Advances in Engineering Education

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From the Editor

This issue features eleven papers spanning a wide range of topics focusing on the freshman to graduate teacher training. At the first-year level papers address a flipped Calculus course, problem-based learning, and experiential learning. In particular:

Hadas Ritz and Lisa Schneider-Bentley in “Collaborative Problem Solving at Chalkboard versus On Paper for First-Year Calculus” introduce a creative twist: switching in-class collaborative problem-solving activities from group work using paper worksheets to group work using sections of the chalkboard/whiteboard as a simple way to improve both the session’s efficiency and the student experience. They found this was effective in keeping everyone on task and progressing systematically through the problems. Further, it increased collaboration within each group, and made it easier for the instructor to have all students engaged. A side benefit was seeing the importance of maintaining the integrity of the workshop’s implementation in a flipped classroom environment.

Jill Marshall, Amit Bhasin, Stephen Boyles, Bernard David, Rachel James, and Anita Patrick in “A Project-Based Cornerstone Course in Civil Engineering: Student Perceptions and Identity Development” used a natural experiment to compare a project-based cornerstone course with the traditionally-taught introductory course in civil engineering. They found that students in the project-based course gained more on measures of creativity and design self-efficacy than traditionally-taught students, but also observed a decrease in mathematical self-efficacy. While students appreciated that the project-based course enabled them to do real engineering, there were concerns that they might not be learning de-contextualized science and mathematics. Their study adds to the body of work on engineering identity by showing that a highly-scaffolded, constrained, first-year design project in context can promote the development of some aspects of engineering identity, design self-efficacy and creativity in particular. Students found the course “interesting” and “engaging”, despite concerns about whether they were learning what they should have learned. Further study with additional students in a variety of settings is required to confirm these results.

William S. Kisaalita in “Inquiry-Based Freshman Seminar on ‘What you Can (or Should Not) Do to End Global Poverty’” describes an inquiry-based freshman seminar in which students conduct poverty simulation term projects. The students are given four project options: dressing the part and panhandling downtown, eating at a local soup kitchen, living on $5 per day for a reasonable number of days, or their own similarly structured project. The key element is to put the student in a poor person’s shoes. Students then reflect on their experiences through an essay. Qualitative analysis of the projects revealed multiple themes, with the majority suggesting that the experience aroused their empathetic feelings. These results support the author's view that stepping into the panhandler's shoes would do just that. The larger meaning of these findings in the context of freshman STEM education, is that it is one "high impact" way for students to see or to be turned on to the humanitarian dimension of their proposed major.

At the sophomore level Benjamin Ahn's and Devayan Bir's "Student Interactions with Online Videos in a Large Hybrid Mechanics of Materials Course" examined the video-viewing behaviors of students and their reasons for deciding to watch or not watch videos in a hybrid sophomore-level Mechanics of Materials course. Their findings revealed that when students viewed the videos, they watched most of the content; for videos 1 to 22 minutes long, the number of times played and the percentage of videos completed did not vary. Rather, the number of times viewed depended on the difficulty of a video's topic; the number of times played increased during exam periods. Students played videos for a variety of reasons: to learn and understand material, to review for exams, and to complete homework and in-class assignments. Videos that addressed difficult topics garnered many plays. While most students found the videos to be a great supplemental resource, some did not enjoy learning via videos due to difficulty concentrating, insufficient or wrong type of information, or a learning style that did not include video watching.

Firdous Saleheen, Zicong Wang, Joseph Picone, Brian Butz, and Chang-Hee Won have proposed a replacement to a live teaching assistant in "Efficacy of a Virtual Teaching Assistant in an Open Laboratory Environment for Electric Circuits." Their paper describes an innovative software-based Virtual Open Laboratory Teaching Assistant (VOLTA) that provides laboratory instructions, equipment usage videos, circuit simulation assistance, and hardware implementation diagnostics. It allows students to perform laboratory experiments anywhere at their convenience. The authors found that VOLTA can support students in open and closed laboratories as effectively as a human teaching assistant. VOLTA was designed to be extensible and can be introduced in other engineering laboratories involving electronics, communications, and control systems. Since the platform is portable, VOLTA can support students taking online courses.

Another take on using videos is provided by Kimberly Talley and Shaunna Smith. Their paper "Asynchronous Peer-to-Peer Learning: Putting Student Projects to Work in Future Classes" proposes that having students create videos as a term project provides not only an opportunity for peer-to-peer learning (via those videos), but also results in course content that could be later used in flipped or hybrid courses. Further, the video project helps the student creators learn the video content material. Their paper explores the effectiveness of the resultant videos in facilitating student learning. The authors found that the student-produced videos do have potential for providing course content, especially for flipped or hybrid courses. Further, students indicated that they viewed the projects favorably and overwhelmingly indicated the projects were informative. Based upon the initial positive results on student learning, the authors plan to create online modules featuring these videos and quizzes for students to complete as part of a flipped course.

