instructors and engineering education researchers attending each year. On the first day, workshop participants are presented research findings on students' conceptual understanding of MoM topics and then are encouraged to share other mechanics of materials topics they see their students struggling with and/or that they struggle with teaching. Instructors then form groups to develop curricular materials (hands-on demonstrations, instructional videos, etc.) based on what they want for their classrooms and the research presented. On the second day, instructors present their innovative materials to the other groups, explaining how to implement them. Each subsequent year the same instructors from the previous year are invited back and encouraged to invite their peers, increasing the size of the workshop and broadening the impact. Instructors from previous years also give their feedback on how adopting and implementing the materials developed at the previous workshop went during the academic year to help build upon lessons learned and improve the researchers' efforts.

Findings

We have developed a richer understanding of how to conduct workshops of this nature based on lessons learned from each year and our engagements with the instructors during the academic year. Focusing the workshop on the highly specific content of MoM has been a major success on the professional development of the instructors and their adoption of curriculum that enhances their students' engagement around difficult concepts. Instructors have expressed greater confidence in teaching MoM and extreme interest in a similar styled workshop aimed at other core engineering topics such as dynamics and statics.

Inviting instructors to participate in the development of curricular materials and pedagogical practices has led to greater ownership and accountability of the materials developed, improving adoption efforts.[8] Over 20 new hands-on demonstrations have been developed at these workshops and implemented in mechanics of materials courses of more than 30 instructors across the country.

Activity 3: Development and Dissemination of Hands-On Teaching Demonstration Materials

Teacher demonstration kits consisting of innovations developed at the 2013 and 2014 summer workshops were put together and sent to each participant during the 2014-15 academic year. Each innovation was accompanied with an in-class worksheet guiding the instructor through how to use the demonstration and providing conceptual questions for their students. Each kit consisted of demonstrations for axial, bending, torsion, and combined loading, stress and strain, St. Venant's principle. Each demonstration consisted of some deformable material, such as a foam swimming noodle or elastic exercise band with stress elements drawn on for students to observe the different types of stress and strain that a stress element experiences at different locations due to various loads.

Findings

Instructors expressed their gratitude in receiving all the materials developed at the 2013 and 2014 workshops to implement during the the 2015-16 academic year because in many cases the instructors would not have had the time or resources to prepare all of these materials on their own which would lead to their innovations not being adopted. Still, instructors expressed at the following 2015 workshop that receiving the materials even sooner would allow them more time to plan their curriculum for implementing their innovations. They also expressed not wanting an in-class worksheet attached with each demonstration because it often took up too much class time for what they originally intended when creating the demonstration. Another major request at the 2015 workshop was for enough hands-on demonstrations to put in the hands of each of their students to follow along with during class lectures and use during interacting learning activities.[9] These concerns were addressed and accounted for in the following year.

Activity 4: Concerns-Based Adoption Model (CBAM) Assessment of Adoption Efforts

Audio data was collected during the 2014, '15, and '16 workshops while participants were in their groups developing curriculum. Following the 2014 workshop, participants were also interviewed during the 2014-15 academic year to understand their implementation and their concerns during this process. This data was analyzed using CBAM to understand instructors' concerns with adoption and how these concerns evolved from those expressed during the workshop and then to those expressed during the academic year

Findings

Instructors interviewed during the 2014-15 academic year primarily expressed management and consequence concerns during their implementation process. According to CBAM management concerns pertain to the organizing, planning, and scheduling of implementation, and the consequence concerns pertain to how the innovation will impact student learning. The consequence concerns were typically directly related to the management concerns because if instructors felt they did not plan well enough for implementing the innovation, then it would adversely affect their students learning and would therefore sometimes abandon use of the innovation. These findings align with the instructors expressing not having enough time to plan for the innovations due to the limited amount of time between when they received their kits and when their course started.[10]

Activity 5: Student Demonstration Kits

After the 2014-15 academic year the instructors expressed at the 2015 workshop wanting to have accompanying student demonstration kits so that their students could follow along with the demonstrations developed at past workshops and the new ones developed at the 2015 workshop. Each instructor teaching during the 2015-16 academic year received a kit for each of their mechanics of materials students, resulting in over 600 students having their own hands-on materials to use throughout the course. These student kits consisted of a rectangular foam beam, foam stress element, foam cylinder, elastic band, and Velcro arrows to stick on the foam elements to represent stress and/or load vectors.

