Flippin' Engineering Mechanics!
Observations of Student Achievement and Engagement

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Author Biography
Donald Webster joined the faculty at the Georgia Institute of Technology in 1997 and is currently the Karen & John Huff School Chair and Professor in the School of Civil & Environmental Engineering. Dr. Webster's research expertise lies in environmental fluid mechanics focused on the influence of fluid motion and turbulence on biological systems. Dr. Webster is a Sustaining Fellow of the Association for the Sciences of Limnology and Oceanography and has won numerous awards including the Class of 1934 Outstanding Innovative Use of Education Technology Award, the Eichholz Faculty Teaching Award, and the British Petroleum Junior Faculty Teaching Excellence Award.

Goal of Activity
The goal of this activity is to improve learning outcomes for core undergraduate engineering mechanics students by transforming the classroom experience from a traditional modeling-and-mimicry pedagogy into an active and engaging learning environment. But, what do "active" and "engaging" mean? Chi and Wylie (2014) developed a taxonomy for learning engagements. In this framework, the categories of engagement describe observable behaviors in students. Interactive (I) engagement occurs when two students engage in constructive dialogue around a product, in which turn-taking is evenly distributed; constructive (C) engagement occurs when students generate or produce an output of some kind; active (A) engagement occurs when students exhibit some kind of motor movement or physical manipulation; and Passive (P) engagement occurs when students receive information without doing anything beyond listening. Chi and her colleagues believe that these categories not only demonstrate a spectrum of learning modes but also form a hierarchy of learning achievement from minimal understanding (P), to deep understanding (I) because higher levels of student engagement correlate with higher levels of student outcomes. The framework is typically referred to as ICAP, an acronym consisting of a letter for each level of engagement and achievement in descending order.

A common (or "traditional") engineering mechanics lecture course format typically can be described as active (A) in that students are taking notes and participating in discussion. Further, students often have constructive assignments outside of the classroom consisting of problem-solving exercises. The challenge is to see whether such a course can be transformed into an interactive (I) learning environment, one that elevates student engagement and achievement.

Description of the Activity
The pedagogy described here has been implemented in a series of engineering mechanics courses, including Engineering Dynamics and Fluid Mechanics. These courses are considered foundational subjects in most undergraduate engineering curricula. They are rigorous and challenging courses that blend fundamental physical principles, applied calculus, material properties, and other technical subjects to address engineering applications.

By employing strategic technological elements in the course design, an interactive learning environment can be created. The approach follows what typically is referred to as a blended or "flipped" classroom. As described below, this pedagogical approach requires a significant shift in the roles and activities of the students and instructor.

Prior to arriving for the classroom session, students watch online video lectures that consist of short (10 minute) introductions to the content and sample problem-solving exercises. During the classroom session, students are given problem-solving exercises on the daily subject. The instructor often starts one exercise on the board and then releases the students to work in teams of two to complete a series of exercises of increasing difficulty. The instructor and assistants roam the room talking to the student teams and answering questions. The interactive nature of the classroom comes through the communication and negotiation within the student pairs and with the instructors. The team size of two students was selected in order to facilitate the conversations. Students do not receive credit for successfully completing the problems beyond credit for attendance and participation, a decision that has the net effect of focusing the students' attention on learning rather than completing the assignment. The instructor's handwritten solutions are posted after class on the course website, so the students can "close the loop" on aspects that remain unclear to them.

Students are given weekly online quizzes that assess their achievement of the learning objectives of the weekly content. The online system generates unique input parameters for each individual student so that no two students have the same numeric answer. Students receive immediate feedback on the correctness of their submissions, and they can receive credit for any of three attempted submissions. After submitting either the correct answer or the third incorrect answer, students gain access to the handwritten problem solution (and cannot submit additional answers for credit). The instructor and assistants are available for in-person or online "office hours" help in the period leading up the quiz submission deadline. On roughly a four-week cycle, exams are given (in class) that consist of hand-written problem-solving exercises. A comprehensive final exam is given at the end of the semester, again consisting of problem-solving exercises. The instructor manually grades all exams to assess student achievement of the problem-solving skills and other learning outcomes.

Reflection on How This Activity Meets the Author's Goal

The instructor was highly motivated to assess the effectiveness of the pedagogy and collected significant data to quantify student achievement, engagement, and perceptions. These data include mid-semester opinion surveys, end-of-semester standardized course and instructor opinion surveys, pre-semester and post-semester concept inventory exams, standardized engagement surveys, and exam scores.

In all cases, course assessment reveals significant gains in student achievement, engagement, and perceptions in the blended classroom format. Specific comparisons conducted include 1) a comparison of parallel offerings of a traditional section and a blended section during the same semester (with common exams); 2) a comprehensive longitudinal comparison of student achievement and perceptions over a 15-year period in classes taught by the same instructor in both course formats; and 3) a comparison of a relatively small blended section with 37 students to a much larger blended section of 82 students (with the same instructor).

The results of these studies are remarkable. Students universally reached higher achievement of the learning outcomes in the blended classroom in the parallel-section study as well as in the multi-year comparison with the same instructor. Student surveys reveal significantly greater enthusiasm, stimulation, self-perception of how-much-learned, perception of the value of the course activities, and the overall effectiveness of the course and instructor in the blended classroom format. The blended classroom format also yielded a significantly lower withdrawal/failure/deficient (WFD) rate, indicating that struggling students are more able to remain in the course and achieve success. Students in the larger blended class performed as well as, or better than, students in the much smaller blended section. They also showed a similar level of engagement and a similar, or even more positive, perception of the course effectiveness in the larger blended section, indicating that the course format defies conventional wisdom about declining engagement and satisfaction with increasing class size. In summary, the blended-classroom approach can be remarkably effective in notoriously challenging engineering mechanics courses.

References

Chi, M. T. H. & Wylie, R. (2014). "The ICAP framework: Linking cognitive engagement to active learning outcomes." Educational Psychologist, 49: 219-243.