Another classroom innovation is provided by Yi Wu, Charlotte de Vries, and Qi Dunsworth in their paper “Using LEGO Kits to Teach Higher Level Problem Solving Skills in System Dynamics: A Case Study.” The paper focuses on a required, junior-level mechanical engineering System Dynamics course that covers the intercoupling dynamics of a wide range of dynamic systems. Its abstract nature and advanced required mathematics make the course difficult for a number of students. To address this, the authors use low cost LEGO® MINDSTORMS® NXT kits to help students learn key quantitative skills in Systems Dynamics. Lab activities use MATLAB®/Simulink® to study the response of LEGO MINDSTORMS units. Multiple surveys and learning assessments collectively indicate that students’ confidence and skills in topics covered by the labs improved. Overall, there was strong evidence that LEGO labs helped students in learning critical quantitative skills. Further, the labs improved student performance similar to courses with more frequent and longer labs.

Stephanie Wettstein’s innovation is described in “Self-paced, Active Problem-Solving Using Immediate Feedback (IF-AT) scratch-off forms in large classes.” Specifically, she uses immediate feedback forms in a junior-level mass transfer unit operations course to allow four person groups to self-pace themselves through in-class problems. The immediate feedback forms allowed students to check their progress, use cooperative learning to resolve their misconceptions, and ask questions only when truly stuck. Student and instructor feedback was highly positive. By having the students check their answers as they worked through a problem dramatically reduced the amount of questions asked of the teaching assistant and instructor and seemingly led to less frustration of students in a large class where wait times for an instructor could be long. Additionally, the IF-AT forms allowed the instructor to determine where the students had the most difficulties and address them in the following class.

Two papers suggest ways to improve product design and innovation. In the first Wei Zhan, Jyhwen Wang, Manoj Vanajakumari, and Michael Johnson in “Creating a High Impact Learning Environment for Engineering Technology Students” present a Product Innovation and Development (PID) initiative. Undergraduate students are hired and placed in teams to develop innovative new products. The teams generate new product ideas, conduct market analyses, design and manufacture the product, market the products, and provide technical support to the customers. The intent is for the projects to generate revenue and eventually to become self-sustainable. To maximize the impact, project materials are being used in various courses to enhance the curriculum. Based on student surveys the overall experiences have been positive.

In the second, David Foley, François Charron, and Jean-Sébastien Plante in “Potential of the CogEx Software Platform to Replace Logbooks in Capstone Design Projects” describe the CogEx software platform, which was developed to support designers' work in both industrial and academic contexts. Their qualitative study on using *CogEx* for mechanical engineering capstone design projects explores this potential to eventually replace a paper logbook. Rather than replicating the paper logbook in a digital form, the *CogEx* platform organizes design work in a radically different way to harness the power of modern computer engineering. *CogEx* also provides an overview of the content and a visual representation that can convey design rationale. Results support that the platform has a good potential for engineering design education by replacing the paper logbook. The structure was efficient for organizing design work, and offers the potential in building a designer knowledge base. The authors conclude that the extended concept map can manage all design work and is an improvement compared to the chronological organization of the traditional logbook by helping to find information and by allowing evolution of the design.

Finally, Ryan Locicero and Maya Trotz address a model for involving K-12 teachers and eventually students in "Green Space Based Learning Model for Repurposing Underutilized Green Spaces within School Campuses." Their paper describes an educational model to mainstream green infrastructure within urban environments. It builds on a partnership between a Research I university, the surrounding underserved community, and the local school district. A Research Experience for Teachers (RET) program provided an opportunity for graduate students and professors to share their field of knowledge with teacher participants in two summer research experiences. Content knowledge was then translated by the participating teachers into grade-specific lessons that support the development of sustainable green spaces within their schools' campus. Ultimately, K-12 students will be guided through the design/build of a green infrastructure improvement project, transforming an underutilized green space within their campuses into a multi-use educational environment. Participating teachers indicated improved pedagogical practices through their experience. The university research experience has supported the development of K-12 lessons and activities that will introduce students to the engineering design process and scientific inquiry. Already the GSBL model has resulted in "the design and construction of seven field-scale bioretention systems, completion of two Campus Green Infrastructure Challenges, publication of the Urban Stormwater Management Curricular Unit, funding for three green infrastructure projects, and implementation of approximately 70 personal bioretention systems."