Findings

The student kits provided increased incentive for the instructors to engage their students through the hands-on demonstrations they developed and also helped further engage the students around difficult MoM concepts. We implemented a survey to students in ten of the classrooms where faculty implemented the student learning kits. The learning kits consist of a beam, torsional member, axial member, stress element, and rulers and markers to use with these elements. More than 75% of students agreed with the statement that the kits "help them be more effective" in the course.[9] Students were also asked in what ways the kits were helpful in learning about mechanics of materials. The following are sample student responses:

- "It helped especially for shear stress, which is for me the hardest to visualize."
- "It was helpful to see how different stresses affected the shape of a square."
- "It helped determine the direction of shears."
- "Drawing lines on the foam to get a visualization on angle of twist."
- "It is much easier using the elements in the kit to make the twists/rotations and actually see what the deformations are."
- "It showed how bending moments can cause compression or tension on one side of the specimen."

- “The kit was helpful in visualizing bending and other stresses.”
- “It helped me understand the concepts of bending and torsion perfectly”
- “This kit is a real life model which eliminates the risk of my own misconceptions.”[9]

Activity 6: Continuous Engagement with Instructors During Adoption Process

Two undergraduate students communicated with 2015 workshop participants teaching during the 2015-16 academic year on a weekly to bi-weekly basis over the phone to discuss the instructor’s progress in implementing their student kits and other previously developed innovations. The undergraduates answered any questions the instructors had to help them during this process, shipped additional materials as requested, and helped develop additional worksheets and instructional videos to be shared amongst the group. Instructors were also interviewed by a graduate student before and after their term of instruction to understand the value of these interactions on the instructors’ effort to change.

Findings

Maintaining continuous engagement with engineering instructors during their adoption process yielded multiple benefits into enhancing and understanding instructors’ adoption efforts and decision-making when implementing new curriculum. By having aids interact with potential adopters throughout the academic term, instructors perceived greater accountability to make changes in their classroom and were more conscious of ways they can improve their adoption and adaptation of new curricula.[9]

Additionally, through conducting interviews with the instructors before and after their term of teaching, we were able to document situational concerns instructors face when implementing new material into their classroom. For example, community college instructors are often the only person teaching a specific course at their institution and they greatly appreciated being able to collaborate with their aid throughout the term because they did not have colleagues to provide a similar relationship. Furthermore, we observed that more experienced instructors were more likely to adapt new teaching strategies and materials into their existing curriculum; whereas less experienced instructors were more likely to adopt new curriculum as is. Newer instructors expressed less confidence with the material and appreciated having additional resources and strategies to build their experience around. The experienced instructors often desired materials and strategies that could specifically target areas in their curriculum that, in their experience, past students had struggled with and therefore wanted resources that could be easily adapted and implemented into their existing curriculum. Overall, we found that by engaging instructors throughout their adoption process not only increases their likelihood to adopt new educational innovations—due to greater self-accountability—but also provided insight into how instructors approach adoption which can help focus future dissemination and adoption efforts.[9]

<u>Discussion:</u>

Our findings about mechanics of materials mark one of the first collections of research findings on student understanding of an entire engineering course. We have identified important underlying themes in the conceptual challenges students face in this course that are likely transferable to other courses. In particular we have found that students rely on overly simplified causal relationships between load and stress across loading cases.[3] Understanding why students have these misconceptions through the lens of conceptual change theory will help us impact more faculty and students by informing our educational approaches. We have compared our findings with existing conceptual change theories and have found useful correlations with theories with broad differences in how they explain misconceptions. These findings will impact educational psychology and the research field of conceptual change, providing evidence that current theories are too narrow and specific.

Additionally, our findings about faculty development through our efforts to involve them in the curricular development process and continuously engaging them during the adoption process has helped us identify some best practices for working with faculty to enact change in teaching practices. Ultimately, from this group we have found that if faculty have greater autonomy and control over development, adaptation, and implementation of curricular innovations, then they are more likely to adopt these innovations in their classrooms.[9] Furthermore, if the faculty are engaged on a regular basis during the implementation process, they are more likely to sustain their adoption efforts. Finally, concentrating professional development efforts on one course focuses the researchers and faculty efforts towards change and once the benefits of these changes are realized, faculty often begin to look for ways to make meaningful changes to their curriculum in other courses on their own.[9]

Conclusion:

By way of our annual workshop, these results have been disseminated to more than 30 faculty at 25 different institutions who teach mechanics of materials throughout the country. These faculty have spread our results and methods to their colleagues that represent about 20 additional faculty. This community has participated in at least one workshop and/or implemented curricular materials developed from at least one of the workshops and is expected to continue growing as participants continue to share their innovations with their peers. The faculty that attended the 2016 workshop have expressed interest in a similar series of workshops for other engineering courses such as statics or dynamics. Therefore, there appears to be a need and desire for similar, faculty-centered approaches to dissemination of engineering education research in several other engineering courses; and that such efforts have the potential for broader impact.

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